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CULTIVATE THE FUTURE.

ISOFAR
International Society of Organic Agriculture Research

CULTIVATING THE FUTURE BASED ON SCIENCE

Proceedings of the Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR), held - at the 16th IFOAM Organic World Congress - in Cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the Consorzio ModenaBio 2008.

18-20 June 2008 in Modena, Italy.

VOLUME 1
ORGANIC CROP PRODUCTION

Edited by Daniel Neuhoff, Niels Halberg, Thomas Alföldi, William Lockeretz, Andreas Thommen, Ilse. A. Rasmussen, John Hermansen, Mette Vaarst, Lorna Lueck, Fabio Caporali, Henning Hogh Jensen, Paola Migliorini, Helga Willer.

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ISOFAR

Should the publication of corrigenda become necessary, these will be posted at the conference homepage http://www.isofar.org/Modena2008/

The 2nd Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) was held June 18-20, 2008 in Modena Italy, in the frame of the 16th Organic World Congress of the International Federation of Organic Agriculture Movements (IFOAM), organised by Consorzio ModenaBio. The 4th Congress of the European Integrated Project 'Quality Low Input Food' (QLIF) was convened as part of the 2nd ISOFAR Conference (see papers in volume 2 of these proceedings).

Daniel Neuhoff, Niels Halberg, Thomas Alföldi, William Lockeretz, Andreas Thommen, Ilse. A. Rasmussen, John Hermansen, Mette Vaarst, Lorna Lueck, Fabio Caporali, Henning Hogh Jensen, Paola Migliorini, Helga Willer (Editors) (2008):

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Preface

To carry home these heavy two volumes of ISOFAR's 2nd Scientific Conference Proceedings might give rise to the question whether these books represent more mass than class and if they are still topical.

After all the author must wonder whether a contribution in a peer-reviewed proceedings volume is worthwhile when there is the alternative of publishing it in a highly ranked scientific journal with the same effort. Moreover, the editors as well as the numerous referees might have felt desperate at times due to the enormous amount of time and strength they invested to compile about 400 selected papers.

I would like to thank all of you for your effort. It was worthwhile since the reader now obtains a valuable overview of the current state of knowledge and research aims of the scientifically based Organic Agriculture which might be important not only for the scientist but also for all other stakeholders interested in the further development of Organic Agriculture.

I owe gratitude to all who contributed to coping with this laborious task. You have all done a tremendous job in contributing to foreseen successful scientific modules held under ISOFAR´s and IFOAM's joined conference/congress umbrella. Our collective hope is that these proceedings will represent a significant milestone on the road towards a better understanding of the potentials and effects capabilities of a scientifically based Organic Agriculture can have.

Prof Dr Ulrich Köpke

President ISOFAR

Dear Reader,

The two volumes of the Proceedings of the Second Scientific Conference of the International Society of Organic Agriculture Research, 'Cultivating the Future Based on Science', represent a considerable part of the worldwide increase in research activities in Organic Agriculture (OA). This observation is in accordance with the overall trend, at least in much of the western world, of increased production and consumption of certified organic products.

In all, 495 four-page papers were submitted to the conference, and all went through a sophisticated review process resulting in 380 papers being selected for presentation at the ISOFAR Conference. Evaluating papers is a difficult task, requiring a sure scientific instinct. It also requires a reasonable judgement of the quality of the language of each paper; since a paper's language is part of what determines its overall quality, even though this gives an unjustified advantage to native speakers of English. Supported by a review form that checked various aspects of the paper's quality, the reviewers tried their best to ensure maximum transparency of the evaluation, which basically reflected the objective of improving the paper's quality.

The first volume deals mainly with various aspects of organic crop production, which traditionally represent the largest share of all papers submitted to conferences on OA. We hope that you will find it interesting to discover the diverse research approaches regarding the management of organic crops. While a tendency to a more problem-oriented approach realized by specialists is evident, as perhaps is to be expected, there is still a strong foundation of papers on traditional agronomy with a systemic approach, which remains a key discipline in OA research. Attentive readers will realize that the diversity of papers also reflects the global differences with respect to an understanding of what OA is.

The second volume gives insights into the increasing research activities on animal husbandry, socio-economics, interdisciplinary research projects, and QLIF workshops, all related to OA. We gratefully acknowledge in particular the increasing interest in organic animal husbandry, which in the past was a poor cousin in OA research. Some topical issues such as global warming and energy supply are discussed in the interdisciplinary sessions.

The scientific committee agreed at the start that cross-disciplinary papers should be given high priority because of the very nature of organic farming and food systems. For many years we have claimed there was a need for a holistic understanding of OA, both because of the interdependencies among sub-systems on the farm (soil-crops-livestock-people) and because of the multiple objectives behind OA (producing wholesome food, conserving soil fertility, maintaining biodiversity, supporting animal welfare, reducing pollution, etc.). However, most often researchers end up meeting and discussing these matters in largely discipline-oriented sessions, even at most organic conferences. Therefore, we wanted to encourage a more cross-disciplinary approach at this ISOFAR event, and we were happy to receive a large number of papers for the cross-disciplinary topics. We hope this tendency will be strengthened in future organic conferences.

Moreover, the great number of papers submitted for the scientific part of the OWC clearly demonstrates the interest in sharing research-based knowledge within the organic sector. To achieve this, it was important to have a section of the OWC where strict methodological approaches are required for participation.

On the other hand, it is a pleasure and an advantage for a scientific conference to be part of a global event that attracts the whole sector and thus allows the researchers to disseminate their findings widely and gain inspiration from other stakeholders in the organic movement.

First and foremost many thanks to all authors who contributed to our joint conference. We also are greatly indebted to the numerous reviewers listed on the next page, who did a first-class job in evaluating hundreds of papers. It was a great pleasure to cooperate with Paola Bonfreschi from the OWC – Organizing Committee, who is the embodiment of reliability and politeness. Last but not least, many thanks to Anja Schneider, of the ISOFAR Head Office, who was mainly in charge of overall communication with the authors and substantially supported the editing of the proceedings.

Managing the review process and editing the proceedings for an international conference is a challenging task in which language difficulties and technical problems may sometimes result in confusion. We kindly ask you to accept our apologies for any problems you may encounter.

We sincerely hope that the Proceedings of the Second Scientific Conference of ISOFAR 'Cultivating the Future Based on Science' will be an important and worthwhile source of information and inspiration for you.

On behalf of the Editors,

Daniel Neuhoff, Niels Halberg, Thomas Alföldi & William Lockeretz

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Soil organic matter management

The Impact of Site and Management Factors on Humus Dynamics in Long-term Field Experiments

Brock, C.[1] & Leithold, G.[2]

Key words: humus dynamics, farming systems, long-term field experiments

Abstract

The impact of management and environmental site factors on quantitative and qualitative indicators of humus dynamics was investigated in eight long-term field experiments in Germany and neighbouring countries. Humus dynamics were basically influenced by environmental site conditions, but at a given site differences between farming systems could be ascerted. Mixed farming systems with farmyard manure application as a rule had a more favourable impact on humus dynamics than stockless systems. Whether an advantageous performance of humus dynamics in organic farming as compared to conventional farming will occur or not, is dependent on the respective farm types of both systems that are related to each other.

Introduction

A favourable performance of humus dynamics is commonly attributed to organic farming systems (e.g. Piorr & Werner 1999). Yet, even organic farming is subject to specialization and intensification processes, mainly induced by economic factors. As a result, the diversity of organic farming systems is increasing. It is therefore necessary to investigate impact factors behind the complex system effects in order to enable a differentiated assessment of humus dynamics. This paper presents results on site and management impact on humus dynamics in field trials displaying various organic and conventional farming systems.

Materials and methods

The performance of indicators of humus dynamics was surveyed in eight field trials in Germany, Switzerland, and Denmark (DOK trial, Therwil/CH; Crop rot. trial Viehhausen/D; Org. arable farming trial, Villmar/D; Farming systems trial Bad Lauchstädt/D; Farming systems trial Bernburg/D; Farming systems trial Dahnsdorf/D; Org. crop. rot. trial, Güterfelde/D; Crop rot. exp., Foulum/Dk and Flakkebjerg/Dk). Farming systems displayed in the trials are *organic mixed farming* (8 trials), *conventional mixed farming* (4 trials), *organic stockless farming with* (5 trials) *and without* (4 trials) *rotational ley*, *conventional stockless farming with* (2 trials) *and without* (2 trials) *rotational ley*, and *biodynamic farming* (1 trial). In some trials, farming systems are further differentiated according to crop rotation and/or fertilization.

As quantity indicators of humus dynamics we used organic carbon content (C_{org}) as well as total soil Nitrogen content (N_t), while hot water soluble fractions of C and N (C_{hws}, N_{hws}) were selected as quality indicators. Soil samples for analyses were

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[2] As Above

collected in spring 2006 from the topsoil layer (Ap horizon) of each included plot to assess the actual state of the selected humus dynamics indicators. Crop in all cases was winter cereal, previous crop was row crop. Furthermore, humus content development dependent on management factors was assessed calculating the long-term linear trends for topsoil C_{org} and N_t content, respectively. Linear trend estimations were based on measurement time series of either indicator. The estimated *b* was used both to assess humus content dynamics in a plot and as a means of levelling out variations caused by differing humus content levels.

Results

Survey of variable factors in the trials and between the trials showed a decisive impact of environmental site factors on humus dynamics indicators (tab. 1). As for content dynamics indicators (linear trend of C_{org} and N_t), the impact was not linear and could not be correlated to neither defined site nor management factors. Due to the relevance of environmental site factors, humus content (C_{org}, N_t) and quality indicators (C_{hws}, N_{hws}) were not correlated to any management factors in the overall survey. This was true referring to fertilization as well as to crop rotation impact. As for content dynamics indicators (linear trend b_C of C_{org} (b_C) and N_t (b_N)), the impact was not linear and could not be correlated to either defined site or management factors, but showed a strong dependency on “trial” as an integrative site x management indicator.

Tab. 1: Correlations between impact factors and humus dynamics indicators in eight long-term field trials in Germany, Denmark, and Switzerland. If significant correlation to more than one impact factor of either category (site, management) could be confirmed, the strongest correlation is displayed. Number of included plot data (n) variable for indicators.

Indicator	***Relevance of impact factors***
C_{org} *n=126*	*site:* r=0,59** for Ackerzahl (german site quality index) *management*: no significant impact
N_t *n=132*	*site:* r=0,68** for Ackerzahl (german site quality index) *management*: no significant impact
C_{hws} *n=128*	*site:* r=0,59** for Ackerzahl (german site quality index) *management*: no significant impact
N_{hws} *n=128*	*site:* r=0,59** for Ackerzahl (german site quality index) *management*: no significant impact
b_C *n=91*	*site x management: significant differences between trials* In ANOVA
b_N *n=91*	*site x management: significant differences between trials* In ANOVA

Yet, a differentiation of farming system impact was possible on the trial level (without figure). Stockless farming systems as a rule produced lower values for all humus dynamics indicators than mixed farming systems with farmyard manure application, especially if a rotational ley was missing. If farming systems of either type in one trial were compared referring to the overall system (conventional vs. organic), the conventional reference variants usually displayed higher values. Still, differences between farming systems were not statistically significant for any indicator, even though the pattern OrgMF > OrgSl, ConMF > ConSl was identical in all trials on the level of descriptive statistics.

Further, a correlation between average dry matter yields and Corg as well as Nt contents could be observed that was considerably stronger for organic than for conventional management (fig. 1). In addition, a negative correlation could be observed for humus content dynamics as indicated by the linear trend of Corg and Nt and yield level for conventional farming systems (without figure). The opposite situation was true for organic farming, even if the positive correlation here was fairly weak.

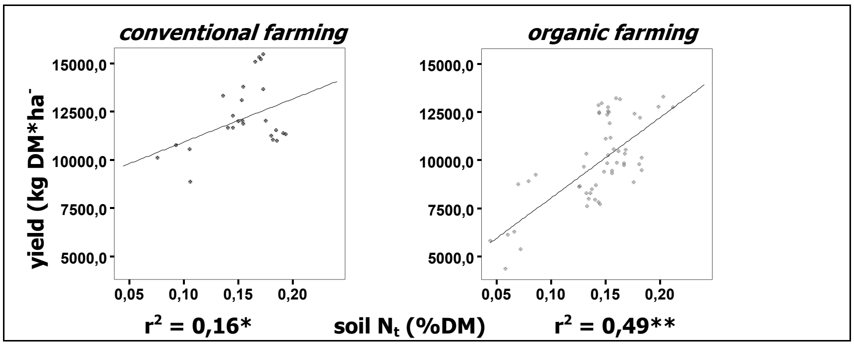

Figure 1: Correlation between Nt as humus content indicator and average dry matter yields dependent on the farming system. Number of plots included n=30 (conventional farming), n=65 (organic farming). *=significant at α=0.05, **=significant at α=0.01.

Discussion

Our results show that the specific impact of a defined farming system on humus dynamics may not be generalized. A consideration of the impact of environmental site conditions is inevitable. On the other hand, farming systems at a given site obviously have a specific impact that allow for a comparative assessment of farming systems with regard to ecological and agronomical parameters. These findings are supported by e.g. Fließbach et al. (2007) or Breland & Eltun (1999), even though differences between farming systems on a high level of spatial aggregation could not be proved by analysis of variance due to the effect of environmental site conditions as well as specific treatment of variants in a given trial. As to the apparently low impact of management/farming systems on humus dynamics indicators, the relatively young age of most trials (<10 years) has to be considered. Due to the complex interactions between mineralization and immobilization processes of soil C and N (e.g. Barrett & Burke 2000) the rather slow dynamics of the humus content level may be overlapped. It also has to be noted that conventional and organic farming systems as displayed in the trials often do not reflect the actual situation in practice. Conventional stockless cash crop farming without ley was only displayed in two out of eight trials, but is the predominant conventional farming system in arable farming practice in Germany. Results on higher humus contents and turnover intensities in organic faming systems as reported by other authors from field survey under practice conditions (e.g. Munro et al. 2002) are therefore not contradictive to our observations. On the other hand, problems regarding nutrient supply and humus reproduction in organic stockless farming without inclusion of a rotational ley or optimized compensation strategies are well known (e.g. Schmidt 2004).

The correlation between average dry matter yield level and N_t must be interpreted as interacting system. It has been assumed that high yields produce a high plant residue mass, promoting humus content (Brock et al., 2008). On the other hand, a high humus content and turnover is a prerequisite for high yields, especially if there is no mineral N fertilizer application (Stockdale et al. 2002). Our results clearly support both assumptions to be true for organic farming conditions. In conventional farming, the processes obviously are overlapped by the effect of mineral fertilization.

Conclusions

A favourable impact on humus dynamics is not an intrinsic quality of organic farming, but the result of management factors that are in principal not exclusivly linked to conventional or organic farming. Still, due to a considerably stronger interaction between soil functions and agronomic performance, a sustainable humus management is of basic interest under organic farming conditions. There is some evidence that stockless organic farming remains a challenge not only with regard to nutrient supply of crops, but also to maintenance and promotion of favourable humus dynamics. Here, further research is necessary in order to support a sustainable development of such systems.

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Indicators for the Evaluation of Soil Organic Matter and their Application in Organic and Conventional Farming Systems

Hoyer, U.[1], Reents, H.-J. [1] & Hülsbergen, K.-J.[1]

Key words: soil organic matter, indicator, farming system, humus balancing

Abstract

In view of the problems caused by soil degradation, it becomes ever more important to estimate the influence of different management systems on soil organic matter (SOM). In the past, a number of indicators characterizing SOM have been elaborated, which, however, do not allow to draw conclusions on separate management measures or even future development tendencies. A promising approach might be humus balancing, which quantifies and evaluates the humus supply of soils on the basis of crop rotation and fertilization. Comparative studies on adjacent arable sites under both organic and conventional management in different climatic regions of Germany have revealed that the indicator soil organic carbon (SOC) depends mainly on the site conditions, whereas indicators characterizing active SOM like hot water soluble C (C_{hws}), C in microbial biomass (C_{mic}) and the enzyme activities of β-glucosidase and catalase are stronger related to management methods. It became evident that humus balancing is a good indicator of the active SOM pool and thus also a qualified tool for demonstrating management effects.

Introduction

Soil degradation caused by erosion, compaction and humus depletion is a severe problem all over the world. In order to assess the effects of agricultural landuse under different site conditions, various indicators of soil conservation have been developed. They include principally the parameters soil organic carbon (SOC), soil organic nitrogen (SON) microbial biomass and active SOM (Gregorich et al. 1994, Arshad & Martin 2002). These measurements help estimate the current quality of a soil; however, they do not allow to make statements on how a soil will respond to management influences in the future (Herrick 2000). Evaluating management effects requires to consider crop rotations, fertilizer input and tillage, in order to describe the relationships between soil properties and management. State indicators like SOC provide information on the current situation of the environment, while pressure indicators are related to the type of management and offer an indirect assessment. As methodical approach to the estimation of management effects on SOM, humus balancing was developed (Leithold et al. 2007). The necessary input data can be collected easily; humus balancing permits to assess SOM depletion and accumulation depending on the quantity and quality of C input. Adverse to C- and N-simulation models, no sophisticated processes or different pools are described, but rather the summed up net effect on SOM is calculated (Leithold et al. 2007, Körschens et al. 2005).

The following paper is to elucidate the relationships existing between different indicators for SOM and humus balancing. On the basis of comparisons between

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organically and conventionally run farms the question is pursued whether common state indicators can reflect system-related differences in management sufficiently and whether humus balancing may be a reliable indicator for the evaluation of sustainable land use.

Materials and Methods

In various agricultural regions of Germany, long-term test plots were established on adjacent arable sites, both under organic and conventional management, but with comparable soil texture. Preferably sites under humid and cool conditions in southern Germany as well as locations in eastern German dry regions were included. Soil types range from light sandy to heavy clay soils. On five plots each per site and management system, soil samples were taken from the topsoil which were then analysed for SOC, SON, C_{hws}, C_{mic}, β-glucosidase and catalase. On each plot long-term management records were kept and entered into the calculations. Humus balance sheets were computed according to the approach by Küstermann et al. (2007). The statistical analysis was executed by use of SPSS 15.0.

Results

The biological active time (BAT = f [silt + clay, air temperature, precipitation]) as site characterizing parameter (Franko & Oelschlägel 1995) was calculated as main influence factor for all investigated indicators. This has been demonstrated in Fig. 1 on the example of SOC and C_{mic}.

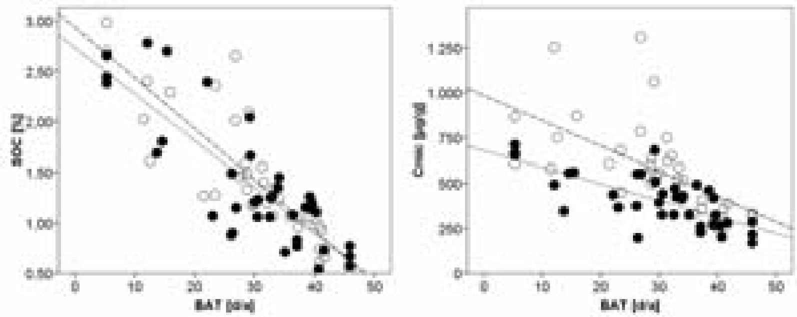

Figure 1: Relationship between biological active time (BAT) and SOC- and C_{mic}-contents; ○organic; ● conventional;
regression curves: - - - organic; ....conventional

Different management factors cause different effects even when all other site conditions coincide. Table 1 shows the results of gradual linear regression for the estimation of the parameters that influence the measurable SOM indicators. Organic farming entails slightly increased SOC contents. The measured parameters C_{mic}, C_{hws}, β-glucosidase and catalase characterizing the active SOM are related to the pH value and more or less also to the different input values. C_{hws} and catalase rise with the quantity of organic fertilizer. C_{mic} is positively influenced by the share of clover grass mixture, organic fertilization and yields. β-glucosidase is enhanced by higher yields, and a slightly negative relation was found for the rates of mineral fertilizers.

Tab. 1: Regression and correlation coefficients for the description of influences on different SOM indicators (weight of influence factors marked with a-d, a = strongest influence)

	Site			**Management**					**R**
	fU	BAT	pH	System	Yield	CG	DM_OF	N_MF	
SOC	0.06[a]	-0.02[b]	-	0.14[c]	-	-	-	-	0.91
C_{hws}	15.58[a]	-	51.41[b]	-	-	-	3.04[c]	-	0.85
C_{mic}	-	-8.71[c]	82.95[d]	-	-	4.57[a]	5.28[b]	-	0.85
Gluc	-	-	17.61[a]	-	0.6[c]	-	-	-0.21[b]	0.75
Cat	0.48[a]	-	2.98[c]	-	-	-	0.22[b]	-	0.82

fU: fine silt (%); BAT: biological active time (d a^{-1}); System: organic or conventional farming; CG: share of clover grass mixture (%); DM_OF: DM input with organic fertilizer (100 kg ha^{-1}); N_MF: mineral N input (kg ha^{-1}); Gluc: β-glucosidase; Cat: catalase

The mean value of the humus surplus quantities for all organic plots differs significantly (+246 kg C ha^{-1} a^{-1}) from the mean of the conventional plots (only -76 kg C ha^{-1} a^{-1}). The correlation between measured values and humus balance surpluses is differently pronounced (Table 2). A comparatively strong correlation was obtained for C_{mic} and the humus balance surpluses.

Tab. 2: Correlation coefficients (Pearson) between balance surpluses and measured values (organic and conventional)

	SOC	**SON**	**C_{hws}**	**C_{mic}**	**Gluc**	**Cat**	**pH**
Humus balance surplus	0.23	0.28*	0.37**	0.65**	0.29*	0.47*	0.25*

* significant for P<0.05

** significant for P<0.01

Discussion

The results obtained in regression analyses have shown that the humus level and all measured values of active SOM were mostly influenced by the site conditions. Nevertheless, these indicators can be modified to a certain extent by management methods. Organic farming entails mostly slightly increased contents of SOC, and especially C_{mic} is clearly enhanced on organically run fields. Enzyme activities and C_{hws} respond positively to yield level and organic fertilizer input. Higher yields raise the input of organic matter, mainly by root residues and rhizodeposition, which represent a preferential substrate for the cellulose-decomposing enzyme β-glucosidase and thus the nutrition of microorganisms.

Due to low portions of field forage and low spreading of stable manure, balancing of conventional farms produced lower humus surplus levels than organic systems. There are only weak correlations between measured values and balance sheet results, except for C_{mic}. C_{mic} rises markedly with an increasing share of clover grass mixture and the input of organic fertilizer. These parameters have a strong weight in humus balancing.

Conclusions

The SOC content as a state indicator can be influenced by management measures within close brackets only; the decisive effect is exerted by the site conditions. Humus balancing depends on management data; surpluses are more evidently related to the active SOM, which is likewise dependant on management. Therefore, the pressure indicator "humus balance" turned out to be a suitable indicator for describing management effects on the active SOM pool.

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Organic and biodynamic cultivation - a possible way of increasing humus capital, improving soil fertility and providing a significant carbon sink in Nordic conditions

Granstedt, A. [1] & Kjellenberg, L.[2]

Key words: biodynamic farming, carbon sink, humus, organic farming, soil fertility

Abstract

In Sweden three different sets of long-term comparative trials have been carried out at the Biodynamic Research Institute since 1958. With biodynamic farming an average annual increase corresponding to 500 – 800 kg soil carbon per ha is documented.

Introduction

At the Biodynamic Research Institute three sets of long-term field trials have been conducted since 1958.

K-experiment in Järna from 1958 -1990

This first trial period ran during 32 years from 1958 to 1990. The quality of food products and interaction and influence on soil fertility of different manuring techniques were studied (Pettersson, Wistingahusen and Reents 1992; Granstedt & Kjellenberg 1999; Kjellenberg & Granstedt, 2005).

UJ (Ultuna-Järna) -experiment 1971 -1979

The results from the initial K-experiment formed the basis for a 6 and a 9-year trial, which were carried out by the Biodynamic Research Institute in collaboration with SLU (Swedish University of Agricultural Sciences) on two locations, in Ultuna near Uppsala and in Järna with four replications and all three crops in the three year crop rotation each year. In the trials Biodynamic cultivation with and without leys was compared with conventional cultivation with and without leys in three-year crop rotations (Dlouhý, 1981). The results from the two trials corresponded well with each other as well from the K experiment (Granstedt, 1995).

Skilleby long-term trial started in 1991 and still continuing

When the K-experiment ended in 1990 field studies were established within an individual farm organism making it possible to evaluate consequences of different treatments within a given farm situation with a closed recycling system and a high level of self-sufficiency in fodder and manure (Granstedt, 1998 and 2002).

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[2] As Above

Materials and methods

K-experiment

The long-term K field trial was run with one crop rotation without replications but with each crop each year from 1958 – 1990: 1) Summer wheat, 2) Ley with legumes, 3) Potatoes and 4) Beets

The 8 different treatments include: K1-Biodynamic (BD) composted manure and BD field preparation; K2-Biodynamic composted manure without the BD field preparation; K3-Raw farm yard manure; K4- Raw farm yard manure and mineral fertilizer (NPK); K5-No manure or fertilizer; K6- Low mineral fertilizer (NPK); K7-Medium mineral fertilizer (NPK); K8-High fertilizer (NPK).

Potatoes and beets were fertilized in the organic treatments and potatoes, beets and wheat were fertilized in the mineral fertilized treatments. The average annual amount of NPK per ha in the composted stable manure in K1 and K2 was averaged for the whole period to 80/38/76, in the not composted manure in K3 to 95/32/91. These amounts corresponded to the possible production of fodder-crops in the crop-rotation and with an animal density of 0,9 animal unit per ha. The average annual amount of NPK per ha in the combined organic and mineral fertilized treatment K4 was 62/24/66, in the mineral fertilized treatments K6 29/18/41, K7 58/36/81 and in K8 117/36/81. The composted manure (30 ton per ha to potatoes and 45 ton per ha to beets) applied in K1 and K2 had lost about 10 % of its biomass and 18 % of its nitrogen content during the composting process before being applied in the field compared to the raw manure applied in K 3.

UJ-experiment

The Biodynamic Institute in Järna and the Swedish University of Agricultural Sciences (SLU) Ultuna collaborated to compare biodynamic cultivation with (B2-Summer wheat, Ley with clover/grass, Potato) and without leys (B1-Summer wheat, Barley, Potato) with conventional cultivation with (A2-Summer wheat, Ley with clover/grass, Potato) and without leys (A1-Summer wheat, Barley, Potato) in three-year crop rotations.

The Biodynamic trials B1 and B2 received biodynamic composted stable manure in an amount comparable to the fodder crop's manure production (0.7 animal units per ha) while the conventional trials A1 and A2 received mineral fertilizers comparable to what was at that time the recommended standard amounts for these crops (an average of NPK 95/45/110 kg/ha). The trial B2 corresponded to standards for biodynamic cultivation with animal production and A1 the standards for conventional specialized cultivation using artificial fertilizers without animal production.

Skilleby long term trial

The effects of applications of non-composted and composted manure in the long term experiment were studied, with and without biodynamic preparation treatments, at three levels of application (12.5, 25 and 50 tons per ha 1991-1995 and 0, 25 and 50 tons per ha 1996-1997), 12 treatments with 2 – 4 replications of each crop and established on each of five fields in the five-year crop rotation: oats with under sowing, ley I, ley II, ley III and winter wheat with the application of farmyard manure. This crop rotation was designed to improve the humus content and soil fertility (Granstedt, 1992).

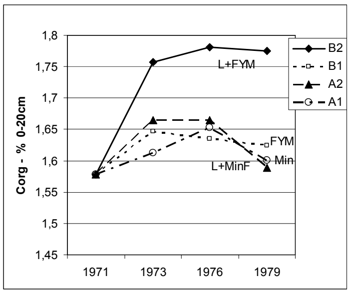
Results and discussion

In the thirty year long K-experiment after the first ten years the yields in the biodynamic (K1) and conventional (K8) fertilized system were on the same level. The treatments with organic manure (K1–K4) combined with the clover/grass ley gave a clear increase of carbon in the topsoil (K1 from 2.4 % to 2.9 % from 1958 to 1989, i.e. an increase of 20 % during 29 years). The annual support of carbon was here 1640 kg per ha and year (Reents, Pettersson & Wiestinghausen, 1992).

Samples of organic carbon were also taken at 25 – 35 cm and 50 - 60 cm depth in the soil profile both 1989 and 1985 and at 25-35 cm 1976 (not shown here). Even the organic treatment without all biodynamic preparation treatments gave a carbon accumulation but with lower values with consideration of data with humus content deeper in the soil. The mineral fertilized treatments and the unfertilized treatment gave no increase of the carbon and humus content despite the inclusion of leys in the crop rotation. The total amount of organic carbon to a depth of 60 cm, after interpolation of the humus content in the soil layers between them, can be calculated to 160 ton per ha in the biodynamic treatment (K1), 146 ton per ha in the organic raw manure treatment, and 135 ton per ha in the mineral fertilized treatment. This means that there has been an annual average increase or assimilation of organic carbon in the order of 800 kg per ha in the biodynamic treatment K1 and 300 kg per ha in the organic treatment. This amount is comparable to what is reported from the renowned Rhodale long term experiment from 1981 to 2005 in Pennsylvania in USA in a more legume based farming system with farm yard manure, Soya beans and clover/grass ley (Hepperly, Douds & Seidel, 2006). Our results also correspond with the DOK experiment in Switzerland where the effect of BD preparation and composted manure are also reported (Mäder et al, 2002).

UJ-experiment

The trial stages B2 and A2 make it possible to analyze the importance of leys in each system. The effect on the amount of humus and carbon in the soil in each system is presented below. The humus concentration in the biodynamic trial with ley increased from 2.72% to 3.06% (1.58 to 1,77 % C-org) during the 8-year trial period (slightly more than 10%) while the humus concentration remained at the same level in the trial with conventional cultivation (Figure 1).



In these trials the importance of leys and organic fertilizer for the assimilation of carbon in soil and the building up and maintenance of the humus content in the soil and with this the associated biological soil properties is apparent (Dlouhý 1981, Granstedt and Kjellenberg 1999). In this experiment the effect of specific BD was not possible to evaluate.

Figure 1: Trials comparing biodynamic and conventional cultivation in Järna 1971 – 1979.

Skilleby long term trial

During the 9 years from 1991 to 2000 the average soil organic carbon increased by 9 % from 2.18 to 2.38 %. This significant average increase in the 20 cm topsoil was calculated to 4450 kg C ha^{-1} from a level of 47850 to 52300 kg C ha^{-1}. Based on data from this study and field experiments with clover grass leys on Skilleby (Granstedt and Bäckström, 2000) it is calculated that a three-year clover grass ley with an annual nitrogen fixation between 100 – 200 kg N ha^{-1} can result in the net assimilation of 18 tons of carbon in soil biomass**.**

Conclusions

Humus degradation can be compensated directly through the incorporation of harvest residues from grassland into the soil and indirectly through recycling farmyard manure derived from fodder produced within the farming system. Both carbon and nitrogen management are key components in these transformations. In biodynamic farming the rebuilding of humus is further developed through composting techniques of manure combined with the use of biodynamic preparations. The importance of leys combined with the recycling of manure from the animal husbandry within the farming system is seen. Organic and biodynamic farming has the capacity to be an important carbon sink to reduce the surplus of carbon dioxide in the atmosphere.

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Are soil biological properties and microbial community structure altered by organic farm management?

Stark, C.H.[1]

Key words: DGGE; enzyme activity; farming techniques; soil biota; soil dilution plating

Abstract

Environmental conditions and farm management practices have a considerable impact on soil biota, affecting nutrient cycling processes and ecosystem functioning. Understanding how management practices influence soil fertility and agricultural productivity is essential to improve the sustainability of agroecosystems. The effect of farming history on microbial soil properties was assessed by analysing soil samples from two organic and conventionally managed sites. C_{mic} and N_{mic}, enzyme activities, bacterial community composition (PCR-DGGE) and total numbers of fungi and bacteria (soil dilution plating) were determined. Results suggested that organic farming practices did not have a clear positive effect on soil microbial biomass and activity; distinct differences in bacterial community composition were detected by PCR-DGGE but not by soil dilution plating. Findings indicate that practices commonly associated with conventional farming (application of mineral fertilisers or pesticides) have a less pronounced effect on the soil microbial community than other management techniques (e.g. manure application and crop rotation).

Introduction

Soil biota plays an important role in maintaining soil fertility and productivity and improving the functioning of the soil ecosystem. Studying the response of the microbial community to agricultural disturbances is vital to our understanding on how management practices contribute to sustaining fertility and productivity to improve soil management systems (Wardle et al. 1999). The effect of different management regimes and perturbations on the soil microbial community, e.g. crop rotations, manure applications and tillage, has been studied in a wide range of soil and management systems, incl. conventional, low-input and organic farming. Most research suggests that organic practices have a positive, stimulating influence on the soil microbial community by increasing microbial biomass, enhancing diversity and improving soil functions like nutrient cycling (e.g. Watson et al. 2002). In comparison, there is little evidence of negative effects of mineral fertiliser and pesticide usage on soil organic matter, microbial diversity and activity (Fraser et al. 1988). This suggests that recognized beneficial management practices (e.g. green manuring, crop rotations, conservation tillage) have a bigger impact on the soil microbial community than the land-use system itself.

Materials and methods

Adjacent organic and conventionally managed sites of the same soil type (Udic Ustochrept, USDA) with similar fertility levels were chosen within the cropping farm at

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Lincoln University, New Zealand (43°38'S; 172°27'E) to compare soils with differing management histories with regard to soil biological properties and microbial community composition, and to identify fungal species that are indicative of the management system. The sites had been farmed under contrasting organic (ORG) and conventional (CON) management systems for 26 and over 100 years, respectively. ORG, previously been under a low-input 6-year rotation, was under a mixed herb-ley for 3 years at the time of sampling. The site had never received fertiliser, compost or manure, had not been grazed or subjected to inversion ploughing. CON had been commercially managed under an 8-year crop rotation and had been under pasture for 2 years at the time of sampling. During the rotation, residues were incorporated to a depth of 15 cm by ploughing. During the 8-year rotation, a total of 70 kg N and 16 kg P were applied per ha and yr. Top soil samples (0-15 cm) were collected in January, March and June 2002, sieved (4 mm) and stored at 4ºC. All analyses were carried out in triplicate: microbial biomass C (C_{mic}) and N (N_{mic}) (Sparling and West 1988), arginine deaminase activity (Alef and Kleiner 1987) (ADA), fluorescein diacetate hydrolysis (Adam and Duncan 2001) (FDA), total C and N (C_{tot}, N_{tot}). PCR-DGGE was performed on 16S rDNA fragments of triplicate DNA extracts using eubacterial primers F984GC and R1378; thermal cycling conditions were as described by Heuer et al. (1997). From each soil sample, spread plates were prepared in triplicate on four different media: Czapek Dox agar (CDA); Nutrient agar (NA); *Trichoderma* selective medium (TSM); King's medium B (KB). After incubation, cfu g^{-1} dry soil were estimated for bacteria and fungi. Selected fungal colonies were subcultured and identified. All numerical data were analysed by general linear model analysis of variance using GenStat on total or $\log_{10}$ transformed values where appropriate. Samples were considered significantly different when $p<0.05$ and least significant differences ($LSD_{0.05}$) were calculated.

Tab. 1: Mean values of three sampling dates in 2002 and levels of significance for soil properties in ORG and CON topsoil samples (0-15 cm). ***, p<0.001; **, p<0.01; NS, not significant.

Soil property	ORG	CON	Significance
C_{mic} (µg g^{-1})	494	596	***
N_{mic} (µg g^{-1})	50.1	47.6	NS
ADA (µg g^{-1} h^{-1})	2.86	1.91	***
FDA (µg g^{-1} h^{-1})	115	123	NS
C_{tot} (%)	2.77	2.93	**
N_{tot} (%)	0.242	0.243	NS

Results

ADA was significantly higher in ORG, while C_{mic}, C_{org} and microbial quotient were significantly greater in CON at all sampling dates. FDA and N_{mic} were significantly higher in CON in April and June, respectively; however, the differences were not significant when assessing overall trends (Table 1). Seasonal variation was similar for both soils. DGGE profiles of the bacterial communities revealed similar numbers of bands in both soils, while the banding patterns were distinctly different. Significantly higher numbers of fungi were recovered from CON on CDA ($p<0.001$) and TSM ($p=0.036$), while differences for bacteria were not statistically significant. The absolute differences in microorganism numbers between the two sites were minor (e.g. fungi on

CDA: 1.8×10^5 cfu g^{-1} (ORG), 2.4×10^5 (CON)) and likely to be of little practical significance with regard to soil ecology and function.

Characterisation of selected fungal isolates did not show major differences between the two soils although seasonal variations could be observed. From both soils, the following species were isolated: *Penicillium*, *Cladosporium*, *Gliocladium*, *Trichoderma*, *Mortierella*, *Botrytis*, *Paecilomyces*, *Coelomycete*, *Fusarium*, *Chrysosporium*, *Phoma*, *Alternaria*, *and Mucor*. While *Penicillium* and *Trichoderma* were most frequently isolated, no particular fungal species occurred predominantly in one soil. The small and inconsistent numbers of isolates suggests a random pattern of occurrence.

Discussion

The results suggest that past organic management did not have a major positive effect on soil microbial biomass and activity. The higher C_{mic} observed in CON samples were in accordance with our expectations, as ORG was a low-input area while CON had been grazed, cultivated and fertilised regularly. Crop rotations and fertilisation have a positive influence on the soil microbial biomass through greater return in crop residues. The overall similar levels of FDA observed for the soils in this study are most likely linked to inherent soil properties such as soil type and long-term management practices (cf. Dick 1997) that might affect chemical soil properties. The slightly higher FDA activity in CON is consistent with higher levels measured in other soils receiving mineral fertilisers and seems to be a positive response to repeated inorganic fertilisation.

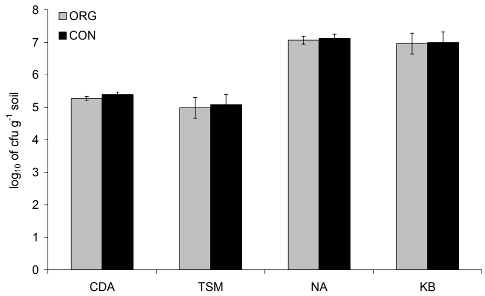

Figure 1: Bacterial and fungal cfu (log_{10}-transformed) in ORG and CON on CDA (fungi), NA (bacteria), KB (bacteria), TSM (fungi). Means of three sampling dates. n=27.

Soil dilution plating proved unsuitable for identifying key species indicative of the farm management system. Despite some differences in total numbers, no bacterial or fungal species were repeatedly isolated from either soil in large numbers. These findings are inconsistent with previous studies where organic management resulted in higher bacterial counts in soils (Fraser et al. 1988). However, most positive effects on microbial numbers in organically farmed soils are due to high organic matter amendments which did not occur in this study. In our study, microbial counts correspond to soil biological properties, which showed small differences. It is likely that the lower microbial numbers in ORG and the general lack of significant differences result from the fact that the two sites were providing comparable conditions for the microbial populations due to comparable chemical and physical soil properties, similar plant cover and both being in a restorative phase. This supports the theory that microbial numbers in soils are mostly influenced by changes in the soil environment and management techniques that cause such changes (Fraser et al. 1988). While the cfu assay suggested similarly sized and structured bacterial populations in the two soils, PCR-DGGE revealed clear differences between ORG and CON indicating distinctly different eubacterial communities. In contrast, the number of bands (i.e. species richness) was similar in both profiles suggesting a comparable number of species in both soils, despite significant differences in microbial biomass. This implies differences in species evenness, which is also suggested by the different intensities of the bands. The data showed how the various methods assess different characteristics of the soil biota. Microbial community composition was affected by the longer-term management, while the fraction assessed by soil dilution plating as well as microbial biomass and activity seemed to be influenced by inherent soil properties or management practices that were similar on the two sites.

Conclusions

Management practices such as manure application or crop rotations have a greater influence on microbial biomass size, activity and community structure and outweigh mineral fertiliser and pesticide usage. Thus differences observed in organic and conventionally managed soils should not necessarily be considered system effects, but be assessed as a collection of different management techniques. FDA seems an unreliable measure of microbial activity and soil quality due to linkages with inherent soil properties and mineral N. The relationship between microbial diversity and activity is not clear-cut and key fungal species indicative of one farming system could not be identified.

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A New Approach to Humus Balancing in Organic Farming

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Key words: humus balance, methods, management assessment

Abstract

Humus balances provide a profitable approach for humus dynamics assessment in farming practice. Nevertheless, there is a clear demand for methodological adaptation. This article presents a new approach to humus balancing using reproducible algorithms for the estimation of balance coefficients. Humus balance coefficients for crops and organic fertilizers are estimated according to a bipartite algorithm. Humus demand is calculated on the basis of crop yields referring to the nitrogen household in the plant-soil system. Humus supply is derived from organic matter input with plant material and fertilizers. The new approach facilitates the adaptation of the method to new situations.

Introduction

The assessment of management impact on the humus dynamics of agricultural soils is of high interest in agronomical as well as ecological terms. For this reason there is a clear demand for adequate tools that facilitate humus dynamics assessment under practical conditions. Here humus balance methods have proved to be a profitable approach since they fulfil the criterion of applicability in practice far better than complex C-simulation models or measurement based approaches (Hülsbergen 2003). Models tend to require extensive input data that usually are not available under practical conditions. Humus balances on the other hand compare organic matter (OM) input (quantity and quality of organic fertilizers, crop residues and byproducts) to OM output (influence of crop-specific effects depending on site, yield and mineral N doses) without aiming at the prediction of absolut humus content changes. As a monocompartment model, humus balance considers OM as a whole with no division into specific and complex pools. The advantage of humus balancing is that only easily available management data are used. This implies that humus balances can help to define best-practice without the need for comprehensive assessment of actual humus content dynamics.

Yet, there have been serious doubts about the performance of humus balance methods, especially when applied in organic farming (Leithold et al. 2007). A major objection is the poor reproducibility of balance coefficients in most methods which prevents an adaptation of the respective methods to new situations. The marginal plausibility of balance results for organic farming systems underlines this methodological handicap.

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Materials and methods

We followed the basic scheme of humus balance methods presently established in Germany which is

humus saldo = humus supply (hs) – humus demand (hd).

“Humus saldo” reflects the net effect on humus content, “humus supply” refers to organic matter supply from plant residues and organic fertilizers and “humus demand” denotes the decrease of soil organic matter due to mineralization. The parameters ‘humus supply’ and ‘humus demand’ are attained by using humus reproduction coefficients (hrc) allotted to crops and fertilizers. The derivation of hrc was mainly based on empirical research in long-term field experiments. However, Leithold (1991) presented a mathematical approach for estimating hd coefficients on the basis of the nitrogen dynamics in the soil-plant system that was later on improved by Huelsbergen (2003). A corresponding reproducible procedure for the determination of hs coefficients to our knowledge does not exist.

For the new method we chose to develop one single algorithm that can be used to calculate hrc for any crop based on available yield data. To that effect, we adapted the approach of Hülsbergen (2003) and Leithold (1991) for the estimation of humus mineralization and combined it with a new algorithm for the calculation of organic matter supply contributing to humus build-up:

$$hrc = C_H - N_H * k$$

with

$$C_H = C_R \cdot h_R + C_{RT} \cdot h_{RT} + C_{EX} \cdot h_{EX} + C_{RE} \cdot h_{RE}$$

and

$$N_H = (N_{PB} - N_{dfa} - N_I * wp_I - N_{FERT} * wp_{FERT}) / wp_H + \Delta N_{min}$$

hrc = humus reproduction coefficient (kg C ha^{-1}).
C_H = C from organic input contributing to humus build-up (kg C ha^{-1})
N_H = mineralization of N from the humus pool (kg N ha^{-1})
k = factor for conversion of mineralized humus-N (kg N ha^{-1}) to mineralized humus-C (kg C ha^{-1})
$C_{R,RT,EX,RE}$ = C input from roots (R), root turnover during the vegetation period (RT) and root exudates (EX) or plant residues (RE) (kg C ha^{-1})
$h_{R,RT,EX,RE}$ = humification rate for a defined organic substrate input (factor)
N_{PB} = N in plant biomass as indicated by crop yield (kg N ha^{-1})
N_{dfa} = N derived from the atmosphere by symbiotic fixation (kg N ha^{-1})
$N_{D,Fert}$ = mineral N from atmospheric deposition (D) and fertilization (FERT) (kg N ha-1)
$wp_{D,Fert,H}$ = whole plant utilization rate for N from a defined source pool (factor)
ΔN_{min} = net change of mineral N in soil solution during cropping period (kg N ha-1)

Basically the algorithm generates humus reproduction coefficients estimating the supply of organic matter contributing to humus build-up on the basis of C input from plant biomass and organic fertilizers and calculates humus mineralization on the basis of N in plant biomass. Contribution of inputs to humus reproduction is estimated considering organic matter input from above-ground plant residues, roots, and exudates. The turnover of root material during the vegetation period is taken into account. Input quantity of the compartments is estimated based on crop specific shoot:root:exudate. Losses of C in turnover processes are taken into account applying substrate specific humification rates. The humification rate denotes the ratio between

OM input from a defined substrate and the proportion of that input that is actually humified, thus contributing to humus build-up. Humus mineralization is calculated by separating the contribution of each active N pool, including the humus pool, to plant nitrogen supply. The ratio between N supply from a defined pool and plant uptake of N from that pool is estimated by applying specific utilization rates (Leithold 1991). In our approach, utilization rates for N are modified dependent on site as well as yield level. The latter factor is included as an indicator of actual N use efficiency. For reasons of data availability, plant uptake of residual N as well as excessive mineralized organic matter N not taken up by a crop (e.g. in potato cropping) are taken into account by the net change of soil N_{min} over the cropping period.

Results

Up to now, hrc have only been calculated for selected crops and fertilizers in test runs of the approach. In the case of non-legume crops the calculation usually results in negative hrc, thus (theoretically) indicating a consuming impact on humus ressources. As for legumes, the contribution to humus reproduction depends on the kind of legume (forage or grain) as well as on utilization (harvested / mulched). Tab. 1 illustrates hrc generation for winter wheat, potatoes, grass/clover with 70% legumes (fodder and mulched ley), and field beans.

Tab. 1: Calculation of humus production coefficients (hpc) for winter wheat, grass/clover (harvested/mulched ley), and field beans.

Parameter	Winter wheat	Potatoes	Grass/clover (Fodder)	Grass/clover (mulched)	Field beans
yield ($t\ FM\ ha^{-1}$)	**5.5 (grain)**	**2.8 (tubers)**	**60.0**	**60.0**	**4.5 (grain)**
$\Sigma(C_R,C_{RT},C_{EX},C_{RE})$ ($t\ DM\ ha^{-1}$)	3.53	2.48	13.20	17.72	3.45
h	$h_R = 0.3$; $h_{RT} = 0.2$; $h_{EX} = 0.05$; $h_{RE} = 0.2$				
C_H ($kg\ C\ ha^{-1}$)	*708*	*498*	*2645*	*3215*	*691*
N_{PB} ($kg\ N\ ha^{-1}$)	125	156	469	469	302
N_{dfa} ($kg\ N\ ha^{-1}$)	0	0	295	295	211
N_D ($kg\ N\ ha^{-1}$)	20	20	20	20	20
N_{Fert} ($kg\ N\ ha^{-1}$)	0	0	0	0	0
ΔN_{min} ($kg\ N\ ha^{-1}$)	0	+50	0	0	0
wp	$wp_I = 0.75$; $wp_{Fert} = 0.75$; $wp_H = 0.9$				
N_H ($kg\ N\ ha^{-1}$)	*140*	*206*	*176*	*176*	*84*
hrc ($kg\ C\ ha^{-1}$)	**-610***	**-1676***	**+789**	**+1359**	**-194***

* assumption: all straw removed

In the example, beneficial site conditions (e.g. luvisol areas) and corresponding whole plant utilization rates for N are displayed.

Discussion

There may be some doubt about the inclusion of both C and N in the algorithm instead of expressing hpc as a function of only C or N. However, a bipartite approach was also used by Hülsbergen (2003). The reason is that there is neither a direct link between C in plant biomass and C mineralized from the SOM pool, nor between N input and humus buildup. Even though the approach for calculation of humus mineralization in principle allows for the assessment of cropping systems with fertilization, parameters cannot be easily calibrated. In the algorithm, SOM mineralization and mineral N supply from other sources are correlated negatively. Admittedly, the impact of mineral N supply on SOM mineralization is complex (Kuzyakov et al. 2000) and usually not regarded in models on SOM turnover (e.g. Petersen et al. 2005). Here, further investigations are necessary to correctly adjust the method. As for organic matter supply by roots and root exudates, the approach has to cope with the heterogenity of root biomass quantity. Still the application of generalized shoot/root ratios for each crop seems to be possible since the estimated values can offer sufficient accuracy.

Further attention has to be paid to the continuous adjustment of whole plant utilization rates for N as well as humification rates. Even though results from comprehensive investigations have been published facilitating the derivation of (tentative) values (Hülsbergen 2003, Klimanek 1997), parameter calculation has to be recognized as a sensitive possible source of error.

Conclusions

The approach presented in this paper considerably improves the methodologial performance of humus balancing by providing a reproducible approach for balance coefficient calculation. In doing so the adaptation of the instrument to new situations is facilitated. Still, further research efforts are necessary to continuously improve and adjust the instrument. It remains a challenge to simplify and generalize the complex context of management measures, site conditions and humus dynamics in order to provide adequate assessment tools for application in practice.

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Soil quality indicators in organic and conventional farming systems in Slovakia

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Key words: farming management system, organic system, conventional system, chemical, biological soil properties

Abstract

In this study we compare some chemical and biological soil properties using the organic and conventional systems. In 2003 and 2004 the soil characteristics were observed on the precise field experiment plots in Borovce (near Piešťany, in the western part of the Slovak Republic) where organic management has taken place since 1995. The soil representative is loam and clay, loam degraded Chernozem on loess. The chemical and biological soil properties were determined within two farming systems: organic and conventional. The lower values of soil reaction and the higher contents of organic matter and inorganic nitrogen in the soil were measured under organic treatment. Organic management also positively affected a number of the cellulolytic and ammonification bacteria as well as microbial biomass content, ammonification and nitrification activity. The earthworm population was more developed at the organic variant. During the years 2003 and 2004, after eight years of organic management utilisation, the tendency of increased biological activity in the soil under organic management was observed.

Introduction

Several studies show that organic farming leads to higher soil quality with higher microbiological activity than conventional farming, due to versatile crop rotations, reduced application of synthetic nutrients, and the absence of pesticides (Hansen et al., 2001 and Shannon et al., 2002). Drinkwater et al. (1995) reported higher pH, organic C and N, N mineralisation potential, and actinomycete abundance and diversity in organic fields than conventional ones. Different authors have indicated similar benefits in soil quality from organic management (Wander et al., 1994, Gunapala and Scow, 1998, Liebig and Doran, 1999 and Bulluck et al., 2002). Despite the recent interest in organic agriculture, little research has been carried out in this area in the Slovak Republic and only a small amount of data is available to assess the long-term effects of organic management. Since the management systems react differently in different soil - climatic regimes with respect to soil quality**,** the objective of this study was to evaluate the impact of organic production practices on soil quality in the western part of the Slovak Republic where organic farming management has been carried out since 1995. Several chemical and microbiological indicators of organically and conventionally managed soils were measured and the soil quality was compared within the precise field experimental plots on degraded Chernozem on loess.

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Materials and methods

The experimental plots are situated in an area with a continental character of weather (average annual temperature of 9.2 ^{0}C and the mean annual precipitation of 593 mm). A large variability of temperature and unequal precipitation are a characteristic of this area. The soil representative is loam and clay loam degraded Chernozem on loess (pH 6.68 – 6.73, humus content 1.8 – 2.0 %, good available potassium store, medium phosphorus content and high magnesium content). The chemical and biological soil properties were determined within two farming systems:

Organic system: All operations were undertaken in compliance with Slovak Law SR 421/2004. Crop rotation: alfalfa, winter wheat + intercrop, pea, winter wheat + intercrop, potatoes, spring barley + alfalfa underseeding. Phacelia and mustard were used as an intercrop mix. This type of crop rotation represents a typical crop rotation for the regional practice in this region in Slovakia. Farm yard manure fertilisation took place three times during the crop rotation to potatoes (dose 30 t/ha) and winter wheat after pea and alfalfa (dose 15 t/ha). Vermisol preparation was used to pea and spring barley and winter wheat (dose 50 l/ha) mainly for the quality of production improvement. The P and K fertilisation couldn't be undertaken as there was no permit available in the Slovak Republic. Within the system there was mechanical weed control but there was no chemical plant protection.

Conventional system: This system had the same crop rotation as the organic system. Farmyard manure fertilisation took place once during the crop rotation on the potatoes (dose 30 t/ha); Vermisol was applied to winter wheat after both forecops (dose 50 l/ha). The synthetic N fertilisers were used to pea, spring barley and to wheat and P and K mineral fertilisation was defined by the balance method. Chemical protection was used against pests and diseases.

The same varieties and soil tillage practices were used in both farming systems and nitrogen inputs from organic fertilisers in organic system were equal as this in conventional system from synthetic fertilizers. The systems simulated farming systems without animal husbandry. Farm yard manure applied into organic and conventional system was bought from nearby organic farm. Farm yard manure composition represented 22 % of dry matter, 17 % of organic compounds, 0.48 % of N, 0.11 % of P and 0.51 % of K. The soil samples were taken four times during the vegetation period, from the depth of 0.02 – 0.2 m. The air dried soil samples were used for the chemical analysis (pH/KCl, C_{ox}, N_t, N_{in}). The biological analyses were determined in the fresh soil samples.

Used methods: pH/KCl measured by Ion Analyser (JENWAY, VB), C_{ox} measured by analyser CNS-2000 (LECO, Corp. St. Joseph, MI, USA), N_t measured by analyser CNS-2000 (LECO, Corp. St. Joseph, MI, USA), inorganic nitrogen (N-NH_4^+ + N-NO_3^-) – (N-NH_4^+) measured by Spekol 11 (Carl Zeiss, Jena, SRN), (N-NO_3^-) izotachophoretic determination by analyser EA 100 (VILLA Labeco Spišská Nová Ves, SR). Ammonification activity = inorganic forms of nitrogen increase N-NH_4^+ + N-NO_3^- after 14 days of aerobical soil cultivation. Nitrification activity = N-NO_3 increase after 14 days of aerobical soil cultivation. Microbial biomass C_{mic} defined by fumigation – extraction method. Cellulolytic bacteria number on mineral agar, ammonification bacteria number on agar No.2. The number of earthworms sorted by hand from the sonde, 0.25 x 0.25 x 0.3 m on a PVC sheet directly in the field, earthworms' biomass and average weight of one earthworm in the laboratory conditions.

The obtained results were statistically evaluated by non-parametric method by means of the Wilcoxon pair test.

Results and discussion

The two farming systems (organic and conventional) compared in Borovce, near Piešťany has emphasised interesting differences in soil quality after eight years of organic farming management utilisation. The soil pH was not statistically different between conventional and organic management (Table 1) although a higher soil reaction was discovered in the organic farming system. The organic management system and the use of organic residues and farmyard manure (FYM) have been shown to maintain soil organic matter at higher levels than inorganic fertilisation. This increase is particularly important in Slovakia, where the decline of organic matter content represents more than 59 % of the land area. Several studies have shown the similar results, that regular application of fertilizers for many years leads to an increase in soil organic C (Reeder et al., 1998 and Kundu et al., 2001). In general, the use of organic manures and compost enhances SOC more than application of the same amount of nutrients as inorganic fertilizers (Gregorich et al., 2001). Similar increases in SOC content due to addition of FYM were also observed by Swarup and Yaduvanshi (2000) in India.

Microbial biomass was higher under the organic system with the application of farm yard manure than the conventional management system. Microbial biomass is among the most labile pools of organic matter and it serves as an important reservoir of plant nutrients, such as N and P (Marumoto et al., 1982). Microbial biomass, in response to environmental changes, can therefore have important implications for nutrient bioavailability. The same results were also obtained by Melero, Porras, Herencia, Madejon, 2006. The number of cellulolytic and ammonification bacteria was significantly higher in the organic system in comparison with the conventional system, based on statistics. More intensively the processes of ammonification and also nitrification run under organic management. The data shows a higher activity of ammonification microflora decomposing nitrogen organic compounds and also nitrification microflora which oxidise a part of ammoniacal nitrogen. Biomass, the abundance of earthworms and the average weight of one earthworm were higher in organic plots as compared with the conventional plots but the differences were not statistically significant.

Tab. 1: Soil chemical and biological characteristics in organic and conventional system in the years 2003-2004

Indicator	Organic System	Conventional System
pH/KCl	6.73	6.68
C_{ox} (%)	1.297	1.225
N_t (%)	0.118	0.113
N_{in} (mg.kg^{-1} dry matter)	15.3	11.0
Ammonification activity (mg.kg^{-1} dry matter)	13.9	12.1
Nitrification activity (mg.kg^{-1} dry matter)	13.9	12.0
Microbial biomass (C_{mic}.g^{-1} dry matter)	700.6	677.8
Number of cellulolytic bacteria (*n*.10^3 CFU.g^{-1} dry matter)	7.81	6.25
Number of earthworms (ks.m^{-2})	39	34
Earthworms biomass (g.m^{-2})	19.4	15.1

Tab. 2: Wilcoxon pair test (significance of differences between organic and conventional system)

Indicator	Number of no-zero differences	Test value	P-value
pH/KCl	12	0.204124	0.838252
C_{ox}	19	3.49149	0,00048043^{++}
N_t	19	3.49149	0,00048043^{++}
N_{in}	25	0.144338	0.885229
Ammonification activity	27	1.19257	0.233037
Nitrification activity	31	2.04211	0,0411404^{+}
Microbial biomass	27	0.721688	0.470484
Number of cellulolytic bacteria	33	2.62557	0,00865046^{++}
Number of ammonification bacteria	31	2.04211	0,0411404^{+}
Number of earthworms	19	0.338062	0.735313
Earthworms biomass	27	1.3568	0.174844
Average weight of one earthworm	24	0.452267	0.651073

$^{+}$ Significant for P<0.05, $^{++}$ Significant for P<0.01

Conclusions

The results indicated that organic management with addition of farm yard manure positively affected soil properties, increased organic matter content and bacteria community. Organic residues added to the soil promoted ammonification and nitrification activity and the amount of microbial biomass.

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The importance of amino-N for humus formation studied by comparing amino-N input to the soil and soil total nitrogen content in long-term experiments

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Key words: soil organic matter, nitrogen fractions, amino acids, soil fertility

Abstract

Humus formation is thought to depend directly on carbon input. Referring to earlier studies we tested the role of amino-bound nitrogen (amino-N) input to the soil using data of 10 long-term experiments with different fertilization and crop rotation treatments. In 8 out of the 10 experiments there was a significant positive correlation between the amino-N input and soil total N content. This correlation was much stronger than the one of total N input and soil N content, indicating that amino-N was more important for soil N accumulation than total N input. Amino-N from farmyard manure seems to be more effective in this respect than amino-N from other organic fertilizers.

Introduction

Humus (soil organic matter) is usually considered as a product of soil life. Humus level and composition are of crucial importance for many biological, chemical and physical properties of soils. Humus analysis and management are usually based on its carbon content. This view, however, seems to be too restrictive. Among others, the findings of Sowden & Schnitzer (1967) and Scheller & Friedel (2000) indicate that amino acids are involved in the synthesis of humic substances in agricultural soils and that amino acid turnover is one of the main factors influencing the organic matter content in soils. When analysing a number of soil samples under arable, grassland and forest use, Friedel & Scheller (2002) observed that 28-50% of total nitrogen was determined as hydrolysable amino acid-N. Therefore, Scheller & Friedel (2000) claimed that amino acids play an important role in the formation of soil organic matter and humic substances. The objective of our investigation was to test the hypothesis that a higher input of amino-N (protein, peptide, amino acids) to the soil leads to a higher humus content, resulting also in a higher soil total nitrogen content. The evaluation was based on data from 10 long-term experiments with different fertilization and crop rotation treatments.

Materials and methods

Long-term experiments have been selected that include at least one organically fertilized treatment and treatments with mineral fertilization. Basic information of the trials is given in Table 1. Trial 3 is located in Switzerland, no. 5 in Sweden and all

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other trials in Germany. Further information and standard references of each experiment has been presented by Schuler (2007).

Tab. 1: Basic information on the selected experiments

No	Name	Period	Treatments
1	IOSDV* Berlin-Dahlem	1984-2003 (20 years)	Unfertilized; min**; FYM***; FYM + min; crop residues; crop residues + min
2	LTE Darmstadt	1981-1995 (15 years)	Min; FYM; FYM + bd**** preparations; each type at 3 rates
3	DOK trial Therwil	1978-1998 (21 years)	5 cropping systems fertilized with composted FYM + bd preparations; rotted FYM; FYM + min.; min solely; unfertilized
4	K trial Järna	1958-1985 (28 years)	Unfertilized; min at 3 rates; comp. FYM; the same plus bd spray preparations; fresh FYM; fresh FYM + min
5	Static Fertilization Experiment Bad Lauchstädt plus Legumes	1926-1982 (57 years)	Untertilzed; legumes; min; min + legumes; FYM at 2 rates; FYM at 2 rates + min; FYM at 2 rates + legumes; FYM at 2 rates + min + legumes
6	Static Fertilization Experiment Bad Lauchstädt	1903-1930 (28 years)	Unfertilized; min; FYM at 2 rates; FYM at 2 rates + min
7	IOSDV Puch	1984-2004 (21 years)	Unfertilized; min; FYM; straw; straw + legumes; slurry; straw + slurry; all the organic treatments were also combined with min
8	Fertilzer Combination Trial Seehausen	1967-1996 (30 years)	Unfertilized; min; FYM + min; high rate of FYM; high rate of FYM + min
9	IOSDV Speyer	1983-2003 (21 years)	Unfertilized; min at 2 rates; FYM; FYM + 2 rates of min; crop residues; crop residues + 2 rates of min
10	Static Soil Fertility Trial Thyrow	1937-1978 (42 years)	Mineral fertilzer at 2 rates; FYM at 2 rates; FYM at 2 rates + min; green manure; green manure + min; straw; straw + min

* IOSDV = international organic nitrogen long-term trial
** min = mineral fertilizer
*** FYM = farmyard manure
**** bd = biodynamic

Data of the fertilizer amounts and N contents have been taken from publications of the experiments. N contents of manure were available in each case. If N contents of other organic fertilizers were missing, standard averages taken from other references were used. The total and the yearly N input by different fertilizers were calculated for each treatment over a defined period. N input by wet deposition was assumed to be the same for all treatments of a trial and, therefore, was not considered. The amino-N input was calculated based on organic fertilizers only, as they are the largest input pool of amino-N. Analytical data for amino-N contents in manure, slurry, straw, beet leaves etc. were taken from different references listed by Schuler (2007). If legumes (in monoculture or mixture) were cultivated as green manure crops, the amino-N input by the crop residues was calculated with the data of residue amounts, their N contents and standard analytical data of their amino-N ratios taken from references listed by Schuler, 2007. In some cases missing data had to be estimated. For example, for pea roots the amino-N ratio of clover roots was used. Amino-N input by other crop residues and root exudates were assumed to be similar in all treatments of a trial and, therefore, were neglected. For each single trial, the relationship between either amino-N input (by organic fertilizers and, if applicable, by legume crop residues) or total N input and soil total N content was tested by Kendall's rank correlation (Sokal & Rohlf, 1995). For all trials the effect of fertilization was tested by calculating the surplus of soil N in a fertilized treatment compared to the respective unfertilized one. This procedure helped to compare N supply effects across different sites. Linear regressions were calculated for the N surplus of a treatment against the amino-N input.

Results

In 8 out of the 10 experiments (apart from no. 1 and 4) the amino-N input was significantly correlated with the N content of the soil; the correlation coefficients varied between 0.54 and 0.89 (Table 2). In all these cases the correlation between total N input and soil N was much weaker and in many cases statistically not significant. Therefore, it can be concluded that the amino-N sypply was more important for accumulation of soil N than the total amount of N applied by fertilizers.

Tab. 2: Correlation between either amino-N input or total N input and soil total N content (at the end of the observation period) in all experiments; Kendall's rank correlation *tau* and its probability p

No.	Site	Correlation between amino-N input and soil total N content	Correlation between total N input and soil total N content
1	Berlin-Dahlem	0.2981 (p = 0.2004)	0.0667 (p = 0.4225)
2	Darmstadt	0.7650 (p = 0.0020)	0.4119 (p = 0.0610)
3	Therwil	0.6708 (p = 0.0502)	0.0000 (p = 0.5000)
4	Järna	0.3118 (p = 0.1400)	0.3536 (p = 0.1103)
5	Bad Lauchstädt	0.7526 (p = 0.0003)	0.6260 (p = 0.0023)
6	Bad Lauchstädt	0.7454 (p = 0.0178)	0.7333 (p = 0.0194)
7	Puch	0.5444 (p = 0.0069)	0.3817 (p = 0.0420)
8	Seehausen	0.8944 (p = 0.0142)	0.8000 (p = 0.0250)
9	Speyer	0.5774 (p = 0.0151)	0.3000 (p = 0.1301)
10	Thyrow	0.8040 (p = 0.0006)	0.3146 (p = 0.1027)

There was no statistically significant relationship between amino-N input and the N surplus in fertilized compared to unfertilized treatments. This was observed with all treatments that have received organic fertilizers only, as well as with all farmyard manure treatments (data not shown). However, the linear regression for all organic treatments showed a much lower probability (p=0.158) than the one for manure treatments (p=0.071) which may be a hint that farmyard manure has a specific function among organic fertilizers.

Discussion

The rank correlation results support the hypothesis mentioned above, as a higher input of amino-N was more important for soil N accumulation (and humus formation) in most experiments than a high total N input. However, the wide range of correlation coefficients indicates that amino-N input had no exclusive effect, but interacted with other experimental details or site conditions. No simple reason can be identified, why amino-N had no significant effect in two trials. Apparently, the role of amino-N was basically independent from whether organic (trial no. 2, 3, 4) or conventional cultivation was practised, though an earlier study with trial 2 indicated an effect of biodynamic preparations on amino acid turnover in the soil (Scheller & Raupp, 2005). The origin of organic fertilizers, i.e. farmyard manure, slurry, straw, legumes, probably is of relevance for the amino-N effect on humus formation, as our results suggest (Schuler, 2007; data not shown). This aspect has to be considered in detail in further research, because of the growing trend, in each type of agriculture, to use residues of plant biomass fermentation as fertilizers. Due to restricted data availability, in our study some simplifications had to be made. In order to obtain more specific results, in further investigations the amino-N input by roots and other crop residues should be quantified. Furthermore, not only input but also a possible loss from soil of amino-N e.g. by mineralization or direct uptake by crops should be considered.

Conclusions

Soil organic matter management solely based on carbon replacement does not reflect current understanding in a sufficient way. The role of amino-N and its fate during composting (and other processes of organic matter decomposition) should be investigated in more detail. Methods for humus budgeting may have to be revised.

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Changes in light fraction soil organic matter and in organic carbon and nitrogen in compost amended soils

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Key words: snap beans, soil organic matter, nitrogen, carbon, compost

Abstract

Organic vegetable growers can use compost to supply crops with nutrients and increase soil organic matter (OM), but little information is available about the transformations of compost OM over time in organically managed systems. This study examined light fraction soil organic matter (LFSOM) and organic carbon (C) and nitrogen (N) in organically and conventionally managed snap bean cropping systems (continuous beans (CB) and a fully phased beans/fall rye rotation (BR)) following three years of fertility treatments (1x and 3x compost, and 1x synthetic fertiliser, where 1x provided 50 kg ha^{-1} N). Light fraction C and N increased with compost amendment, with the C:N ratio significantly lower in composted plots than in synthetically fertilised plots. Rotation and weeding method played no role in the composition of LFSOM, or the percentage of LFSOM making up whole soil organic C or N. Light fraction N and C roughly doubled in the 1x compost plots over the three years, compared with synthetically fertilised plots, but was only 2.5 times higher in 3x compost plots. While the addition of 13 t ha^{-1} C increased whole soil C by 5.6 Mg ha^{-1}, tripling the amount of added C raised whole soil C by 9.9 Mg ha^{-1}. 1x and 3x compost increased whole soil N by 20 and 33%, respectively, compared with the 1x synthetically fertilised plots. The 3x compost treatment only, by reducing bulk density, improved soil physical properties.

Introduction

Soil organic matter has many important functions in promoting crop growth, including provision of nutrients, retention of water, connecting pore spaces and supporting plant-growth promoting organisms (Weil and Magdoff, 2004). When fertilising organic crops with compost, large quantities of organic matter are added to the soil influencing physical properties such as bulk density (Lynch et al., 2005), as well as pools of organic carbon. One densiometric fraction, the light fraction soil organic matter (LFSOM), represents a pool of organic matter intermediate to labile pools of fresh crop residues and recalcitrant pools of humic materials. LFSOM is considered a useful early indicator of changes in SOM due to management practice (Gregorich and Ellert, 1993), and has been used to describe the fate of compost amendments to soil (Lynch et al., 2005; Carter et al., 2004; Grandy et al., 2002). Fertility treatments affect the

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proportion of LFSOM in the soil, as well as its constituent proportions of carbon and nitrogen (Lynch et al., 2005; Grandy et al., 2002). Other cropping practices may affect LFSOM, including crop rotation (Grandy et al., 2002) and, over the long term, tillage (Murage et al., 2007). This study aimed at determining the effects of three years of fertility regime (synthetic fertiliser vs. compost rates), crop rotation, and weeding tillage on LFSOM and LF C and N.

Materials and methods

A long term organic rotations experiment was established in 2002. The layout consisted of three replicates at two sites, each comprising three strips, to which each was assigned a rotational sequence of continuous beans (CB), or one of the phases of a beans/fall rye two-year rotation (BR). Strips were divided into six plots. To each was assigned a treatment combination (Table 1) of fertiliser and weeding method. Compost had a mean C:N ratio of 19.8, with total nitrogen on a dry matter basis of 1.2%. The 1x compost rate delivered the equivalent of 50 kg N ha^{-1}: the same rate of N applied in synthetically fertilised plots. In herbicide-treated plots, herbicide applications followed commercial practices. Mechanical weeding was carried out twice per season. Treatments are summarized in Table 1. Bulk density cores and soil (0-15 cm depth) samples for organic matter analysis were taken after the completion of the crop rotation cycle, early in 2006. Total soil organic matter was separated into heavy and light fractions using a sodium iodide solution with a density of 1.7 g cm^{-1} in the manner described by Gregorich and Ellert (1993) and carbon and nitrogen were measured using dry combustion in a LECO CNS analyser. Analysis of variance was used to assess effects of rotation and fertility treatments, and calculations estimated the amount of applied compost C and N, and remaining whole soil C and N.

Tab. 1: Summary of treatments applied in the first rotation cycle (2003- 2005)

Treatment	Source of nutrients	Yearly N-P-K on Beans (kg/ha)	Yearly N-P-K on Rye (kg/ha)	Weeding method
F1x -M	Fertiliser	50-68-82	100-15-60	Mechanical
F1x-H	Fertiliser	50-68-82	100-15-60	Herbicide
C1x-M	Compost	50-28-26	50-28-26	Mechanical
C1x-H	Compost	50-28-26	50-28-26	Herbicide
C3x-M	Compost	150-84-78	150-84-78	Mechanical
C3x-H	Compost	150-84-78	150-84-78	Herbicide

Note: P and K rates are averages for the three years. For fertiliser, rates varied according to soil test. For compost, rates varied according to compost composition.

Results

Compost amendment affected the C and N content, and the C:N ratio of the LFSOM compared with synthetic fertiliser amendment (Table 2). In addition LF C and LF N as percentages of TOC increased with compost amendment (Table 3). Only the 3x rate of compost reduced soil bulk density. Weeding treatment and crop rotation did not significantly affect any of the parameters, though a significant rotation x weeding interaction existed for whole soil C:N showing it higher in mechanically weeded CB plots than in herbicide treated CB plots. In BR, weeding method did not affect whole soil C:N.

Tab. 2: Mean light fraction (LF) carbon (C), nitrogen (N) content and C:N in soil (0-15 cm) from different fertility treatments applied from 2003-2005.

Treatment	LF %C	LF %N	LF C:N
F1x	27.40	1.33	20.42
C1x	29.76	1.58	18.82
C3x	31.40	1.70	18.48
Standard error of mean	0.026	0.019	0.304
Significance			
Fertility application	***	***	***
Fertiliser vs. Compost	***	***	***
Rotation	ns	ns	ns
Weeding	ns	ns	ns

ns non-significant, *** significant for $P<0.001$

Tab. 3: Mean light fraction (LF) carbon (C) and nitrogen (N) expressed as percentatges of whole soil (0-15 cm) organic (O) C and N, and bulk density in fertility treatments over 2003-2005.

Treatment	LF-C as % of whole soil OC	LF-N as % of whole soil ON	Bulk density (g $(cm^3)^{-1}$)
F1x	7.40	6.33	1.30
C1x	13.47	11.86	1.30
C3x	18.86	16.71	1.24
Standard error of mean	0.070	0.076	0.015
Significance			
Fertility application	***	***	**
Fertiliser vs. Compost	***	***	~
Rotation	ns	ns	ns
Weeding	ns	ns	ns

ns non-significant, ~ significant for $P<0.1$ *significant for $P<0.05$, **significant for $P<0.01$, *** significant for $P<0.001$

Tab. 4: Carbon (C) and nitrogen (N) applied over three years, and changes to mass of whole soil C and N measured in 2006.

Treatment	Total C applied (Mg ha^{-1})	Total N applied (kg ha^{-1})	Whole soil C (Mg ha^{-1})	Whole soil N (kg ha^{-1})
F1x	0	150	31.6	1950
C1x	13	150	37.2	2340
C3x	39	450	41.5	2604

Discussion

Gains in LFSOM, C and N are expected when amending soils with composts, which are composed of organic matter in varying stages of transformation from labile fresh material toward humic materials. In this study, gains in LFSOM, C and N were not proportionate to compost application rate. This runs contrary to the results of another study which examined corn silage compost at two rates, one double the other, and found that soil C concentrations and total soil C both increased proportionately with compost rate, compared with a non-compost amended control (Lynch et al., 2005). Compost did not transform into more resistant heavy fraction soil organic matter (HFSOM) more quickly in the 3x compost rate than in the 1x compost rate, since HFSOM data showed equal increases in HF C and HF N between synthetic fertiliser and 1x compost as between 1x and 3x compost (data not shown). Other interactions are likely at work, which may be revealed with further study of crop residues returned to the soil during the period of study, crop products exported. Study of plant nutrient data may give insight into the mineralization of organic matter in the different treatments.

Conclusions

Compost application increased whole soil C and N, LFSOM, LF C, LF N, and the LF C:N ratio. Weeding method and crop rotation did not affect these parameters, except in the CB rotation, where mechanical weeding resulted in a higher C:N ratio than did herbicide. Compost amendment at the 3x rate decreased bulk density compared with both 1x compost and synthetic fertiliser. Though the SOM parameters increased with compost application, the increase was not a linear relationship with rate. This may interest growers whose cost of compost (fixed $ per ton) increases linearly with rate.

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Effects of organic matter input on soil microbial properties and crop yields in conventional and organic cropping systems

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Key words: soil organic matter, crop yield, crop rotation, soil microbiology.

Abstract

Unlike conventional cropping systems, which are characterised by targeted short-term fertility management, organic farming systems depend on long-term increase in soil fertility and promotion of soil biodiversity. This study sought to investigate long-term effects of organic matter inputs on various cropping systems in a 10-year-old experiment. Results show that in the long-term high C and N inputs enhance microbial activity. Microbial biomass N and the potential nitrification rate were higher in cropping systems based on green manure than in those reliant on inputs from animal manure and mineral fertilizer. Soil microbiological properties were affected by the individual crops in the rotation. The high microbial activity with increased organic matter inputs did not transform to enhanced crop productivity.

Introduction

Crop production in organic farming systems relies to a large extent on soil fertility for nutrient supply. The soil fertility must be maintained via choice of crop rotation and (green) manuring practices. Fertility building by such means requires a long-term integrated approach, rather than the short-term and targeted solutions common in conventional agriculture. The fertility building in organic cropping systems has consequences for soil biological properties, which subsequently may influence N and C flows and emissions, including greenhouse gases (Mäder et al., 2002). The changes in organic matter input may affect crop yields and soil properties differently in different systems depending on mineral nutrient supply to the crops. These effects can only be properly studied in long-term experiments, where the fertility effects of various cropping systems are reflected in changes in soil properties and in crop responses. In this paper we explore the effects of different organic matter inputs on crop yields and soil microbiological properties in a 10-year old cropping system experiment in Denmark.

Materials and methods

A crop rotation experiment was initiated in 1996/97 at three sites in Denmark (Olesen et al., 2000), but only data from the site at Foulum is used in this paper (Table 1). Foulum is located in Central Jutland on a loamy sand with an annual rainfall of 704 mm. During the period 1997 to 2004 the experimental factors were 1) proportion of N_2-

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fixing crops in the crop rotation, 2) with (+CC) and without (-CC) catch crop, and 3) with (+M) and without (-M) animal manure. Two crop rotations (O2 and O4) with different proportions of cereals and nitrogen fixing crops in a four-year rotation were tested (Table 1). All crops in all rotations are represented every year in two replicates (blocks). The plots receiving manure were supplied with anaerobically stored slurry at rates where the NH_4-N amount corresponded to 40% of the N demand of the specific rotation based on a Danish national standard (Plantedirektoratet, 1997). The grass-clover was used solely as a green manure crop, and the cuttings were left on the ground. All straw was left in the field.From 2005 the design was changed to include a conventional cropping system (C4) with a crop rotation similar to the O4 rotation (Table 1). Conventional treatments (C4) replaced the previous -CC/-M treatments in O2 and O4 such that O2/-CC/-M was converted to C4/+CC and O4/-CC/-M was converted to C4/-CC. The crops in C4 received mineral fertiliser at recommended rates. A mixture of legume and non-legumes were used for the catch crops in O2 and O4, whereas non-legumes were used in the C4 catch crop treatment. From 2001 the cuttings in grass-clover in O2/+M was no longer mulched, but removed from the field. Manure application is based on the principles of recirculation, where nutrients in the cuts from the grass-clover are processed by anaerobic digestion and redistributed to the row crop and cereals in the rotation. In O4/+M treatments the manure application is based on import from conventional farms. Weeds were controlled by mechanical means in O2 and O4, whereas pesticides were used at recommended rates in C4 to control weeds, pests and diseases.

Tab. 1: Structure of the crop rotations.

	Crop rotation	O2	O4	C4
1st course 1997-2000	1 2 3 4	S. barley:ley Grass-clover Winter wheat^{CC} Pea/barley^{CC}	Spring oat^{CC} Winter wheat^{CC} Winter cereal^{CC,1} Pea/barley^{CC}	
2nd course 2001-2004	1 2 3 4	S. barley:ley Grass-clover Winter wheat^{CC} Lupin/barley^{CC}	Winter wheat^{CC} Spring oat^{CC} S. barley^{CC} Lupin	
3rd course 2005-2008	1 2 3 4	S. barley:ley Grass-clover Potato Winter wheat^{CC,3}	S. barley^{CC} Faba bean^{CC,2} Potato Winter wheat^{CC,3}	S. barley^{CC} Faba bean^{CC,2} Potato Winter wheat^{CC,3}

^{CC}Catch crop in the +CC-treatments, [1] Triticale in 1999 and 2000, [2] Pea/barley in 2005, [3] S. oats in 2005.

Grain yields were measured at maturity using a combine harvester. Samples of total above-ground biomass in the grass-clover were taken in 1 m^2 sample areas in each plot at each cut. To determine total crop production, samples of total above-ground biomass were taken in 1 m^2 sample areas in each plot 1-2 weeks before maturity. Similar samples of total above-ground biomass were taken about 1 November to measure the above-ground biomass of catch crops and weeds. Total N in the grain and plant samples were determined on finely milled samples from each plot by the

Dumas method. Carbon content in plants was estimated under the assumption of 46% C content in plant DM biomass. Soil organic C and N were determined by dry combustion. Microbial biomass was determined by the chloroform fumigation incubation technique (Joergensen and Brookes, 1990). Nitrification potential was assessed using the method described by Hart et al., (1994).

Results

There were higher C and N inputs from aboveground material in the organic compared to the conventional systems, in particular affected by the catch crop (CC) treatment (Table 2). The organic system O2/+CC received significant C and N inputs from grass-clover and O4/+CC from crop residues and catch crops. This was reflected in a higher soil organic C content in the organic compared to the conventional treatments (Table 3). Microbial biomass N and nitrifier activity was highest in the O2/+CC and lowest in the conventional system (Table 3). The microbial population and activity, which increased with organic inputs in plots that will have spring barley in 2008, but showed no clear trend in the winter wheat plots. Annual grain yields were consistently higher in conventional compared to organic systems (Table 4). Grain yields obtained in the O4/+CC were comparable with yields from the O2/+CC. The low yields obtained for spring oats in the conventional system in 2005 were due to crop lodging.

Tab. 2: Annual C and N inputs in organic matter of manure and above-ground plant material (1997- 2006).

	Source	C4/-CC	O4/-CC	O4/+CC	O2/+CC
C input	Manure	0.0	0.3	0.3	0.2
(Mg DM/ha/yr)	Grass-clover	0.0	0.0	0.0	1.6
	Crop residues	2.1	2.4	2.9	2.4
	Catch crops	0.2	0.2	1.0	0.3
	Total	2.3	2.9	4.2	4.5
N inputs	Manure	0	18	18	15
(kg N/ha/yr)	Grass-clover	0	0	0	95
	Crop residues	42	40	61	44
	Catch crops	10	9	58	16
	Total	52	66	137	170

Tab. 3: Soil biological and chemical properties (+ *S.E; n =2*)

Soil Parameter	2008 crop	Treatment			
		C4 /-CC	O4/-CC	O4/+CC	O2/+CC
Organic C (%)	S. barley	1.95	2.10	2.09	2.28
	W. wheat	1.91	2.29	2.00	2.39
Microbial biomass N (µg N / g soil)	S. barley	32.1(2.3)	36.3(2.3)	36.0(4.0)	47.2 (0.8)
	W. wheat	27.2 (2.2)	32.7(1.3)	27.2*	29.2 (3.3)
Potential Nitrification (nmol NO_3 / g soil / h)	S. barley	10.6(0.3)	13.9(0.01)	15.5(1.6)	16.6(0.4)
	W. wheat	12.3(1.7)	16.3(1.9)	15.1(0.2)	17.9(0.2)

Discussion

The results suggest that increased microbial activity follows increased annual C and N inputs in cropping systems. This finding agrees with Raupp (1995), who reported higher microbial biomass in organic compared to conventionally managed soils. Catch crops significantly increase soil organic matter levels (Olesen et al., 2007), thus microbial activity and grain yield were as expected lower in organic system without catch crops. In line with the observations made by Acosta-Martinez et al., (2004), microbiological parameters, unlike organic C, were effected by crop type. The lower microbial population after the potato crop that preceded winter wheat suggests that potatoes had a negative effect on soil rhizosphere microbial populations. The generally higher nitrifier activity could be due to high residual N as the 2007 potato crop was affected by disease. Increased organic matter inputs enhanced microbiological properties, but did not necessarily translate to improved crop productivity. This is inevitable in organic systems where plant nutrient demand is rarely in synchrony with nutrient availability (Watson et al., 2002).

Tab. 4: Dry matter grain yields Mg DM ha^{-1} (±*SE; n = 6*)

Crop	Year	Treatment			
		C4/-CC	O4/-CC	O4/+CC	O2/+CC
S. oat	2005	4.12	5.11	5.42	5.27
W. wheat	2006	7.05	5.19	6.08	6.16
	2007	6.86	3.50	3.32	4.00
S. barley	2005	6.25	4.92	5.19	4.86
	2006	5.74	4.38	5.14	4.77
	2007	4.64	3.13	4.53	4.51
Mean		5.78 (0.41)	4.37 (0.3)	4.95 (0.32	4.93 (0.25)

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The Potential Role of Organic Soil Fertility Management in the Kenya Highlands

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Key words: soil fertility, Kenya highlands, smallholders, legumes, organic farming

Abstract

Soil fertility degradation still remains the single most important constraint to food production in the Kenyan Highlands. It is estimated that 64% of the population resides in the highlands, with population densities in some areas of over 1000 persons/km^2. Use of inorganic fertilisers on smallholdings in the Kenya Highlands has been steadily declining since the 1960s, when heavy promotion and subsidization of fertilisers coincided with the release of improved maize varieties and the creation of co-operatives such as the Kenya Grain Growers Co-operative Union. Currently, their use continues to be constrained by their high cost, the low purchasing power of smallholders, and limited access to credit facilities. Farm sizes are getting smaller, and this promotes continuous cropping with limited scope for crop rotation and inadequate soil fertility replenishment. Soil fertility improvement can be achieved through organic farming techniques such as biomass transfer, re-activation of the 'N bulge', and phosphorus scavenging. Legume intercropping with maize – Kenya's staple food – as well as the implementation of short rain legume fallows are known to enhance maize yields in most cases.

Introduction

Kenya is a remarkably fine illustrative case of the causes and consequences of soil nutrient depletion. Countrywide, under increasing land pressure from a still burgeoning population, nutrient losses (e.g., from leaching and erosion) and off-takes from crop harvest removals often exceed additions from biological processes (e.g., nitrogen fixation) and application of organic and inorganic fertilizers (De Jager *et al*., 1998). Yields of key commodities have stagnated, not only in areas with marginal agricultural potential, but also in regions with relatively good production prospects. As it is in other Sub-Saharan African countries, it is increasingly difficult to concurrently satisfy short-term production needs and long-term demands for environmental sustainability. Forced by the need to produce more staple crops for a growing population and to grow cash crops to integrate into the monetary economy, farm households replaced once stable systems with intensive systems relying heavily on external inputs, or they moved into ecologically fragile areas. The use of inorganic fertilizer in Kenya dates back to early 1920s. At the time of independence in 1963, fertilizers were mainly used by large-scale farmers, most of whom were European. After independence, fertilizer use was advocated and small-scale farmers started using it. However, the implementation of Structural Adjustment Programmes (SAPs) resulted in increased prices for external inputs, while price levels of agricultural products decreased or

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remained stagnant, and only a limited growth in productivity was realised. These developments have forced farm households to exploit soil nutrient resources, leading to negative nutrient balances in most parts of this region (see table 1).

Current On-Farm Nutrient Balances in Kenya

Many studies have been carried out to quantify nutrient balances in different ecological zones (i.e. Smaling *et al*., 1997; De Jager *et al*., 1998 and Onwonga and Freyer, 2006). They have all shown that there are negative nutrient balances. A few cases give reason enough for considering alternative soil fertility management, e.g. the case of Kisii district, a densely populated area with high agricultural potential in the western region of Kenya. Soils in the area are predominantly well drained, deep, and, with the exception of phosphorus, rich in key nutrients (Smaling *et al*., 1997). Mean annual rainfall is high, exceeding 1000 mm. Major food crops are maize and beans, key cash crops are tea, coffee, and pyrethrum, while livestock and improved pastures are common farm components. Most significantly, given the high population density, little land is left fallow during the year. Where inorganic fertilizers are used, application rates are well below recommended levels. Annual nutrient depletions in the district have been estimated at 112 kg/ha of N, 2.5 kg/ha of P, and 70 kg/ha of K (Table 1).

Tab. 1: Farm Level Soil Nutrient Balances in Kenya (kg ha^{-1} a^{-1})

Soil Nutrient	Kisii District[1,2]	Kakamega District[1]	Embu District[1]	Nakuru District[3]
Nitrogen (N)	-112	-72	-55	-30
Phosphorus (P)	-3	-4	9	14
Potassium (K)	- 70	18	-15	11

Source: Smaling et al. (1997)[1], De Jager et al. (1998)[2] and Onwonga & Freyer (2006)[3]

Similar patterns are reported for Kakamega district, which can be compared to Kisii in population density and agroecological potential, and in Embu and Nakuru districts, where population density and agroecological potential are lower (Table 1). Purchasing mineral nitrogen fertilizer is hardly possible because of financial reasons. The main emphasis is given to supplying mineral P through diammonium phosphate (DAP).

Economic returns to food-crops in these districts tend to be insufficient to cover the costs of additional N fertilizers required to replenish lost nutrients (De Jager, 1998). Negative N balances underline that farmers do not cultivate enough legumes as an alternative to add N. Mainly a limited proportion of beans, cowpea, and soyabeans contribute to the N-balance. Because clover or alfalfa is an exception in the long rains and the short rains are scarcely used for N-fixing fallow plants, besides the negative N balance there also is a lack of humus-relevant biomass production. Low humus contents lead to an increased risk of leaching of mineral P as well as loss of soil fertility in general driven by erosion processes.

Opportunities for Organic Soil Fertility Management in Kenya's Agriculture

Agricultural systems productivity can be invigorated through nurturing soil organic matter build-up, which allows higher and more stable yields. The addition of soluble nutrients is not a viable option for Kenya's smallholders experiencing declining farm household incomes and poor output markets coupled with increasing food insecurity.

Furthermore, this strategy is not sustainable for soil fertility development. Low-external input sustainable agriculture (LEISA) has been viewed as an alternative remedy for these areas. More recently, one particular alternative that has gained interest is organic agriculture because of its comprehensive advantages. Traditional farming systems practised over time by smallholder households in these regions rely on the recycling of organic matter to maintain soil fertility. Subsequently, by adopting organic agriculture, which requires less financial inputs while placing more reliance on human resources, farmers could move towards more sustainable agricultural practices.

Legume intercropping is an organic farming strategy in the tropics aiming at replenishing soil fertility, improving soil structure, and suppressing weeds, while generally providing the benefit of a higher overall yield. Many studies have been carried out to evaluate the agronomic and economic benefits of legume-cereal intercrops in Kenya and other parts of the world (Rao and Mathuva, 2000; Mburu et al., 2003; Lelei, 2004 among others).

N deficiency is a major constraint on the productivity of the Kenyan smallholder farming systems. Green manure and forage legumes have the potential to improve the soil N fertility of smallholder farming systems through biological N-fixation. The effects of legumes on yields of associated major crops have been well documented. Maize has been studied extensively in association with pigeon pea (Rao and Mathuva, 2000), common bean (Lelei, 2004) and mucuna (Mburu *et al*., 2003). These studies all have indicated that maize grain yield was not negatively affected but sometimes enhanced by the legume intercrop, suggesting a balanced effect of competitive depression and N transfer from the legume. For example, maize-pigeon pea intercropping systems produced 17 to 24% higher maize yields than continuous sole maize (Rao and Mathuva, 2000).

The incorporation of green manure is another technique to strengthen soil fertility. Soil fertility is related to soil structure, which can be measured by aggregate stability. A study conducted on maize plots in rotation with cover crops showed aggregate stability values of 41.3%, 45.7% and 50.5% after biomass removal, mulch application, and incorporation of biomass respectively (Gachene *et al*., 1999). The cover crops used were *Mucuna pruriens, Vicia benghalensis* and *Crotalaria ochroleuca*. The soil aggregate stability of plots with incorporated biomass was not affected by the type of biomass added.

The application of biomass from a previously grown leguminous or non-leguminous crop can prevent soil erosion, reduce nutrient losses, stimulate microbial activity in the rhizosphere, improve soil structure, and raise the yields of subsequent crops (Schlecht et al., 2006). In the Kenya Highlands, six legumes have been identified as promising green manure crops for smallholder farming systems, namely purple vetch (*Vicia benghalensis*), velvet bean (*Mucuna pruriens*), perennial soyabean (*Neonotonia wightii*), Tanzanian sunhemp (*Crotalaria ochroleuca*), lablab (*Lablab purpureus* or *Dolichos lablab*) and lima bean (*Phaseolus lunatus*) (Kiama and Muriithi, 2001).

Conclusion and Recommendations

The steady fall in Kenya’s stock of soil nutrients appears to be closely linked to soil fertility management practices such as monocropping and slash-and-burn methods, which are ill-suited to the relatively recent imperative of continuous cultivation under burgeoning population pressure. However, with appropriate soil fertility management practices, population pressure may not lead to nutrient depletion, but rather to improved soil quality and adequate yields.

Leguminous species have shown some potential for soil fertility improvement and soil conservation. Soil fertility improvement can be achieved through biomass transfer, short-term fallows, nitrogen fixation, re-activation of the 'N bulge' and P scavenging. Additionally, they have similarly shown potential for reducing soil erosion through five processes: interception of rainfall impact by tree canopy; surface runoff impediment by tree stems; soil surface cover by litter mulch; promotion of water infiltration; and formation of erosion-resistant blocky soil structure.

Because these systems require less financial input while relying more on human capital, there exists a huge potential, given the high population in these areas. The excess labour can be used for hauling biomass, mechanical weeding and composting, among other labour-intensive operations. In view of the aforementioned consideration, this review calls for more integrated soil management research beyond legumes so that farmers can always have fallbacks when one option is limiting. Agricultural extension agents should promote the use of legume intercrops to replace nitrogenous fertilizers and supplement human protein sources.

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Nutrient management

A Conceptual Framework for Soil management and its effect on Soil Biodiversity in Organic and Low Input Farming

Koopmans, C.J.[1] & Smeding, F.W.[2]

Key words: Soil biology, soil management, biodiversity, sustainability, soil model

Abstract

Learning how to manage beneficial soil biological processes may be a key step towards developing sustainable agricultural systems. We designed a conceptual framework linking soil management practices to important soil-life groups and soil fertility services like nutrient cycling, soil structure and disease suppression. We selected a necessary parameter set to gain insight between management, soil life and soil support services. The findings help to develop management practices that optimise yields, soil fertility and biodiversity in organic farming.

Introduction

Learning how to manage beneficial soil biological processes may be a key step towards developing sustainable agricultural systems. Organic farming aims at optimising production while maintaining a rich biological diversity of the soil (Davis and Abbott, 2006).

Farmers have an ongoing economic interest in soil ecosystem services like nutrient cycling and soil aggregate formation. Little knowledge exists however, about the relationship between specific soil management practices influencing soil biodiversity and these services. It may be true that environmental variables like soil type and climate determine to a large extent the soil community (Davis and Abbott, 2006). However, individual practitioners have many opportunities to influence this community in regard to optimising biological fertility at their individual farms.

In this paper we present a the conceptual framework linking soil services, soil management and its effects on soil biodiversity. The study focuses on the question: if we want to achieve certain soil ecosystem services, which soil life is then important and with which soil management practices can we obtain the desired soil life? The conceptual framework is a mind map that enables the evaluation of the effects of farming practices on soil biodiversity parameters. This study contributes to national research programs concerning the Biological indicator-system for soil quality (BiSQ) (Rutgers et al., 2005).

Materials and methods

The study included the elaboration of two typologies of both soil (ecosystem) services as well as (organic) soil management practices. With the typology as a starting point, interactions were explored, based on literature (e.g. Bloem et al., 2005) between important soil services and soil management practices like nutrient cycling, soil

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structure formation and disease suppression. Soil biodiversity is involved in these interactions. Parameters of soil biodiversity (based on BiSQ) were selected, that are supposed to be essential for linking management to soil services. The result was a conceptual framework based on experimental data, literature and expert judgement, that links soil management practices, soil life groups and soil services like soil fertility. Subsequently the framework was used to evaluate and understand the impact of type of manure on soil biodiversity and soil services, as an example of one of the most important soil management practices

Results and Discussion

Figure 1 presents the link between the services an agricultural soil can perform, the most important soil management practices by farmers and effects of these practices on soil biodiversity and productivity. The soil practices in our study focus primarily on the soil fertility service and all services linked to soil fertility like nutrient cycling, soil structure and disease suppression.

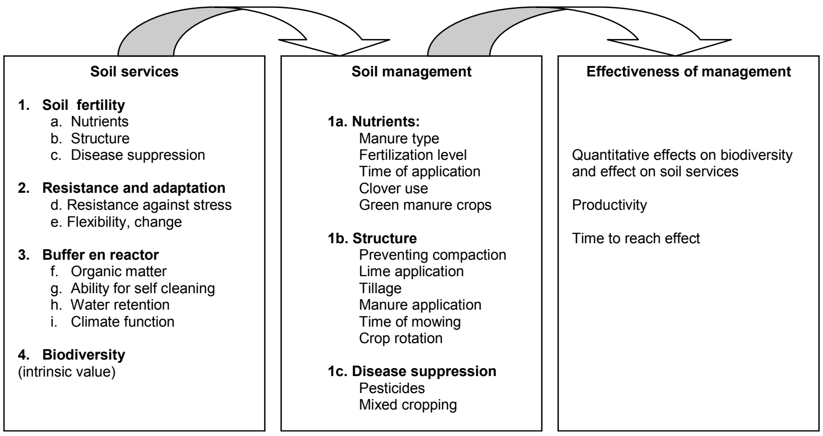

Figure 1: relates soil services to certain soil management practices and the effect of the soil management on soil biodiversity.

Linking soil management practices and services can be considered as a new management tool. The choice of services reflects the local use of the soil by farmers (Rutgers et al., 2005).

In the conceptual framework of figure 2 the central question is: how to obtain a particular soil service? The framework clarifies the most important relations to soil life and requirements in terms of soil management practices. Therefore the framework consists of three important squares which are related to each other: soil management (including tillage), soil life and soil ecological services.

Additional to the three squares, the circle includes the management effects that are mediated by crop development i.e. the root system. As indicated by many authors soil management can impact soil life directly or through plant growth and especially root production.

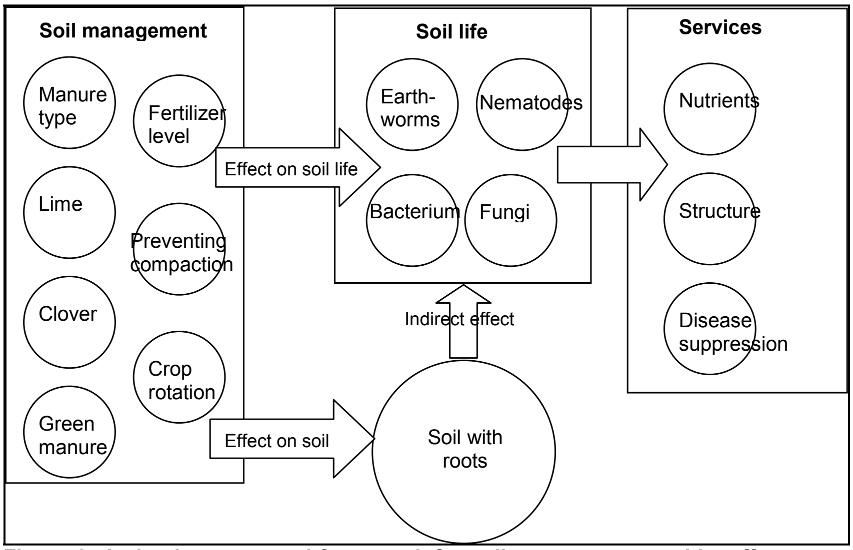

Figure 2: A simple conceptual framework for soil management and its effect on soil biodiversity and soil services.

The value of the elaborated approach is primarily the link between soil management practices and soil (ecosystems) services that represent the farmers profit and external demands (e.g. clean drinking water). Second: a conceptual framework can help the practitioner to better understand the soil-life black box. In this respect decision support is important because in practice different soil management practices are always taken simultaneously. The framework can show whether soil practices synchronise in their effect on soil life or work in the opposite direction. The framework is able to give an estimate of the impact of different management practices.

The soil food web structure and the life support services of soil organisms can be indicated by a selection of parameters (table 1). With this standardised parameter set based on the BiSQ (Rutgers et al., 2005) it is possible to determine the effects of management on these biodiversity parameters which should be measured.

An example of the application of the framework is presented by Zanen et al. (this issue). That study shows that soil management practices like organic amendments allowed in organic agriculture, alter soil life (i.e. nematode population) and change soil indicated by organic N mineralization potential. Other studies (Koopmans et al., 2006) suggest that changes in the response of crop roots due to different organic inputs altering the composition of the soil community over time.

Conclusions

This study shows that important soil services, soil management practices and soil biodiversity indicators can be linked in a framework to develop sustainable agricultural systems that manage beneficial soil biological processes. This may be a key step towards understanding the biological mechanisms behind soil biodiversity. The findings could be useful to support management practices that optimise yields, soil fertility and biodiversity in organic farming.

Tab. 1: Parameters of the dataset of the soil biodiversity framework.

Area	Parameter	Unit
Biological	Bacterial biomass	µg C/g soil
	Thymidine incorporation	pmol/g soil/hr
	Leucine incorporation	pmol/g soil/hr
	Fungal biomass	µg C/g soil
	Active Hyphae	%
	Pot. N mineralization	mg N/kg/week
	Pot. C mineralization	mg C/kg/week
	Bacterial feeding nematodes	n/100 g soil
	Fungal feeding nematodes	n/100 g soil
	Plant feeding nematodes	n/100 g soil
	Nematodes predators	n/100 g soil
	Earthworm biomass	g/m^2
	Lumbricus rubellus	n/m^2
	Aporrectodea calliginosa	n/m^2
	Lumbricus terrestris & Aporrestodea longa	n/m^2
Physical	Structure crumb	% in 0-10 cm
	Structure round	% in 0-10 cm
	Structure angular	% in 0-10 cm
	Plant roots 10 cm	n/400 cm^2
	Plant roots 20 cm	n/400 cm^2
Chemical	Organic matter, clay, pH, Ct, Nt, Pt, Pw, P-Al, K2O	divers

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Improving Soil Structure and Nitrogen Use Efficiency by GPS-controlled Precision Tillage Technology in Organic Farming

Zanen, M. [1] & Koopmans, C.J.[2]

Key words: soil structure, GPS-controlled traffic systems, nitrogen use efficiency.

Abstract

A field experiment was conducted to determine the effects of tillage technique (GPS-controlled traffic system and traditional tillage) and level of fertilization (farmers' practice or phosphate equilibrium) on yield, soil structure and nitrogen use efficiency. Manure inputs could be seriously reduced without yields being diminished during the first three years of the intensive crop rotation. Results suggest that an improved soil structure under GPS-controlled precision tillage enhances nitrogen use efficiency.

Introduction

Organic agriculture should play a leading role and set an example for sustainable soil management. This implies greater nutrient use efficiency and fewer inputs. GPS-controlled precision tillage using the same traffic lanes every year offers the opportunity to improve soil structure (Vermeulen & Klooster, 1992). Our hypothesis is that the improved soil structure of the beds will provide better aeration and rooting for the crop and access to necessary nutrients. This would mean that nitrogen use efficiency would improve in GPS-controlled precision tillage systems. In this study we evaluate the effects of a GPS-controlled precision tillage system using permanent traffic lanes in combination with low manure input on soil structure, nitrogen use efficiency and crop yield in an intensive crop rotation.

Materials and methods

During a period of four years on site field experiments were conducted at an organic vegetable farm in Langeweg (N. Br), the Netherlands (4° 38' East, 51° 39' North). The soil of the experimental field was characterized as clay loam (2.6% organic matter, 23% clay, pH-KCL 7.4). In 2003 the experiment was set up with two tillage treatments (GPS-precision and Traditional) and two fertilization treatments (Farmer's practice (FP) and Phosphate Equilibrium (PE), defined as P_2O_5 removed at harvest = P_2O_5 input with manure) in a split-plot arrangement (Tab. 1). The experimental design was a randomised complete block with four replications and 6,3 m x 25 m plot size. In each experimental year one crop was studied, following the intensive vegetable rotation of the farm: spinach (2003), carrot (2004), potato (2005) and grass seed (2006). During each growing season, soil structure was determined visually. Soil structure was rated as a percentage of crumbly and angular structures at a relevant depth, using a modified method according to Shepherd (2000) as described in Koopmans & Brands (1993). Nitrogen use efficiency was calculated in 2004 (spinach) and in 2006 (potato) as the N-application rate with fertilization divided by the total N amount taken up by

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the leaves and tubers, excluding roots. The data were analyzed by analysis of variance (ANOVA) using tillage treatment as main plots and fertilization levels as subplots. Significant effects were separated by the least significant difference (LSD) at P = 0,05.

Tab. 1: Tillage and fertilization treatments of the field experiment in Langeweg

Tillage system	Fertilizer application	N	P_2O_5	K_2O
		Kg ha^{-1} year^{-1}		
Traditional	Farmer’s practice (FP)	128	53	150
Traditional	Phosphate equilibrium (PE)	62	26	72
GPS precision	Farmer’s practice (FP)	128	53	150
GPS precision	Phosphate equilibrium (PE)	62	26	72

Results

In the first year, significant (P<0.05) higher yields were obtained in spinach using GPS-precision techniques (Fig.1).

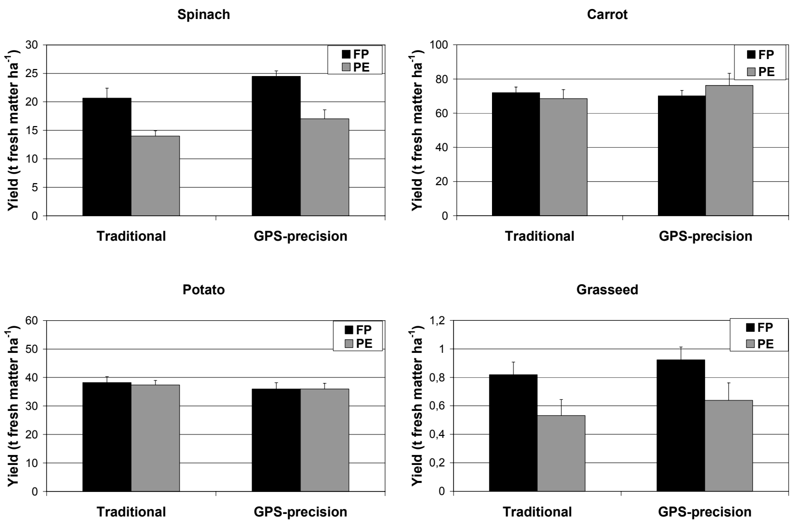

Figure 1: Yields of spinach (2004), carrot (2005), potato (2006) and grass seed (2007) in management practices Traditional (FP and PE) and GPS-precision (FP and PE). Errorbars indicate standard error of the mean (SE).

In spinach (2004) yields at FP fertilization level were significantly higher (P<0.001) than yields at PE fertilization level. Interestingly there was no significant difference between yields in plots with GPS-precision techniques with PE fertilization level and traditional tillage with FP fertilization level, indicating a higher nutrient availability in GPS-precision plots. In carrots (2005) and potatoes (2006) no significant differences between treatments were observed. Grass seed yield (2007) in the PE fertilization treatment significantly diminished (P<0.001) compared to the FP treatment. No effect of tillage strategy was observed. Results in grass seed confirmed the earlier observation in spinach in which there was no yield difference between GPS-precision tillage at PE fertilization level and traditional tillage at FP fertilization level.

Soil quality

Visual determination of soil structure clearly showed the effect of GPS-precision tillage on soil quality in 2004 and 2007. The percentage of angular elements at 0-15 depth in spinach and at 0-10 cm depth in grass seed was significantly higher (P=0.02) using traditional tillage as compared to GPS precision tillage (Tab.2). In carrots no angular elements were found. The percentage of crumble elements in the ridges was significantly higher using precision tillage. In potato, after traditional harvest of the carrots under suboptimal soil conditions, soil structure was diminished in all treatments and soil clods in all plots were characterized as 100% angular elements.

Tab. 2: Percentage of angular soil elements per soil layer per year. Values are mean, n=4.

	Angular elements (%)			
	0-10 cm depth	0-20 cm depth	0-20 cm depth	0-10 cm depth
	Spinach	Carrot	Potato	Grass seed
	2004	2005	2006	2007
Traditional				
FP	31	0	100	43
PE	38	0	100	45
GPS precision				
FP	6	0	100	19
PE	2	0	100	6
Tillage system	*	NS	NS	*
Fertilization	NS	NS	NS	NS

* Indicate significance at $P \leq 0.05$.

Nitrogen use efficiency

In the first year of the experiment nitrogen use efficiency of spinach was significantly higher (P<0.001) with PE fertilisation (87%) as compared to FP fertilisation (44%). Two years later, in 2006, similar results of nitrogen use efficiency were found in potato. Nitrogen use efficiency was significantly higher (P=0.006) with PE fertilisation (255%) as compared to FP fertilisation (145%). However, there was no difference in yield of potatoes grown with PE fertilisation and yield of potatoes grown with FP fertilisation.

Discussion

The results of this study support the hypothesis that tillage techniques using GPS-precision can enhance soil structure, resulting in lower manure input needs and higher nitrogen use efficiency. Lowering the amount of fertilizer towards phosphate equilibrium, meant that nitrogen input was seriously reduced. Strikingly, this reduction had no significant effect on yield reduction of spinach, carrot and potato. Visual determination of soil structure showed the negative effects of traditional tillage on subsoil structure which is in agreement with earlier studies on the effects of subsoil compaction (Van den Akker and Schjönning, 2004). Furthermore, in 2005 and 2006 it showed the negative effects of conventional harvest under suboptimal conditions of the soil. If carrots and potatoes had been harvested by using traffic lanes, there would have been less soil compaction and this could have resulted into higher yields and N utilization coefficients of the crops. The higher nitrogen use efficiency at lower fertilisation levels stretches the possibilities for reducing inputs in organic agriculture.

Conclusions

The study shows that manure inputs could be reduced to phosphate equilibrium without lowering yields in three out of four years of an intensive crop rotation on a clay loam soil in the Netherlands. Our results in spinach and potato suggest a higher nitrogen use efficiency due to a better soil structure after GPS-precision tillage. The results also make clear that this promising new technology only can improve soil structure and result in higher yields on the long term, when all tillage is done from the same traffic lanes, including harvest.

Acknowledgments

We thank the organic farm Biotrio De Nieuwe Weg for their work on the trial and availability of the land. Coen ter Berg helped us with sampling of the trial over years. The authors gratefully acknowledge funding from the Dutch Ministry of Agriculture, the Rabobank and Louis Bolk Institute.

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Season-long supply of plant-available nutrients from compost and fertiliser in a long term organic vs. conventional snap bean rotations experiment

Owen, J.[1], LeBlanc, S.[2] & Fillmore, S.A.E.[3]

Key words: compost, plant nutrients, ion exchange membranes, seasonal changes

Abstract

In Canada, stockless organic vegetable cropping systems may use compost for fertility. However, information to guide growers about when nutrients become available in the soil over the growing season is lacking. Detailed analysis of plant nutrient supply was conducted over three years in a multi-site rotations experiment using two cropping sequences. The experiment compared conventional fertility treatment (synthetic fertiliser (1x N)) with organic treatments (annual compost amendment at a low (1x N) and a high rate (3x N)). Plant-available soil nutrients were captured using sequential two-week burials of ion exchange membranes. Ions were eluted and quantified. Variation in nutrient supply over time, and effects attributable to crop rotation and fertility regime were evaluated with analysis of variance and of principal components. Results showed season-long supply of plant nutrients was more affected by year than fertility regime or rotation, even in composted plots where large residual effects were expected. Synthetic fertiliser and 1x compost resulted in very similar seasonal plant nutrient supplies. While 3x compost caused some significant changes, the gains in plant nutrient supply was modest enough to suggest little or no advantage in this one respect to warrant the cost of amending at greater than the 1x rate.

Introduction

Plant nutrient supplies available for crop growth in organic systems are often comparable and sometimes exceed those found in conventional systems, yet synchronizing the availability of those nutrients may be more difficult (Berry et al., 2002). Because composition of compost is notoriously variable, and mineralization of organic matter in the soil is mediated by a host of factors such as temperature, moisture, soil chemistry and microbial communities (Magdoff and Weil, 2004), predicting the timing and quantity of nutrient supply in the soil becomes difficult. While beneficial effects of compost are well documented (Rosen and Allen, 2007) growers in Canada still often rely on rules of thumb about nutrient availability in the first year to determine application rates. This study used ion exchange membranes to evaluate season-long plant nutrient availabilities in soils amended with two rates of compost, compared with soils amended with synthetic fertilisers, over three years in a continuous bean cropping system, and a fully phased snap bean/fall rye rotation.

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Materials and methods

This research was conducted over three years of a long term organic-versus-conventional rotations experiment, with three replicates at a research farm site and three at a commercial farm site in Bouctouche, New Brunswick, Canada. Each replicate comprised three strips, to which each was assigned a rotational cropping sequence (continuous beans (CB), fully phased beans/fall rye two-year rotation (BRB or RBR)). Strips were divided into plots to which were assigned one of three yearly-applied fertility treatments (synthetic fertiliser, low (1x) rate compost, high (3x) rate compost). Compost was a commercial organic certified mix of forestry, fishery and farmyard waste (Cardwell Farms Compost Products, Penobsquis). It had a carbon to nitrogen ratio of 15.2, with total nitrogen on a dry matter basis of 1.5%. The 1x compost was applied at a rate calculated to deliver the equivalent of 50 kg N ha^{-1}: the same rate of N applied in synthetically fertilised plots. N, P and K amendments in synthetically fertilised plots were based on regional crop production guides. Amounts of nutrients added in each treatment are summarised in Table 1.

Anion and cation exchange membranes were used to monitor supply of plant-available ions in the soil solution of bean plots. The membranes, Plant Root Simulator™ probes (Western Ag Innovations, Saskatoon), were buried vertically in the soil, each exposing an area of 17.5 cm^2 of ion-exchanging surface to the soil at approximately six to thirteen cm below the soil surface. Four pairs of anion and cation probes were buried on the crop row in each plot to form composite samples to account for soil heterogeneity. Each pair of probes was shielded from interference by plant roots by a length of pvc pipe hammered into the soil. Probes were buried for sequential two-week periods, for 6, 7 and 8 burials in 2003, 2004 and 2005, respectively. Each new set of probes was inserted directly into the holes left by the previous set. In the laboratory, ions adsorbed to the membranes were eluted and quantified by colorimetric or inductively coupled plasma techniques. Because burial dates varied from year to year according to the cropping season, seasonal curves of nutrient supply were developed for each year, and from these curves, predicted values were generated for a specific set of dates. Principal components were computed for seasonal totals of plant nutrients supplied in bean plots, and presented in biplot form.

Tab. 1: Three-year totals of plant nutrients (kg ha^{-1}) applied as synthetic fertiliser, low rate (1x) or high rate (3x) compost to plots in continuous beans (CB), Beans-Rye-Beans (BRB) and Rye-Beans-Rye (RBR) crop sequences.

		Nutrients applied (kg ha^{-1})						
Treatment	Crop Seq.	N	P	K	Ca	Mg	Fe	Al
Synthetic fertiliser	CB	150	210	215	0	0	0	0
	BRB	200	140	215	0	0	0	0
	RBR	250	70	215	0	0	0	0
Compost 1x	CB, BRB, RBR	150	107	93	271	60	88	*
Compost 3x	CB, BRB, RBR	450	321	279	813	180	264	*

* not analysed

Results and discussion

Extended burials of ion exchange membranes provide an opportunity to measure the nutrient supply rate in soils over time while accounting for short term dynamic interactions of nutrients within the root zone (Qian and Schoenau, 2002). In this study sequential burials captured season-long plant nutrient supplies over three years. Compost application, particularly at the 3x rate, was expected to increase the supply of nitrogen and other plant nutrients. Supply rates tended to be similar between the synthetic fertiliser and the 1x compost treatment (Figure 1). NO_3-N supply was greatest in the synthetic fertiliser treatment, and decreased significantly with increasing compost amendment, likely because the addition of massive amounts of organic C in the compost treatments over the years immobilised N. Potassium supply increased significantly with increasing compost, though potassium supplied at the 3x compost rate was only about 65 kg ha^{-1} greater than that applied as synthetic fertiliser (Table 1). The modest differences in nutrient supplies between 1x and 3x compost treatments was surprising, suggesting that while organic matter increased (data not shown) this did not translate into gains in nutrient supply proportionate to the inputs.

Biplot analysis (Figure 2) revealed clear clusters of fertility treatments by year. Nutrient supplies were least in 2003, but despite high inputs of compost, did not increase incrementally by year in compost amended plots. In 2004, nutrient supply exceeded nutrient supply in 2005, suggesting that year effects play a defining role in nutrient supply. Mg and K were affected in much the same way by fertility treatments, independent of Fe, Al and P which formed another tight cluster. In acid soils, such as those of this study, inorganic P precipitates as Fe/Al-P secondary minerals and may become adsorbed to Fe/Al oxides (Tisdale et al., 1993). The association of Fe, Al and P with the 1x and 3x compost treatments in 2004 is therefore likely related as well to an increase in pH found in composted treatments (data not shown). Ca and N supply were most affected by 1x compost and synthetic fertiliser treatments. Overall, the average nutrient supply among all treatments was best represented by 1x compost in the CB rotation in 2005, with total season supplies (mg ion cm^{-2} per 12 weeks) of: NO_3-N, 2287; NH_4-N, 41; P, 70; K, 2063, Ca, 8397; Mg, 1613; Al, 224; and Fe, 259 mg ion cm^{-2}. Other factors likely contributed to the year effects, including crop uptake, and crop residues returned to the soil, which would have differed by crop, and possibly by treatment as well. These important relationships will be explored at length elsewhere.

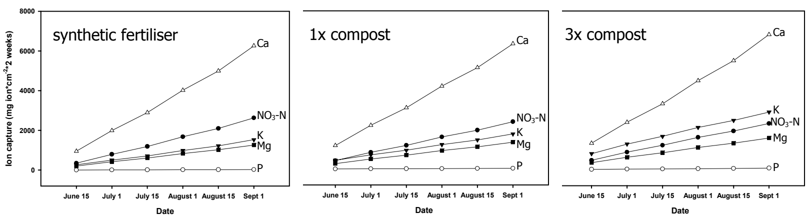

Figure 1: Cummulative supply of plant nutrients in soils amended with synthetic fertiliser, 1x compost and 3x compost, over three years and two cropping sequences.

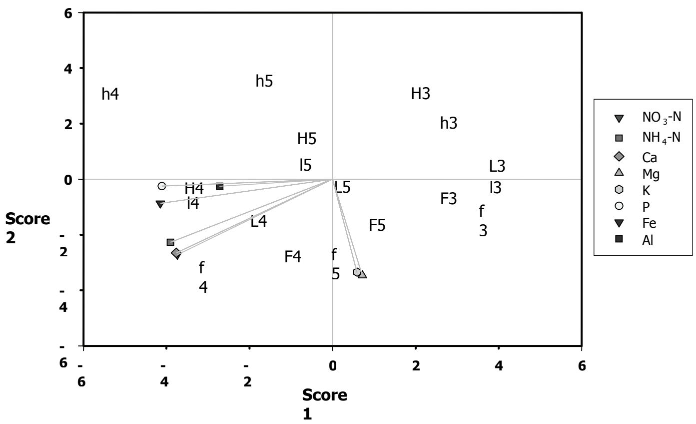

Figure 2: Biplot of principal components of fertiliser amendment/crop sequence on seasonal total plant nutrient supplies (caps refer to Continuous Beans; lower case to Beans/Rye; 3, 4, 5 to 2003 to 2005; letters l, h, f to low (1x) and high rate (3x) compost and synthetic fertiliser)

Conclusions

Compared with synthetic fertiliser, compost application resulted in less NO_3-N, and greater amounts of K and Ca over the course of the season. Nutrient supply was more affected by year than by any other factor, with the effect of year resulting in lower nutrient supplies in 2004 than in 2005 despite any residual contributions of previous years' compost applications. Applying 3x compost increased Ca and K supplies, but other gains were not enough to warrant the considerable associated costs.

Acknowledgments

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Elemental Contaminants in Fertilizers and Soil Amendments Used in Organic Production

Baker, B.[1] & Tracy, D.[2]

Key words: fertilizers, soil amendments, elemental contaminants.

Abstract

Elemental contaminants in fertilizers pose a threat to human health and the environment. Organic agriculture can take measures to protect the public and the environment from the long-term effects of these contaminants, also known as heavy metals. Arsenic (As), cadmium (Cd), and lead (Pb) were identified as the top priority metals that need attention. Fertilizers and soil amendments used in organic production were randomly selected, and the laboratory results for the levels of As, Cd, and Pb compared against six different standards based on different models. Organic farmers are advised to avoid using fertilizers that may degrade the average levels found in soils in the United States. Standard-setting bodies are advised to prohibit the use of fertilizers and soil amendments that have As, Cd, and Pb that will result in the accumulation of those elements in the soil when applied at average loading rates on an annual basis.

Introduction

Heavy metals occur naturally in soils. They can also be accumulated through conventional agricultural practices and are found in a variety of industrial by-products, some of which are combined with fertilizers and soil conditioners. The elemental contaminants known as heavy metals pose a threat to food safety and can harm the environment, whether they come from synthetic or natural sources. The Organic Materials Review Institute (OMRI) has identified and characterized the concerns raised by the application of heavy metals found in the fertilizers and soil amendments permitted for use in organic production. The purpose of this study was to determine the levels of heavy metals in a representative sample of organic fertilizers, and to predict how many fertilizers and soil conditioners would meet various standards that limit heavy metal contamination.

Materials and methods

OMRI staff used the data submitted by our listed suppliers for product review. Staff drew the files of 50 products at random that had been submitted at some point. To be considered valid, analytical results needed to be clearly linked to and identified with the submitted product. The product needed to comply with organic standards. The sample needed to have been taken within the previous five years. Of the 50 selected, 32 products had valid results of analyses on file for As, Cd, and Pb using EPA's Strong Acid Digest/ Inductively Coupled Plasma (ICP) methods.

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As, Cd, and Pb were selected as the highest priority elemental contaminants based on a consensus of experts consulted. Other contaminants might also be of concern, but were beyond the scope of this study.

The analytical results were then compared with six different scenarios:

1) OMRI's Maximum Concentration of Contaminants Contained in Synthetic Micronutrient Products (OMRI, 2002).

2) The Association of American Plant Food Control Officials' (AAPFCO) Statement of Uniform Interpretation and Policy (SUIP) (AAPFCO, 2006). AAPFCO standards base heavy metal limits on phosphorus or micronutrient content. Limits for compost and manure based products were set based on phosphate content.

3) The US Environment Protection Agency's (EPA) standards set for metals resulting from the land application of sludge, also known as the 503s (US EPA, 1994).

4) The Washington State Department of Agriculture's limits established for metals loading in fertilizers expressed in lb/acre/yr (WSDA, 2006). For the WSDA limits, products were viewed based on the loading rates on their label. For compost, an annual loading rate of 2 tons/acre (approximately 4.5 metric tons/ha) on an 'as-is' basis was used. If dry weight was reported, then an annual loading rate of 1 ton/acre (2.24 metric tons per hectare) was used.

5) The No Net Degradation (NND) limits are based on the US Geological Survey and other researchers' estimates of average background levels of heavy metals in soils in North America. (Lepp, 1981; Shaklette and Boerngen, 1984; Gustavsson et al., 2001).

6) The European Union (EU) limits for metals when sewage sludge is used in agriculture. (EU, 1986). The Annex IB Lower Limit Value was used.

Table 1 lists limits of the different scenarios examined. Data from the sampled products were entered into an Excel spreadsheet and analyzed using the different model standards.

Tab. 1: Limits of the Different Scenarios (ppm)

Scenario	Arsenic (As)	Cadmium (Cd)	Lead (Pb)
OMRI [1]	10	20	90
AAPFCO[2]	13	10	61
503s[3]	41	39	300
WSDA[4]	149	40	290
NND[5]	7.2	0.4	19
EU[6]	--	20	750

[1] OMRI 2002. Table 3.
[2]Association of American Plant Food Control Officials SUIP 25, Column 2,
[3]US EPA, 1994. Table 3 of 40 CFR 503.13,
[4]Washington State Department of Agriculture, 2006. WAC 16-200-695 and RCW 15.54.800.
[5]Shaklette, et al., 1984; Lepp, 1981; and Gustavsson et al., 2001.
[6]European Union Council Directive 86/278

Results

The results are summarized in Table 2. The highest As levels were found in dehydrated poultry litter and rock phosphate. Conventional broiler production in the US uses As as a parasiticide. It is a known impurity in many rock phosphate deposits. Rock phosphate also had the highest level of Cd, exceeding the limit for all but one of the standards. In the case of rock phosphate, the source of contamination is believed to be natural impurities. The highest Pb level was 66.6 ppm, found in compost made from municipal green waste. Demolition material, such as lumber coated with lead paint, is a common contaminant at such facilities.

Tab. 2: Summary of Results of the Random Selection of Fertilizers and Soil Conditioners Used in Organic Production

Parameter	Arsenic (As)	Cadmium (Cd)	Lead (Pb)
Average (ppm)[1]	9.6	8.5	12.8
# (%) Positive[2]	19 (58%)	18 (55%)	20 (61%)
Maximum (ppm)	53.6	96.6	66.6
# >OMRI 2002 (%)	4 (12%)	2 (6%)	0 (0%)
# >AAPFCO (%)	2 (6%)	0 (0%)	1 (3%)
# >503s (%)	0 (0%)	1 (3%)	0 (0%)
#>WSDA (%)	0 (0%)	1 (3%)	0 (0%)
#>NND (%)	5 (15%)	11 (33%)	4 (12%)
#>EU (%)	--	2 (6%)	0 (0%)

[1]Average of the positive samples.
[2]Number of samples exceeding the limit of detection reported by the laboratories.

Some of the fertilizers in the sample exceeded average soil background levels for all three of the contaminants. Because Cd has a relatively low average background level, the percentage of fertilizers that exceed background level was the greatest, accounting for about a third of the randomly selected products.

Discussion

When the various scenarios were applied to the selected fertilizers, The No Net Degradation standard was the most precautionary, as expected. However, it would also be the most restrictive in terms of what fertilizers and soil conditioners could be used. Of the remaining standards, none was consistently more protective. The risk assessment models did not have a consistent estimate of the risks posed by the different elemental contaminants. The loading rate model was the most permissive with Pb, but was stricter with Cd and As.

Most of the experts noted that soil contamination is a function of both the loading rate and the background level. Thresholds for each of the priority contaminants should be established at two levels: the lower threshold based on a no net degradation policy that requires monitoring for increases in soil levels over time, and the higher threshold based on a loading rate that predicts levels of contamination in soil monitored on an annual basis and expected to increase to a level toxic to plants.

Conclusions

As, Cd, and Pb were found in most fertilizers and soil conditioners that were randomly selected. The levels found were within the thresholds of most of the regulatory limits and would not be expected to result in soil degradation. Poultry litter, rock phosphate, and compost made from municipal green waste were found to be the most likely kinds of fertilizers and soil conditioners to exceed regulatory limits and threaten soil degradation. We believe that organic farmers should be made aware of the long-term consequences of applying soil amendments that are contaminated with heavy metals and take precautions to not cause long-term degradation.

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Management Strategies and Practices for Preventing Nutrient Deficiencies in Organic Crop Production

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Key words: Amendments, crop rotation, organic crop production, rock phosphate, nutrient deficiencies

Abstract

*Field experiments are underway in Canada to determine the influence of management practices (crop diversity, green manure, legumes) and amendments (*Penicillium bilaiae*, rock phosphate, elemental S, gypsum, manure, wood ash, alfalfa pellets) on crop yield. In the alternative cropping systems study established in 1995, crop yields for organic system without any chemical input were 30-40% lower than the conventional system with high inputs. But, lower input costs plus price premiums for organic produce normally more than offset lower yields, resulting in favourable economic performance and energy efficiency. Legume, green manure and compost manure helped to replace nutrients lacking in the soil and improved crop yields. In the organic system, amount of P removed in crop exceeded that of P replaced and this can be a major yield limiting factor. In amendments experiments, there was small effect of granular rock phosphate fertilizer and/or* Penicillium bilaiae *in increasing soil P level and crop yield in the application year. Other findings suggested the use of elemental S fertilizer, gypsum, manure, wood ash or alfalfa pellets to improve nutrient availability, and yield and quality of produce. In conclusion, integrated use of management practices and amendments has the potential to increase sustainability of crop production as well as improve soil quality plus minimize environmental damage.*

Introduction

Maintaining soil fertility, controlling weeds and developing appropriate crop rotations are important production issues facing organic agriculture in the Canadian prairies (Jans, 2001). Crops with taproots can absorb nutrients from deeper soil depths (Entz et al., 2001a), and nutrients become available in surface soil after crop residues are returned. This can improve the economic productivity when surface soil has low fertility. Rotation of fibrous and taproot crops in a cropping system can therefore improve the cycling and crop use of nutrients.

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In organic farming, synthetic fertilizers/chemicals are not applied to increase crop production. Any nutrient(s) limiting in soil can cause substantial reduction in crop yield. In the Canadian Prairie Provinces, most soils under organically farmed systems are deficient in available N for optimum yield (Watson et al., 2002). There are many organically farmed soils low in available P, and some soils contain insufficient amounts of S and K for high crop yields (Entz et al., 2001b). The N deficiency in soil on organic farms can be corrected by growing N-fixing legume crops in the rotations. However, if soils are deficient in available P, K, S or other essential nutrients, the only alternative is to use external sources to prevent their deficiencies. Manure/compost can provide these nutrients. But often there is not enough manure to apply on all farm fields, and the cost of transporting manure to long distances is uneconomical in remote areas. On such soils, rock phosphate fertilizer, elemental S fertilizer, gypsum, alfalfa pellets or wood ash may be used to correct deficiencies of these nutrients. The information on the feasibility of these products in preventing nutrient deficiencies under organic farming is lacking.

Materials and methods

Alternative cropping systems experiment

The on-going field experiment was established in 1995 on a Dark Brown Chernozem (Typic Boroll) loam soil at Scott, Saskatchewan to compare input level and cropping diversity under various alternative cropping systems. The 54 treatments were combinations of three input levels [organic – ORG (no input of fertilizers and other chemicals under conventional tillage), reduced – RED (reduced input of fertilizers and other chemicals under no-till) and high – HIGH (recommended input of fertilizers and other chemicals under conventional tillage)], three cropping diversities (low diversity – LOW, diversified annual grains – DAG and diversified annual grains and perennial forage crops - DAP) and six crop phases including green manure (GM), chem-fallow or tilled-fallow (F). Data collection focuses on crop yield, nutrient concentration and uptake, potential for soil degradation, soil quality, pest dynamics, economic performance, energy efficiency as well as indicators of environmental well being and biodiversity.

Rock phosphate and other amendments experiments

A number of field experiments are underway to determine the influence of *Penicillium bilaiae* on the release of available P from rock phosphate fertilizer in preventing P deficiency on P-deficient soils, elemental S fertilizers and gypsum in preventing S deficiency on S-deficient soils, and compost manure, wood ash or alfalfa pellets in preventing deficiencies of N, P, K, S and other nutrients in soils lacking in these nutrients for organic crops. Data collection includes yield, produce quality, and nutrient uptake of crops, nutrient accumulation and quality of soil, and greenhouse gas (GHG) emissions.

Results and discussion

Alternative cropping systems

The results to date demonstrated that crop yields for the ORG were 30-40% lower than for the production systems with the HIGH input. But, lower input costs plus price premiums normally more than offset lower yield in organic agriculture. Net energy production was greater for conventional than organic, but energy output to input ratio was greater for the ORG system. This indicated favourable economic performance and energy efficiency of organic systems. Legume crops and green manure helped to replace N in organic systems. Summer fallow also helped to replace N and some other nutrients in organic systems, but there is risk of erosion and deterioration of soil quality especially on tilled fallow. The findings also suggest that application of compost manure can provide N, P, K, S and other nutrients lacking in the soil.

Extractable P in the 0-90 cm soil was higher with HIGH input than with ORG. In the organic system, the amount of P removed in crop exceeded that of P replaced. This resulted in low extractable P in the surface soil and extremely low in the subsoil layers, and this can be a major yield limiting factor for high crop production in organic systems. This indicates that there may be little potential for taprooted crops to bring P from deeper soil to the surface at this site (Malhi et al., 2002). This also suggests that if the whole soil profile is low in available P or other nutrients, it may not be possible to sustain high crop yields under organic systems without external nutrient additions.

Nitrate-N in the 0-240 cm soil was greater at HIGH input than at ORG input. The nitrate-N data in different soil layers suggested some downward movement of nitrate-N in plots receiving HIGH input. Our findings related to ORG input are in agreement to earlier observations by Kolbe et al. (1999) that properly managed organic crop production may considerably reduce potential risk of nitrate leaching in soil because of decreased input of N to the soil-plant system. Nitrate-N soil was higher in rotations that included GM/F than in rotations with continuous cropping, suggesting that if N fertilizer is applied at high rates and crop frequency is low, there is a potential for leaching of nitrate-N in the soil profile, increasing risk of ground water contamination.

Rock phosphate and other amendments

In the rock phosphate experiments, there was a significant but small increase in crop yield from granular rock phosphate in the year of application on a P-deficient soil. The results suggest that it is unlikely that the addition of rock phosphate will produce any economic returns for organic producers in the year of application, but it may provide economic yield benefit in the long term. Application of *Penicillium bilaiae* alone increased crop yield, but its application in combination with rock phosphate did not increase the crop performance over *Penicillium bilaiae* applied alone on P-deficient soils. Composted livestock manure in the alternative cropping experiment showed greater potential in restoring soil P than other strategies such as rock phosphate application. In the previous on-going experiments, granular rock phosphate was not very effective in correcting or preventing P deficiency in crops, most likely due to large particle/granule size. In future experiments, we are planning to also broadcast and incorporated into the soil a finely-ground rock phosphate fertilizer to increase interaction between P particles and soil microorganisms to increase P release and its availability to crops.

The addition of wood ash, without concurrent addition of N, showed increase in seed yield and economic returns of barley and field pea in Alberta, and alfalfa forage yield and protein content in Ontario. The main yield benefit most likely resulted from improvement in the availability of P and/or other nutrients from wood ash. In addition to correcting/preventing nutrient deficiencies and improving yields of crops grown on soils deficient in these nutrients under organic farming systems, wood ash has other potential benefits, such as reduction in soil acidity (which may last for several years), improvement in soil tilth, increased microbial biomass and reduced weed infestation. The results of other experiments suggest that elemental S fertilizer and gypsum may have the potential to correct/prevent S deficiency and improve yields of crops grown on S-deficient soils under organic farming systems. In growth chamber, application of alfalfa pellets to soil was found effective in increasing crop growth.

Conclusions

Crop yields for organic systems were 30-40% lower than the conventional production systems with high inputs, but lower input costs plus price premiums normally more than offset lower yield in organic agriculture. Legume crops, green manure, compost manure and other amendments (elemental S fertilizer, gypsum, manure, wood ash or alfalfa pellets) could prevent nutrient deficiencies in soil on organic farms. The findings suggest that integrated use of management practices and amendments has the potential to increase sustainability of crop production and net returns to producers as well as improve soil quality and prevent soil erosion by returning more crop residues to the soil plus minimize environmental damage by leaving less nitrate-N in the soil.

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Potential of Oil Palm Empty Fruit Bunch (EFB) as Fertilizer in Oil Palm (Elaeis guineensis L Jacq.) Nurseries

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Key words: organic agriculture, oil palm seedlings, empty fruit bunch, cow dung, fertilizer

Abstract

Oil palm is one of the major oil crops in the world. Oil palm empty fruit bunch (EFB) could serve as an alternative and cheaper organic fertilizer in oil palm farms. This study investigated the value of composts of different forms of EFB for raising oil palm in the nursery. The experiment, which covered the pre-nursery (< 3 months) and nursery stages (3-13 months) used different EFB: cow dung ratios (100:0, 90:10, 80:20, 70:30 and 60:40) as compost as well as cow dung only and mineral fertilizer (NPKMg 12-12-17-2). The composts were added to the soil at the rate of 4.8 g N /plant. The experiment was laid out in a randomized complete block with three replicates. Data were collected on dry weight, nutrient concentrations, and soil pH changes. Oil palm seedlings under the application of unsoaked oil palm EFB and cow dung (60:40) were significantly (p< 0.05) higher in dry weight (18.0 g / plant) than those from the mineral fertilizer and control treatments (15.7 and 10.5 g / plant respectively) in the nursery stage. Composts of unsoaked EFB and cow dung (ratio 60:40) was more suitable for raising oil palm seedlings in the nursery than other treatments used.

Introduction

Development of organized organic agriculture system is still young in most developing countries. However, sourcing and adoption of sustainable organic inputs and resources by practitioners are essential for lasting development in this area. Application of mineral fertilizers is the most common means of improving soil fertility among farmers. However, the positive effects of mineral fertilizers on soil for crop production last only for a short time. In the long run, mineral forms of N fertilizers (urea and ammonium sulphate) can lead to decreasing base saturation, acidification, and a drop in soil pH (Phicot *et al.*, 1981). Ogedengbe (1991) observed a cationic imbalance in the soil of the Okomu oil palm plantation, Benin, Nigeria and linked this to the problem of intensive application of mineral fertilizer. Another complication is the fact that the commonly used mineral fertilizers are becoming scarce and not usually available to most farmers. This situation has triggered the problem of underfertilization on many farms. As a result, crop performance has been reduced. Organic fertilizers have the potential to correct almost all negative impacts of mineral fertilizers on soil. Efforts targeting increases in agricultural production should be backed up with environmentally friendly fertilizer application practices that should guarantee safety and sustainability of the soil natural resources.

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Oil palm (*Elaeis guineensis* L Jacq.) is a crop of national economic importance in Nigeria. Mineral fertilizers (urea and NPKMg 12-12-17-2) are the conventional fertilizers in raising oil palm. However, oil palm empty fruit bunch (EFB) and cow dung (from oil palm/ livestock integration), usually available year-round, seem to be underutilized. These materials, if composted and used as organic fertilizer in toil palm production, could increase yield and also eliminate problems associated with intensive mineral fertilizer application. Thus, this investigation focussed on determining effective combinations of oil palm EFB and cow dung in composting for raising oil palm in the nursery.

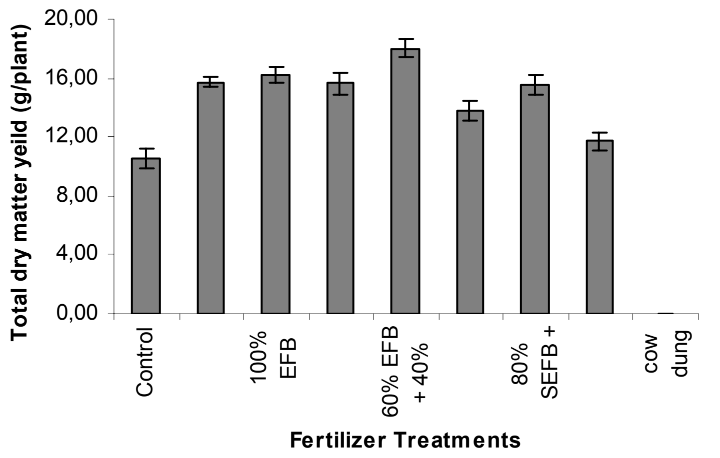
Materials and methods

Geminated oil palm (var. 'Tenera' was used. Pre-nursery stage (0 – 3 months after planting) took place in the greenhouse, whereas the plants were exposed to prevailing environmental conditions during the nursery period (3 –13 months after planting). The experiment was laid out in a randomised complete block design with three replicates. 2 kg of rain-washed river sand was used to raise the plants at the pre-nursery stage, while at the nursery, the soil was made up to 5 kg per bag. Treatments investigated were: (1) Control (no application), (2) Mineral fertilizer, (3) 100% Unsoaked Empty Fruit Bunch (UEFB), (4) 80 % (UEFB)+ 20 % cow dung, (5) 60 % (UEFB) + 40 % cow dung, (6) 100% Soaked Empty Fruit Bunch (SEFB), (7) 80 % (SEFB) + 20 % cow dung, (8) 60 % (SEFB) + 40 % cow dung and (9) Cow dung. Conventional mineral fertilizer was applied at 7 g urea / 5 L water per 100 seedlings (Hartley,1988) as fertigation in the pre-nursery as well as N-P-K-Mg (12-12-17-2 compound fertilizer, 14 g per plant [Onwubuya, 1982]) in the nursery. This was applied twice (2nd and 8th months) during the nursery period. The compost treatments were applied once at a rate equivalent to 4.8 g N /plant one week before planting. Dry matter yield was determined. The most recently matured leaf (Mengel and Kirkby, 2001) of the pre-nursery treatment plant was used for nutrient analysis in the pre-nursery stage, while at the nursery stage total plant shoot was used. Soil and plant material analyses were conducted using standard methods. Means of dry matter yield were compared using the treatment error ($p<0.05$).

Results

The un-soaked EFB: cow dung – 60: 40% compost treatment performed significantly ($P<0.05$) better than other treatments in total plant dry matter yeild at 10 months in the nursery (Fig. 1). At the end of this period, no plant on the cow dung compost treated soil survived.

Manganese concentration in the oil palm plants at the end of the pre-nursery stage ranged from 52 – 1126 $mgkg^{-1}$ (least in control and 100% UEFB and highest in cow dung treatments). Iron concentration at this stage ranged 906 – 3332 $mgkg^{-1}$ (least in mineral and highest in cow dung treatments). At 10 months in the nursery, manganese concentration in the plants ranged from 196 - 1204 $mgkg^{-1}$ (least in soaked EFB: cow dung – 80: 20% and highest in mineral fertilizer treatments respectively). Also, iron ranged 1704 – 2418 $mgkg^{-1}$ (least in 100% soaked EFB and highest in mineral fertilizer treatments respectively). Soil pH at the end of the 10 months in nursery ranged 5.4 – 7.1 (least in mineral and highest in control treatments respectively). See Table 1.



Bars indicate treatments' error ($p<0.05$)

Figure 1: Effects of oil palm empty fruit bunch (EFB) compost on oil palm dry matter yield at 10 months in the nursery

Tab. 1: Effects of oil palm empty fruit bunch (EFB) compost treatments on nutrients concentration in leaves of oil palm seedlings and soil pH

Stage	Pre-nursery		Nursery		
Treatments	Mn	Fe	Mn	Fe	Soil pH
	mg/kg				
Control	52	1219	382	1785	7.1
Mineral fertilizer	72	906	1204	2418	5.4
100% UEFB	52	1848	252	2351	6.7
80% UEFB + 20% cow dung	69	2257	215	1796	6.8
60% UEFB + 40% cow dung	57	2282	233	1928	6.6
100% SEFB	65	2530	211	1704	6.6
80% SEFB + 20% cow dung	53	2683	196	2103	6.7
60% SEFB + 40% cow dung	59	1891	214	1659	6.8
Cow dung	1126	3332	-		6.0

Discussion

Unsoaked oil palm EFB plus cow dung (60 : 40) resulted in significantly higher dry matter yield than the conventional mineral fertilizer and control (no fertilizer) treatments at the end of the nursery stage. Generally, nutrient concentrations in the leaves of the plants ranged from optimum to excessive as a result of the treatments (von Uexkull, 1992; Hartley, 1988). The plants treated with cow dung compost died shortly after the 3rd month in the nursery. Manganese toxicity was suspected as the cause, arising from the high Mn concentration and the marginal leaf necrosis observed at the prenursery stage. Hochmuth *et al.* (2004) reported that Mn, which is an immobile nutrient in plants, could be toxic to plants when the concentration in the plants' tissue is very high (above 500 mg / kg). This means that the very high concentration of Mn in the plants treated only with cow dung compost could have resulted into the death of those plants. Thus, it seems inadvisable to use compost of only cow dung for raising oil palm seedlings in this type of soil.

Highest soil acidity caused by the mineral fertilizer treatment is a negative consequence in this tropical soil. Soil acidity is usually enhanced by rapid decline in soil organic carbon content (Bagayoko *et al.*, 2000). However, adequate compost application to soil could arrest this situation, as was observed in this investigation.

Conclusions

The overall results of this investigation indicated that composting a combination of oil palm empty fruit bunch with cow dung led to better performance of oil palm seedlings. Thus, this treatment could be used as an alternative to mineral fertilizer for raising oil palm seedlings. Soaked or unsoaked EFB and cow dung (60:40) composts seemed to enhance plants' performance better than other EFB composts. Composted soaked EFB and cow dung in the ratio 60:40 performed better in the oil palm pre-nursery, while unsoaked EFB and cow dung (60:40) compost performed better in the oil palm nursery than other EFB composts used in this investigation. However, sustainable integration of oil palm and livestock is essential for getting sufficient cow dung for this compost combination.

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Use of a mixture of biotite- and apatite-rich rock powder in a soil with inherent low soil fertility

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Key words: Potassium, Phosphorus, Rock Powder, Ryegrass, Clover

Abstract

Long-term fertility of organically managed soils is challenged by repeated removal of plant nutrients through cash crops. The use of selected rock powders may contribute to maintain soil fertility. A pot trial with Italian ryegrass and white clover was used in order to study the potential of a biotite-rich and of an apatite-rich rock powder to maintain and improve the nutrient supply of organically managed soils.

Introduction

Motivated by the high price of soluble K-fertilizer during the 1st World War, a number of field trials showed that biotite-rich rock powder has a long lasting ability to improve crop yields on K deficient soils (Solberg 1928). Only a few studies have followed those early works (e.g. Bakken *et al.* 2000). Due to its bulky weight and volume, rock powder is not competitive relative to low price soluble K fertilizer. However, its use can be of interest on organically managed farms in order to counteract the continuous removal of nutrients through sale of cash crops, which is challenging the long term fertility of soils with moderate nutrient reserves on farms without animal manure (Løes *& Øgaard*. 1997). It may also enable the conversion to organic management of poor sandy soils, which is usually discouraged even in the case of animal production. Even the most easily weathering rocks release nutrients very slowly, however this does not need to be a drawback since slow nitrogen supply often retards the initial growth rate of organically managed crops.

This work is a contribution to the study of the potential of biotite-rich rock powder (**biotite-Rp**), alone or in combination with igneous apatite-rich rock powder (**apatite-Rp**), as source of potassium (K), phosphorus (P) and other plant nutrients. Igneous apatite is less soluble but has lower heavy metal content than sedimentary phosphates. A working assumption is that if a rock powder can increase the nutrient uptake by plants grown on a very deficient soil, it is also likely to be able to maintain soil fertility in areas where nutrients removed by crops can neither be compensated by the weathering of local soil material, nor by large supply of organic amendments. Both nutrient uptake by plants grown in pots and artificial rock weathering were studied (Speetjens 2007). Selected results from the plant trial are presented here.

Materials and methods

A finely ground biotite-Rp (biotite gneiss, K content 1.3 % by weight, 50 % grain size 0,36 mm) was added alone, or together with low-grade igneous apatite-Rp (apatite

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norite, P content 2.2 %, 50 % grain size 0,38 mm), to the top 10 cm of three-litre pots filled with a sandy soil known to be extremely deficient in plant nutrients, from a an eolian deposit ("Elverum sand") poor in organic matter. The low dose (**LB,** 13 ton ha^{-1}) of biotite-Rp was merely sufficient to raise the index for easily plant available potassium to what is considered the exhaustion levels by repeated cropping of unfertilized sandy soils. The high biotite-Rp dose (**HB**) was five times as much. Apatite-Rp was added in low dose (**LA**, 9.8 ton ha^{-1}) or high dose (**HA,** 29 ton ha^{-1}).There were three controls: limed fertilized (**K1),** non-limed fertilized (**K2**) and limed unfertilized (**K3**). The latter two received moderate doses of potassium sulphate and calcium phosphate. Liming raised the soil pH to the same level as the large application of biotite-Rp. In an additional treatment, calcium phosphate was added to HB (**HB-P**). As plants, in particular clover, showed symptoms of micro-nutrients deficiency, a solution containing Cu, Zn, B, S and Mo was added to all pots once.

Pots were planted with either Italian ryegrass or white clover plants which had germinated on an organically certified soil, in order to ensure vigorous seedlings and infection of clover roots by symbiotic bacteria. Ryegrass pots were fertilized repeatedly with low doses of ammonium nitrate, while clover plants received no nitrogen application. Treatments were replicated four times. Plants were harvested consecutively three (clover) or four times. At the end also stubbles (ryegrass) and stolons (clover) were collected, and the N, K, P, Mg, S and Ca content of each sample was analysed.

Results

Application of rock powder always significantly increased the total dry matter yield of ryegrass (sum of 4 harvests + final stubble), compared to the unfertilized control. Clover showed a similar trend (sum of 3 harvest + final stolons), although the total yield increase was statistically significant only when a large dose of apatite-RP was added in addition to biotite-Rp (Figure 1). HB combined with a moderate application of calcium phosphate raised the dry matter yield of both species to the same level as the next best fertilized control, which indicates that biotite-RP was a good source of K. As expected, K and Mg uptake increased with application of biotite-Rp, and even more so when pots were moderately fertilized with calcium phosphate (data not shown). Unexpected was though the effect of biotite-Rp on the total amount of P taken up by the plants. Low biotite-Rp dose raised the amount of P absorbed by the plants. This can be attributed to the small amount of P (0.09 %) present in the biotite-Rp, but the amount of P taken up was significantly reduced when more biotite-Rp was applied (Compare LB with HB on Figure 1). For ryegrass this was true also when apatite-Rp was added (compare LB-HA with HB-HA in Figure 1).

Application of apatite-Rp did not increase the total P uptake, but for one case with white clover (compare HB with HB-HA in Figure 2). However, it significantly increased the uptake of S by ryegrass (not shown). A similar, although not statistically significant increased S uptake was found in white clover. Unexpectedly, addition of apatite-Rp increased the uptake of K (data not shown). Clover benefited well from the combined application of HB and HP, which raised the biomass production to 70 % of the "best" fertilized control (K1 = 100 %, K3 = 42 %).

Total nitrogen uptake by clover (sum of 3 harvest + final stolons) was always increased (Table 1). Due to the very low N content of the soil this indicates a strong positive effect of the rock powders used, on biological fixation. This will obviously benefit also grasses and herbs present in a clover-grass leys. As mentioned, N fertilizer was applied to ryegrass only.

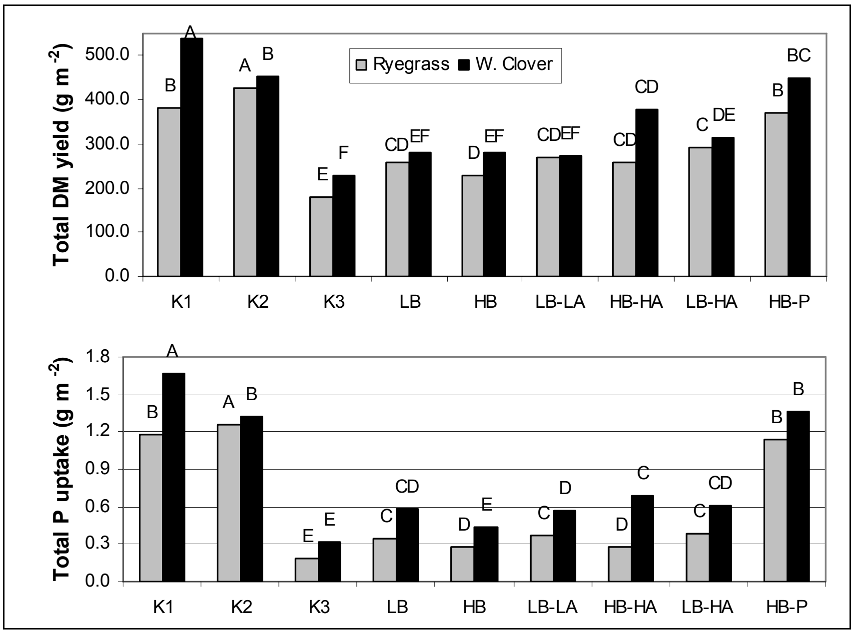

Figure 1: Dry matter yield and P uptake (g m^{-2}), sum of four ryegrass harvests + final stubble, or three white clover harvests + final stolons. See text for explanation of treatments. Within the same plant species, treatments with the same letter are not statistically different (P>0.05)

Tab. 1: N uptake by white clover. Treatments as in Figure 1. Treatments with the same letter are not statistically different (P>0.05)

Treatment	K1	K2	K3	LB	HB	LB-LA	HB-HA	LB-HA	HB-P
N (g m^{-2})	19.0a	13.7bc	5.3e	9.0d	8.5d	8.7d	11.9c	9.6d	15.3b

Discussion

The weathering trial indicated that the small amount of P present in biotite-Rp was more soluble than P contained in the apatite-Rp. This can explain the positive effect of a moderate biotite-Rp application on the amount of P taken up. One would then expect an even higher P uptake when the biotite-Rp application was increased from LB to HB, while the results show that P uptake was lowered. A raise in pH (aq), from 5.9 to 6.7 in the soils with low and large biotite-Rp dose, respectively, can be a reason for the negative effect of increasing the biotite-Rp dose on the P uptake. However, other mechanisms may have played a role. For example the weathering trial showed that contact with biotite-Rp reduced the amount of soluble P extracted from apatite-Rp using a 0.01 M citric acid solution. A possible reason for this can be the precipitation of phosphates reacting with iron. Although the large biotite-Rp dose is not practicable in common farming, this result shows that the use of biotite-Rp can pose some problem on P-deficient soils. On the other hand, plant growth on the HB-P treatment indicates that where P is not severely deficient, the biotite-Rp tested in this trial can effectively improve the K and Mg supply available for plants.

Given the extremely low P level in the soil, we expected a positive effect of apatite-Rp on P uptake. However, the lack of a positive effect on ryegrass is in good agreement with many field trials under conventional management. It is thus most interesting that, when supplied with a large dose of biotite-Rp, white clover took clear advantage of a large dose of apatite-Rp. In general white clover took up much more P than ryegrass, and in real field situation this will benefit ryegrass as well, through decomposition of white clover residues. A higher microbial activity than in the test soil used in this study, a lower pH and the presence of mycorrhiza may improve the apatite-Rp ability to supply P in organically managed soils. Application to composting heaps has been suggested as a way to increase bio-availability of rock phosphate (Sekhar & Aery 2001). This opportunity should be tested further.

Increased uptake of Mg (present in large amount in the biotite-Rp) and of S (present in small amount, most in apatite-Rp) were also important, with positive consequences on the nutritional values as well as on yield mass. For example, ryegrass and white clover grown on HB-P had equally high yields as one of the fertilized controls, but a lower K/(Mg+Ca) ratio, which is preferable for cattle nutrition.

Conclusions

The results confirm the hypothesis that the selected rock powders can improve the supply of elements that are essential for growth of plants, suggesting that they can help sustaining soil fertility. However, some unexpected and complex results exemplify the need for more knowledge of the weathering and chemical reactions when rock powders are added to soils. They also indicate that applications of biotite-Rp in large quantity should be handled carefully. Most important, the results show that clover can take advantage of apatite-RP better than ryegrass, but there is still a scope to search for techniques that can improve the bio-availability of igneous phosphate rocks.

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Soil Fertility and Biodiversity effects from Organic Amendments in Organic Farming

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Key words: soil biology, soil microbial biomass, soil quality, manure, compost

Abstract

After a completed rotation of seven years, soils of the Manure as a Chance (MAC) trial were analysed for the effect of organic amendments on soil physical, chemical and biological properties. Yields suggest significant differences due to different organic amendments after seven years. In treatments receiving farm yard manure and bio waste compost yields increased over time. Soil properties indicate changes in soil carbon, nitrogen mineralization en plant feeding nematodes due to different organic amendments. No significant changes in microbial and fungal biomass were found.

Introduction

Organic farming strives for a balance between a reasonable good yield, a high produce quality and a limited environmental impact. Inputs include plant residues and plant based composts, animals manures from various origin and stages of decomposition and additional fertilizers like rock dust (Anonymous, 2005). Soil fertility and especially soil biological fertility is promoted within organic farming for reasons of nutrient cycling, structure improvement or biodiversity (von Fragstein, 2006). Very little research has been done to facilitate farmers to make choices between available amendments and improve soil fertility within the legal framework of organic farming. In this study we evaluate the effects of eight (out of thirteen) different organic amendments applied within the legal framework of organic farming in the Netherlands. Effects on crop and soil fertility are evaluated in terms of yield and in terms of physical, chemical and soil biological properties.

Materials and methods

Starting in 1999, the fertilisation trial Manure As a Chance (MAC) in Lelystad, The Netherlands (5° 30' East, 52° 32' North), examines the effects of thirteen different organic amendments on crop yield. In 2006, after one rotation was completed and amendments had been applied for seven years, effects of eight selected amendments on soil fertility and crop yield were compared. Only data from 2006 are used in this paper. The on site farm experiment was set up as a randomised complete block with four replications and 7m x 9m plot size. The soil was characterized as a sandy calcareous marine deposit (1.6% organic matter, 9% clay, pH-KCL 7.6). Mean annual precipitation is 780 mm. Except for fertilisation, all other elements of cultivation are the same in all treatments and follow normal organic farming practices. The intensive vegetable rotation, common in Dutch organic farming systems, includes red cabbage, potatoes, beet, carrot, parsnip, broccoli, pumpkin and cauliflower in 2006. The legal framework limited the manure or compost additions: 1)The manure or compost

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addition is limited by a maximum of 100 kg N ha^{-1} $year^{-1}$. 2)The manure or compost addition is limited by a mean net legal maximum of 80 kg P_2O_5 ha^{-1} $year^{-1}$. 3). The compost addition is limited by a legal maximum of 6000 kg dry matter ha^{-1} $year^{-1}$.

Tab. 1: Selected treatments of the organic amendment experiment MAC and average application of active nitrogen, P_2O_5 and organic matter in kg.ha^{-1} $year^{-1}$.

Level	Amendment	Active nitrogen*	P_2O_5*	Dry matter*	OM*
1	Deep stable manure (FYM)	67	66		4930
1	Cattle slurry (CS)	67	35		1530
1	Mineral fertiliser (MIN)	67	43		0
1	Biowaste and slurry (GFT+CS)	67	69		2910
2	Chicken manure (CM)	47	80		1680
2	Plant compost 1 (NC)	24	80		7870
3	Biowaste compost (GFT)	9	57	6000	1490
3	Plant compost 2 (GC)	8	48	6000	1770

* amendments are applied two years in three.

Yield of cauliflower was assessed in 4 rows per plot, 5 plants per row. Soil samples (0-10 cm depth) per plot were taken in November 2006 and analyzed for their total N, total C, organic C and POM-C contents. For physical characterization the pH in water, bulk density and earthworm pores according to Koopmans and Brands (1993) were determined. Microbial and fungal biomass, N mineralization, nematodes and basal respiration were determined according to Mulder et al. (2005). Data were analyzed by analysis of variance (ANOVA). Significant effects were separated by the least significant difference (LSD) at P = 0,05.

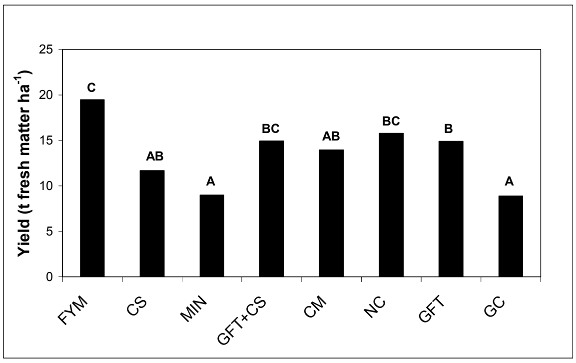

Figure 1: Yields of cauliflower in the MAC trial in 2006 (p<0.001).

Results

After seven years the use of FYM resulted in the highest yields (Fig.1). The GFT and GFT+CS treatments showed similar yields indicating that a higher nitrogen availability in the GFT+CS treatment did not result in higher yields. The results confirm a trend observed in the past seven years in which yields in the MIN treatment diminished, yields in the CS and CM treatments remained at the same level and yields in the FYM and GFT treatments increased if compared to averages of all treatments. Soil physical, chemical and biological properties were affected by the amendments. NC resulted in the highest C-total content, CM in the lowest (Fig.2). Nitrogen mineralization was relatively low in all treatments. Significantly lower values were found in MIN and GFT (Fig 2.).

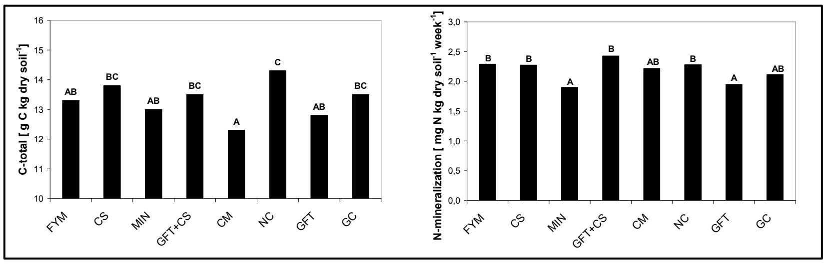

Figure 2: Total soil carbon and potential anaerobic nitrogen mineralization in soils of the MAC trial with different organic amendments (significant at P<0.05).

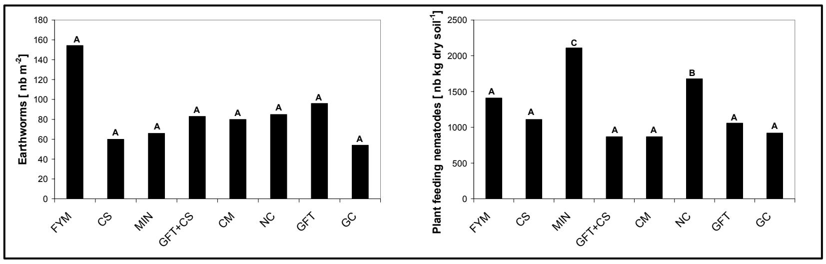

Figure 3: Number of earthworms and plant feeding nematodes in soils of the MAC trial with different organic amendments (significant at P<0.05).

No significant effects were found on the biomass of bacteria, fungi and earthworms (Fig. 3). However, earthworm pores, counted at 20 cm depth were significantly higher in the FYM as compared to the other treatments (data not shown). Amendments mainly had an effect on the number of plant feeding nematodes with MIN and NC resulting in the highest numbers (Fig 3.).

Discussion

The results show that organic amendments affect yields and soil fertility properties within a time frame of seven years. The lasting effect of FYM and the GFT+CS treatment in terms of yields and mineralization is especially pronounced and confirms earlier findings (Koopmans and Zanen, 2007). Soil mineralization and nematode population are among the soil properties that are most easily affected by fertilizer choice. However, fertilizer choice and crop production may interfere, resulting in a change of soil biodiversity through for instance root production.

Conclusions

The study shows that organic amendments used within the legal framework of organic farming may impact soil fertility and biodiversity indicators within seven years. Further research is required to understand the biological mechanisms behind this. The findings help to gain insight into the relationships between soil management, soil biodiversity and soil support services like soil fertility to optimise yields, mineral-use-efficiencies and soil structure formation in organic farming.

Acknowledgments

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The effects of different cattle manure levels and branch management methods on organic production of *Cucurbita pepo* L.

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Abstract

To study the effects of different manure levels and two branch management methods on organic production of Schneider squash, a field experiment was conducted during 2005 and 2006. Treatments were four manure levels (10, 15, 20, 25 ton ha^{-1}) and two branch management methods (with and without a wood pole), which were allocated to main plots and subplots, respectively. Results showed that the crop performed better in branch management without a wood pole than with a wood pole. Results showed that in the first year, manure level had a significant effect on fruit and seed yields. However, these traits were not significantly affected by manure levels in the second year. For both years, there were no differences in seed numbers due to manure levels. Seed oil content was slightly increased when the manure level was increased from 10 to 25 ton ha^{-1}.

Keywords: Schneider squash, manure, seed oil, yield, organic production.

Introduction

In recent years the safety and health of food has becoming a major concern due to overuse of chemicals for food production and its negative impacts on human health and environment (Gliessman 1998; Pimentel 2005). For this reason, cultivation of medicinal plants and other food plants with medicinal properties have been expanded (Berenyi 1998). *Cucurbita pepo* is an important oilseed plant that is used in food and also in cosmetics and health items (Aruyi et al. 2000; Younis & Al-Shihry 2000; Bombardelli et al. 1997; Murkovich et al. 1996). Murkovich et al. (1996) worked on a hundred lines of this species and found 39.5-56.5 % oil and 21-67.4 % linoleic acid content. Aruyi et al. (2000) reported that the ranges of oleic and linoleic acids in the seeds were 75.98-81.84 and 12.1-16.54 %, respectively. The purpose of this experiment was to study the effects of different manure levels and branch management methods on yield, oil and protein content of *C. pepo*.

Materials and methods

This study was conducted for two growing seasons of 2005-2006 on the Research Farm of the Faculty of Agriculture, Ferdowsi University of Mashhad, Iran. The experiment was in the form of split plot based on a randomized complete block design with three replications. Cattle manure levels of 10, 15, 20, 25 ton ha^{-1} were applied in the main plots, and branch management method (with and without a wood pole) were allocated to the subplots. The nutrient content of the cattle manure used was 2.11, 0.73, and 1.88 % N, P and K, respectively. The original nutrient content of the soil was 755, 42 and 465 ppm N, P and K, respectively. No chemical fertilizers or biocides were applied and weeds were controlled by hand. In the second year no soil tillage

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was conducted and seeds were planted on the same place and the same date as the first year. However, based on the results of the first year in which the superiority of plants without a wood pole was confirmed, this treatment was not continued for the second year. Therefore, in this year only the effect of manure was investigated, and the experiment was analyzed with levels of manure only. For analysis of variance (ANOVA) Minitab software Ver. 13 was used and means were compared using Duncan's multiple range tests at 5% probability level.

Results and discussion

Results of combined analysis of the experimental data showed that the effect of manure application on fresh fruit yield was significant; however, manure application did not affect seed dry weight and seed number (not shown). With increasing application of cattle manure to 25 ton ha^{-1} an increasing trend was observed in the yield of fresh fruit (Fig. 1). However, in the second year, application of manure did not affect yield. Averaged over two years, an increasing trend in fruit yield was observed from 10 to 20 ton ha^{-1} cattle manure, but no significant difference was observed between 10 and 15 ton ha^{-1}.

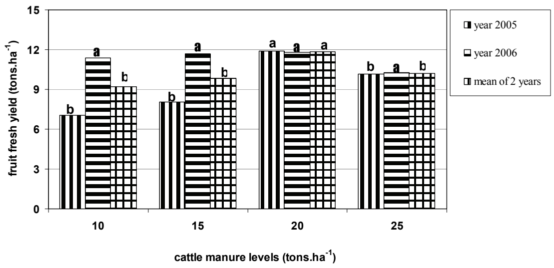

Figure 1: Effect of cattle manure levels on C. pepo fresh fruit yield. Similar letters indicate no significant differences between means within a year (p<0.05).

In general, the effect of cattle manure level was inconsistent, and a reduction of yield at 20 ton ha^{-1} seems to be unusual. However, it may be postulated that the effect of cattle manure on this species is achieved up to 20 ton ha^{-1}, and a further increase may have had a detrimental effect, possibly due to plants dying off. It also could be assumed that higher levels of cattle manure might have caused water to be stored in the root zone and hence leading to the spread of root pathogens. Visual investigation showed die-off of more plants at the highest manure level (25 ton ha^{-1}), which could have been associated with this effect. There is evidence (Bombardelli et al. 1997; Khorrami Vafa, 2006) that a well-drained soil is suitable for this species. This could be an indication of the sensitivity of plants to a high level of water in the root zone. On the other hand, it has also been reported (Aruyi et al. 2000) that application of high level of nitrogen fertilizers caused fresh vegetative growth and hence low yield of fruit. Therefore, the low yield at 25 ton ha^{-1} cattle manure could be associated with higher water level in the root area and also availability of more nitrogen, which changes the proportion of vegetative to generative growth.

Figure 2 shows that with increasing the cattle manure level from 10 to 20 ton ha^{-1} in the first year seed yield was increased, but there was no further increase from increasing the level of manure to 25 ton ha^{-1}. However, in the second year there were no significant differences among the seed yields.

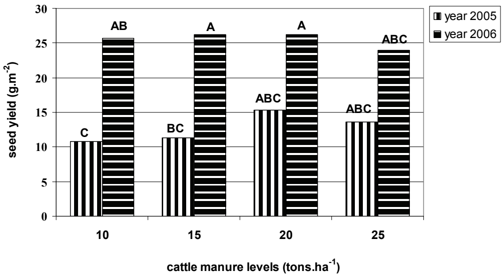

Figure 2: Interaction between cattle manure levels and year of experiment on C. pepo seed yield. Means followed by the same letters do not differ significantly ($p<0.05$).

From comparing Figures 1 and 2 it appears that the trends of change in fruit and seed yields are somehow similar. In general, the response of both components to cattle manure was higher in the second year compared with the first year. This is not unusual because more nutrients are released in the second year (Kuepper 2000). However, lack of response to fertilizer levels seems unclear. In other words, the reason there were no differences between fruit or seed yield at 10 ton ha^{-1} and other manure levels is unusual.

With an increase in the amount of manure, oil percent showed a decreasing trend (Fig. 3). This decrease was 5 percentage points from an application of 10 ton ha^{-1} of cattle manure to 25 ton ha^{-1}. This has also been confirmed elsewhere (Aruyi et al. 2000). Also, the effect of cattle manure on protein content was negligible, an increase of 1 percentage point unit was observed going from 10 to 25 ton ha^{-1} (Fig. 4). As a general trend, nitrogen fertilizer has been reported to increase protein content (Levitte 1980; Khorrami Vafa 2006).

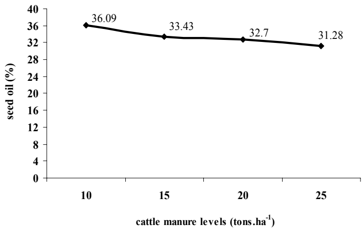

Figure 3: Effect of cattle manure levels on *C. pepo* seed oil content

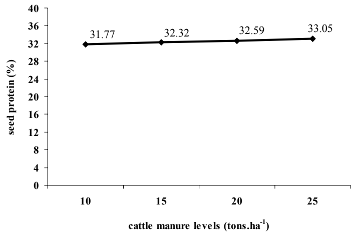

Figure 4: Effect of cattle manure levels on *C. pepo* seed protein content

Conclusion

The effect of cattle manure on fruit and seed yields are similar; when the rate of cattle manure was increased to 20 ton ha^{-1} an increasing trend was observed, but a further increase in cattle manure either did not change the yield or a slight reduction was observed. Therefore, an optimum amount of manure seems to be 20 ton ha^{-1}. The effect of cattle manure, as expected, was higher in the second year than in the first year; this was more pronounced for seed yield than for the fresh fruit yield.

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Inoculation affects nitrogen balances of composts and growth, yield and microflora of *Phaseolus* beans

Sangakkara, U.R.[1], Weerasekera, D.N., Attanayake, K.B. & Attanayake, A M U.

Key words: Compost, Inoculation, Effective Microorganisms, Quality, Crop growth,

Abstract

The impact of organic matter and two types of inoculums on composting and subsequent growth of common beans was evaluated under tropical field conditions. The composts were made of commonly available organic matter with different C:N ratios, and inoculums consisting of cattle manure slurry, Effective Micro organisms or a mixture of both were added. The mixture of cattle manure and Effective Microorganisms increased N availability and reduced C: N ratios of compost than when applied individually. Legume green matter enhanced compost quality and growth yields. The nodulation and mycorrhizal populations of roots of beans were increased by a mixture of inoculums and using diverse materials in the compost. The usefulness of inoculums such as EM, which is available in all continents is presented on the basis of this study .

Introduction

Composting is a very common source of manures in organic farming due to the non use of cropping land for its production and the possibility of using different sources as its components (Diaz, 2007). The application of partially decomposed material also helps providing nutrients more rapidly, while long term experiments show its benefits in producing high yields in organic farming (Herencia et al, 2007).

Composing requires inoculation and is carried out using animal manures, old compost or forest soils (Diaz, 2007). Many inoculants have been developed and Effective Microorganisms (EM), consisting of Lactic acid bacteria, yeast and phototrophic bacteria in a mixture maintained at a low pH has proven to be useful for compost (Jenkins and Daly, 2005), although Mupondi et al (2006) report its non effectiveness when compared to feedstock materials in composting pine bark, which has a high C:N ratio. Thus, studies determined the impact of EM and feedstock material (cattle manure) used individually or in combination on nitrogen (N) and C:N ratios of compost made with green manures, weed and straw, which are common material in the tropics and the impact of these composts on growth, root microbes and yields of common beans (*Phaseolus vulgaris* L), as N is the most difficult nutrient to manage in organic farming (Gaskell and Smith, 2007).

Materials and methods

Experiments were carried at the University of Peradeniya, Sri Lanka from January – May, 2006. The compost piles were made with equal parts of rice straw, leaves of *Gliricidia sepium, Tithonia diversifolia* and common weeds, in equal proportions (1 kg fresh material) Four replicates of each pile were made and N and C:N ratios determined by conventional methods (Anderson and Ingram, 1993). The inoculums

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used were cattle manure CM (250 g in 1 l water) activated EM (100ml in 1 l water), a mixture of CM and EM (250 g CM and 100ml EM in 1 l water) with water as a control and 500 ml of each inoculum were added to the respective compost piles and covered for a period of 40 days with mixing at 10 day intervals. At 40 days samples were analysed for N and C: N ratios and the respective composts added to separate plots of 1 x 1m, replicated 4 times within a Randomized Block design. Uniform seeds of beans (Var. Top Crop) were planted at a spacing of 10 x 15 cm, 5 days after the addition of composts, and maintained organically, At the R1(flowering) stage, 4 plants were carefully uprooted, plant height recorded, nodule numbers counted and root length determined by the grid technique. Mycorrhizal infection was determined by the grid line intersect method as described by Ambler and Young (1977). Fresh pod yields were recorded and the data analyzed statistically using a GLM procedure.

Results and Discussion

Legume green manure (Gliricidia) increased N contents and reduced the C: N ratios of preinoculated compost (Table 1), highlighting their value in composting when compared to non legume green manures. This is due to the greater N content in this material. The use of all components developed the best composts, highlighting the usefulness of material diversity in obtaining quality compost for organic farming

Tab. 1: N and C: N ratios of different compost materials (dry matter basis)

Composts	**N mg.g-1**	**C:N ratio**
Straw + Gliricidia + Weeds **(C1)***	5.84	26.5
Straw + Tithonia + Weeds **(C2)**	3.65	36.8
Straw + Gliricidia + + Tithonia + Weeds **(C3)**	4.16	30.4
LSD (p=0.05)	0.007	0.003

C1, C2 and C3 notations will be used in all tables to identify compost types

Microbial solutions (cattle manure or EM) increased N availability and lowered the C: N ratio of all composts, the use of a mixture had the most significant impact on these measured parameters (Table 2). EM had a greater beneficial effect in enhancing N availability of all composts, thus reducing the C: N ratios to a greater extent than CM. This clearly implied the importance of using an inoculant with known microbes for composting, rather than using ad hoc feedstock material, which could have different effects on the basis of microbes present. However, the use of inoculants such at EM must be carried out as per instructions to obtain the maximum beneficial effects.

Inoculation increased growth and yields of beans and the root microflora (Table 3). The impact of the three types of inoculum were EM + CM>EM >CM, highlighting the benefits of using both types of solutions. If one inoculum was to be used, EM which contains a known mixture of microbes had a more beneficial effect in enhancing growth, nodulation, mycorrhizal infection and yields of beans. The use of all plant material for compost also had a beneficial effect in terms of promoting yields, which is the most important factor in small holder farming systems and this could be attributed to the better quality of the material, especially when inoculated with EM and CM, which stimulates the roots and the rhizosphere.

Conclusions

Compost with legume leaves or preferably with a diverse range of material inoculated with EM and CM was of the highest quality and the most beneficial in terms of plant growth, yields and microbial populations of the roots. This clearly suggested the importance of using a range of inoculum and also the value of EM as a compost processing material. EM, which is now available in over 125 nations worldwide and made with the local microbes, would be a useful additive in composting within organic farming systems, as it is available at a relatively low cost. Thus tropical and even temperate organic farming systems could easily develop good compost by using EM with other feedstock inoculum for obtaining quality compost for successful cropping.

Tab. 2: N and C:N ratios of composts at 40 days after inoculation (dry matter basis)

Inoculation	C1 Compost		C2 Compost		C3 Compost	
	N mg.g-1	C:N ratio	N mg.g-1	C:N ratio	N mg.g-1	C:N ratio
CM	4.14	25.4	2.11	34.2	3.12	25.6
EM	4.36	21.5	2.21	33.9	3.59	24.8
CM + EM	4.99	20.8	2.65	30.6	4.01	20.5
Water	2.42	26.8	1.42	35.8	2.24	29.5
LSD (P=0.05)	0.24	0.05	0.33	0.02	0.18	0.01

LSD (P=0.05) for compost comparisons N = 1.04; C:N ratio = 0.13; Interaction Significant at P=0.05

Tab. 3: Growth, root microbial infection and yields of beans as affected by different composts and inoculations

Composts	Inoculum	Shoot height (cm)**	Total root length (cm)	Nodules .plant-1	%Root infection (Mycorrhiza)	Yield. g.plant-1
C1	Cattle manure slurry (CM)	25.6	258	16	22	421
	Effective Microorganisms (EM)	26.4	284	24	27	511
	EM + CM	30.5	324	35	31	567

	Water	21.5	205	10	12	224
C2	Cattle manure slurry (CM)	20.6	289	22	34	367
	Effective Microorganisms (EM)	22.6	314	31	36	451
	EM + CM	24.5	338	46	45	472
	Water	20.6	266	18	18	215
C3	Cattle manure slurry (CM)	26.6	315	26	32	494
	Effective Microorganisms (EM)	30.4	342	40	41	699
	EM + CM	32.5	390	51	47	781
	Water	36.2	284	42	20	267
LSD (p=0.05)	Compost	0.004	0.014	0.009	0.021	0.018
	Inoculum	0.009	0.001	0.020	0.008	0.007
	Interaction	*	*	NS	*	*

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Nitrogen management

Nitrate leaching and energy efficiency of stockless arable systems compared with mixed farming and a non-organic system on fertile soils in Northern Germany

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Key words: nitrate leaching, energy efficiency, stockless organic farming, conventional farming

Abstract

Previous studies based on either small-scale plot experiments or modelling approaches, indicate a lower risk of nitrate leaching and a higher energy efficiency in organic than in conventional farming systems. Because there is still a lack of data measured at the farm scale, which also take farm type and farming practices into account, a comparison between an N-intensive non-organic, two organic all-arable crop rotations and a typical rotation of a mixed organic farm was carried out over a three-year period at a highly productive site in Northern Germany. Comparing the all-arable crop rotations, the organic systems had 70% lower potential yields than the regional typical conventional crop rotation. In spite of 60% lower input of fossil energy an N-intensive organic crop rotation showed 20 percent lower energy efficiency than a comparable conventional. In the present study, the higher N inputs and higher N surplus in the conventional system did not lead to significantly higher nitrate leaching than in the organic all-arable crop rotations. Comparison of an organic all-arable crop rotation with the corresponding mixed farming system showed significantly higher potential yields, higher energy efficiency and lower nitrate leaching in the organic mixed farming system. Management of the grass/clover (mulching versus feeding) had the strongest influence on nitrate leaching and energy efficiency in the organic systems. The decision to undertake stockless instead of mixed organic farming should not only be based on economic reasons, but also take the important aspects of energy and nitrogen efficiency into account.

Introduction

Several studies have shown that that changing from conventional to organic farming can represent a way to reduce negative impacts to the environment, for example nitrogen (N) losses (Hansen et al., 2000) and the input of fossil energy both per unit land and per unit product (Dalgaard et al, 2001). In contrast to this, some studies on farm nitrogen budgets (e.g., Scheringer et al., 2001) and field measurements indicate a substantial risk of nitrate leaching on specialised organic farms. This indicates that it is not the simple case of conversion to organic farming alone which guarantees a reduction of all negative impacts to the environment. Factors such as farm type, cropping method, soil and climatic conditions strongly affect the relative performance of organic farming systems from both an agronomic and an environmental point of view. Also in organic agriculture there is currently a trend towards specialized farming systems. Until the early 1990's, organic farming in Europe was represented mostly by

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mixed farms with livestock since a tight nutrient cycle with a high share of forage legumes and nutrient recycling through livestock was regarded as a prerequisite in nitrogen (N)-limited organic farming systems. Recently the growing market for organic cereals, field grown vegetables and the conversion of all-arable farms to organic standards created the context for an increasing specialisation towards all-arable stockless organic farms. These farms have followed up the intensification and specialisation as observed in conventional agriculture. Cereals and other cash crops are grown in short rotations (3-4 years) with a minimum proportion of forage legumes. Studies comparing the relative performance with respect to yields and environmental effects of organic mixed and all-arable farms are scarce. Comparisons of organic and conventional all-arable cropping systems under favourable soil and climatic conditions are scarce as well. Since most studies based their conclusions on results from small-plot field trials or on farm nitrogen budgets, especially comparative studies based on measured data at a farm scale are lacking. For this reasons N- and energy-fluxes of different conventional and organic cropping systems were compared in a farm-scale study on highly productive arable soils at Kiel University's experimental farm Lindhof in Northern Germany that has been sub-divided in an organic and a conventional farm unit.

Materials and methods

During the conversion from conventional to organic farming, different crop rotations were implemented at the field scale at the experimental farm Lindhof (Kiel university) in Northern Germany The site is characterised by Luvisols and Cambisols as soil types, a mean annual air temperature of 8,7°C and a mean annual precipitation of 774 mm. Over a three-year period (1999/2000- 2001/2002), organic and conventional crop rotations were analyzed for productivity, nitrogen balances and nitrate leaching. At Lindhof one non-organic and three organic crop rotations which represent 4 farm systems where established in 1994. The three organic crop rotations differed with regard to legume content and farm type. Each of the following crop rotation was carried out on four fields representing four replications: (1) non-organic, (2) stockless organic with a crop rotation content 50% legumes, (3) stockless organic with 30% legumes and (4) mixed organic 50% legumes. The non-organic crop rotation was oilseed rape – winter wheat – sugar beet – winter wheat. Average annual N input was 186 kg ha^{-1}. In the organic all-arable farming systems grass/clover was mulched while the mixed farming system was characterised by harvesting and feeding grass/clover to a small herd of suckler cows as well as manure application to non-legume crops. Only the harvest years 1999-2001 were considered, in order to minimize the risk that organically managed fields that had been converted to organic standards in 1994, were still affected by residual effects of conventional practices, such as high levels of soil nutrient supply. The farm scale of the experiment ensured that crops were managed as on commercial farms, and that yields were comparable to practical conditions. To compare the at field level determined yields of the different crops, it was necessary to transform them to comparable standards. The yields of the all-arable crop rotations were transformed to grain equivalents (GE) using values for standardised fresh matter contents from the official tables of the German Federal Agency for Agriculture and Nutrition. To compare yields of the all-arable crop rotation with those of the mixed farm system (Table 2), yields were transformed into metabolisable energy (ME) using data of the official German feedstuff evaluation tables. The energy input was determined as sum of direct and indirect fossil energy inputs. Leaching of nitrate was determined with ceramic suction cups, of which 300 had been installed on the farm area. Leachate was sampled weekly during the three winters and analyzed for NO_3 concentrations. The volume of drainage water was calculated by a general water balance model. Nitrogen fixation was estimated on subplots as difference of the absolute measured N-amounts of crop and crop residues (root, stubble and litter) between the considered legume and a similar managed non-N-fixing reference crop. For statistical analyses, the untransformed data was subjected to analysis of variance (ANOVA).

Results and discussion

Some agronomic and environmental characteristics of the analyzed all-arable farming systems are given in Table 1. Yields (in grain equivalents) of the conventional system were much higher than of the organic all-arable systems. This may be attributed to a higher nutrient input, a target-oriented use of plant protecting agents, and the absence of a non-yielding mulched grass/clover ley in the conventional system. In spite of the significantly higher N input and N surplus of the conventional system, nitrate leaching did not differ significantly from the organic crop rotations. The observed range in nitrogen leaching was from 20.1 to 23.6 kg NO_3-N ha^{-1}. Related to the average drainage (253 mm in 3 winters), NO_3-N loads were below the EU threshold value of 50 ppm NO_3 in drinking water, which is equivalent to the leaching of 28.6 kg N ha^{-1}. The relatively high N losses via leaching in the organic all-arable systems were due to inefficient utilization of mineralized N from the grass/clover mulch.

Tab. 1: Yield of grain equivalents (GE), N input, N balance, N leached, fossil energy input, and energy efficiency of all-arable farming systems during the experimental period 1999/2000-2001/2002

Farming system	Crop rotation	Yield [GE ha^{-1}]	N input [kg ha^{-1}]	N balance [kg ha^{-1}]	Leached NO_3-N [kg ha^{-1}]	Energy input [GJ ha^{-1}]	Energy efficiency [GE GJ^{-1}]
1. Conventional all-arable farm	1.1 Sugar beet 1.2 Winter wheat 1.3 Winter oilseed rape 1.4 Winter wheat	107.5 a[1)] (100%)	186.0 (100%)	47.5 (100%)	23.6 a (100%)	15.57 a (100%)	6.65 a (100%)
2. Organic all-arable farm 50% legumes	2.1 Grass/clover mulched 2.2 Oats 2.3 Grain legume 2.4 Winter wheat/potato	31.8 b (30%)	88.5 (48%)	12.1 (25%)	21.2 a (98%)	6.07 b (39%)	5.28 b (79%)
3. Organic all-arable farm 33 % legumes	3.1 Grass/clover mulched 3.2 Oats 3.3 Winter rye	29.8 b (28%)	67.0 (36%)	17.5 (37%)	20.1 a (85%)	4.50 c (29%)	6.58 a (99%)

[1)] same letters in one column are not significantly different P≤0.05

Furthermore, the relatively high average input of mineral fertiliser-N of 186 kg ha^{-1} into the conventional system was the main reason for the much higher input of fossil energy compared to the organic systems. As productivity in the conventional system was also much higher, energy efficiency was not lower. Table 2 shows the same characteristics for the organic all-arable and mixed farming systems with 50% legumes. Utilisation of grass/clover herbage in animal production and higher yields of non-leguminous crops due to the application of manure led to 50% higher energy yields and 30% higher energy efficiency in the organic mixed farming system. Nitrate leaching was significantly lower in the mixed farming system than in the all-arable system even though total N input was higher. Harvesting the grass/clover herbage resulted in higher nitrogen fixation and lower leaching losses in the following winter.

Tab. 2: Metabolisable energy yield, N input, N balance, N leached, fossil energy input, and energy efficiency of organic all-arable and mixed farming systems during the period of 1999/2000-2001/2002

Farming system	Crop rotation	Yield [GJ ME ha^{-1}]	N input [kg ha^{-1}]	N balance [kg ha^{-1}]	Leached NO_3-N [kg ha^{-1}]	Energy input [GJ ha^{-1}]	Energy efficiency [GJ GJ^{-1}]
2. Organic all-arable farm 50% legumes	2.1 Grass/clover mulched 2.2 Oats 2.3 Grain legume 2.4 Winter wheat/potato	36.3[1)] b[2)] (100%)	88.5 (100%)	12.1 (100%)	21.2 a (100%)	6.07 b (100%)	5.90 b (100%)
4. Organic mixed farm 50% legumes	4.1 Grass/clover harvested 4.2 Oats 4.3 Grain legume 4.4 Winter wheat/potato	55.4 a (153%)	137.2 (155%)	11.1 (92%)	11.4 b (62%)	6.96 a (115%)	7.87 a (133%)

[1)] mean of entire crop rotation, all values are averages per year, [2)] significant at $P \leq 0.05$

Conclusions

Under the sites growth conditions, stockless organic farming was not advantageous in terms of nitrate leaching and fossil energy efficiency. Farming system had a decisive impact on agronomic and environmental performance. In terms of nitrate leaching and fossil energy efficiency mixed farming with livestock was advantageous. The decision to undertake stockless instead of mixed organic farming should not only be based on economic reasons, but also take energy and nitrogen efficiency into account.

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Legume catch crops for reducing N leaching and substituting animal manure

Askegaard, M.[1] & Eriksen, J.[2]

Key words: soil fertility, catch crop species, residual effect.

Abstract

Organic cereal production on coarse sandy soil is a challenge because of low soil fertility and a general limitation on the use of animal manure. The possible exclusion of conventional animal manure in organic crop production increases the challenge further. Two factorial experiments were carried out aiming at investigating the potential of legume catch crops with respect to residual effects and effects on N leaching. Legume catch crops were compared with non-legume catch crops in systems with spring barley as the main crop each year. Grain yields were determined and N leaching losses measured by means of installed ceramic suction cups. The legume catch crops, especially white clover and red clover, showed large residual effects in succeeding spring barley, and clover was efficient in reducing N leaching losses. A clover catch crop had the potential to replace animal manure but attention should be paid to the risk for poor growth in soil recently cropped to clover.

Introduction

Animal manure (AM) is an important nutrient source in organic agriculture. However, in Denmark a significant part of applied AM, especially on organic arable farms, is imported from conventional farms. It is widely debated whether this import of conventional AM should be prohibited, and if that happens it will become urgent to compensate for the missing nutrients through import from alternative sources. In grain production there is a special focus on the nitrogen (N) supply. For the compensation of conventional manure there is a need to focus on increased utilization of N_2 fixation in legume plants and on catch crops, which reduce the N-leaching losses and thus improve the N nutrition of subsequent crops. The most commonly used catch crops in Denmark are non-legumes such as ryegrass. A field experiment "organic crop rotations for grain production" on coarse sand has shown large effects of ryegrass catch crops in reducing nitrate leaching (Askegaard et al., 2005). However, there is a need to study the effects of catch crops other than ryegrass, and legume catch crops may become valuable because they both fix atmospheric N_2 and take up nitrate-N from the soil solution (Thorup-Kristensen et al., 2003). The potential of legumes as catch crops was investigated on a coarse sandy soil (<5% clay), which represents about 25% of the agricultural soil in Denmark. One objective was to test the possibility of replacing a cropping system based on ryegrass catch crops plus AM with a system relying on clover catch crops only. Another objective was to test the residual effects of legume catch crop species.

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Materials and methods

The experiments were carried out at Jyndevad Research Station, Denmark, on irrigated coarse sand. Spring barley (*Hordeum vulgare* L.), harvested at maturity, was sown in all plots after spring ploughing each year, and the catch crops were undersown at the beginning of stem elongation. All straw was chopped and left on the soil. During autumn the plots with no catch crops were kept bare by means of two shallow harrowings; the plots with catch crops were left undisturbed.

Legume catch crops as a substitute for animal manure (Experiment I): The treatments established in barley in 2001 in 144-m^2 plots with four replicates were: 1) no catch crop with AM (CC_{no}/AM); 2) perennial ryegrass (*Lolium perenne* L) catch crop with AM (CC_{grass}/AM); and c3 clover catch crop (mixture of red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.) without AM (CC_{clover}). The combination of treatment and plot was maintained during the experimental period. Each spring, 70 kg total-N ha^{-1} in conventional pig slurry was injected into the spring barley seedbed in the two AM treatments. Potassium (K) was applied to the treatment with clover catch crop in an amount corresponding to the K content of the AM treatments. The experiment was discontinued after harvest in 2003 because of poor clover development. Leaching of nitrate-N was measured using porous ceramic cups installed at 1-m depth. Samples taken every one to four weeks were analysed for nitrate-N. The estimated accumulated annual leaching was calculated from 1 April to 31 March.

Residual effects of legume and non-legume catch crops (Experiment II): The experiment was established in spring 2001 and replicated on an adjacent area in the 2002/03 season, where slurry (70 kg total-N ha^{-1}) was injected into the seedbed of spring barley. Nine plots with catch crop species/mixtures and four plots without catch crops were randomly established in three blocks in 48-m^2 plots. The catch crop species were: white clover; red clover; Persian clover (*Trifolium resupinatum* L.); black medic (*Medicago lupulina* L.); kidney vetch (*Anthyllis vulneraria* L.); rye/hairy vetch mixture (*Secale cereale* L./*Vicia villosa* L.); ryegrass; chicory (*Cichorium intybus* L.); and fodder radish (*Raphanus sativus* L.). Rye/hairy vetch and fodder radish were first sown after harvest of spring barley. Spring barley was sown the following spring for measurement of the residual effects. Four reference N-fertilizer treatments (0, 40, 80 and 120 kg N ha^{-1}) were applied in spring to the plots without a previous catch crop. In the catch crop treatments the succeeding spring barley was unfertilized.

Apart from N fertilizer application to the reference plots in exp. II and application of K to the clover as a KCl salt in exp. I, the treatments were managed according to the Danish certification standards for organic farming.

Results

Experiment I: In 2001, when a grass-clover catch crop preceded barley in all treatments, the application of AM to the treatments with no catch crop and ryegrass catch crop increased grain yields (Table 1). The effects of the clover catch crop and the ryegrass catch crop plus AM on grain yields in 2002 and 2003 were at similar levels and significantly higher than in the treatment with AM application and no catch crop.

The annual flow-weighted mean NO_3-N concentration (nitrate leaching per volume of drainage) in the CC_{no}/AM treatment was between 13 and 16 mg L^{-1}. This was significantly higher than the values for the catch crop treatments, which were between 5 and 8 mg NO_3-N L^{-1}. The WHO guideline for drinking water is a maximum of 11.3 mg NO_3-N L^{-1}.

Tab. 1: Effects of three catch crop treatments on annual N leaching and grain yields of a succeeding spring barley. Values with the same letter are not significantly different within the column (P<0.05).

[1]Treatment	Leaching kg nitrate-N ha^{-1}		Grain yield t DM ha^{-1}		
	2001/02	2002/03	2001	2002	2003
No catch crop, with animal manure (AM)	100^a	96^a	3.8^a	2.4^b	2.2^b
Ryegrass catch crop, with AM	55^b	23^b	3.6^a	3.2^a	3.2^a
Clover catch crop, without AM	60^b	31^b	2.2^b	3.1^a	2.7^{ab}

[1]The treatments were carried out each year.

Experiment II: Catch crop treatments significantly affected grain DM yields of the succeeding spring barley (Fig. 1). The yield levels following the non-legumes were similar to the treatment with no catch crop and no N fertilizer, whereas the residual effect of white clover on grain yields corresponded to 120 kg N fertilizer ha^{-1}.

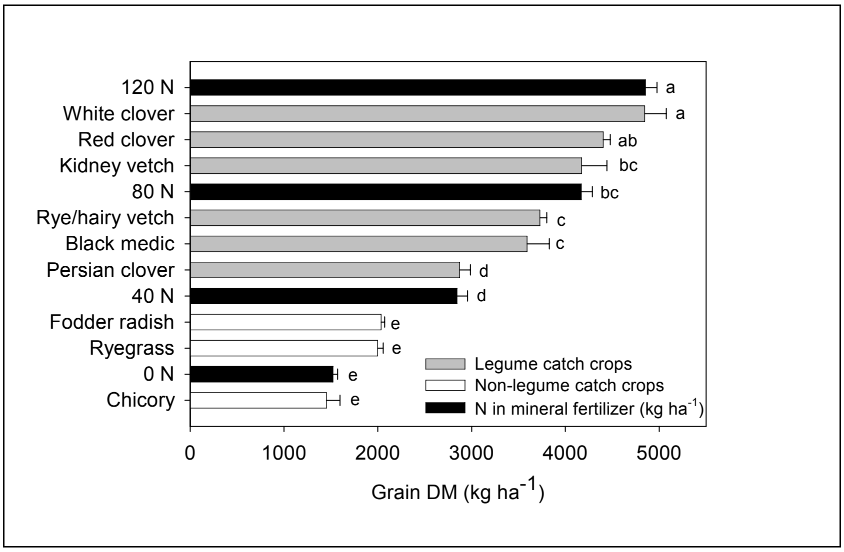

Figure 1: Effect of catch crop species and mineral N fertilizer application on spring barley grain yields. Values with the same letter are not significantly different (P<0.05).

Discussion

The significant difference in residual effects between legumes and non-legumes was caused by the low fertility status of the coarse sandy soil. This low fertility is the result of a coarse soil texture and high autumn/winter precipitation that is typical for the site. In the comparison of grain yields from barley getting nutrients by feeding on clover residues or on spring applied AM only, the larger yield response following a clover catch crop indicates that more N was captured and made available to plants through N_2-fixation than the allowance in AM.

In the present experiment the clover catch crop was as effective as the ryegrass in reducing N leaching. In another experiment on the same site a ryegrass catch crop reduced N leaching more than clover, but the clover was still efficient (Askegaard and Eriksen, 2008). The reason for the relatively good effect of clover on N leaching could be better timing between clover NO_3-N uptake after harvest of the main crop and onset of the NO_3-N leaching losses, which normally start early in the autumn on this soil type (Askegaard and Eriksen, 2008).

The spring barley system based on clover catch crops undersown each spring as the sole N source was not stable, as the clover exhibited poor growth after a few years. This could be due to the simple variation between years or more likely the build-up of clover cyst nematodes in the soil, which can be significant with repeated sowing of white clover in the same field (Søegaard and Møller, 2005).

Among the tested legume species, the largest residual effects originated from the two most common legumes in ley production, white clover and red clover. It needs to be emphasized that only one variety per species was included in this experiment.

Conclusions

Clover catch crops significantly increased yields and reduced the loss of nitrate-N to the environment. It appears that clover catch crop has the potential to replace AM as a nutrient source for spring barley on the coarse sandy soil. Among the tested clover species, white clover and red clover had the largest residual effects, which corresponded to the effect of 100-120 kg N ha^{-1} in mineral fertilizer. A possible drawback with clover as a catch crop is the poor establishment in recently clover-cropped soil, a subject that is currently under investigation.

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Winter grazing as an alternative to mulching or mowing grass clover swards

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Key words: grassland, grass/clover, forage quality, wheat, nutrient management

Abstract

Management factors like the type of defoliation and seed mixture influence yield and forage quality of grass clover mixtures. In comparison to harvesting, grazing is less cost intensive. For economical reasons a maximum duration of grazing period is required. Grazing over winter can cause pasture damages. This problem is of minor relevance for grass clover grown on arable land in the last production year, which is ploughed in the following spring. This study compares different grass clover mixtures concerning yield, forage quality and suitability for winter grazing.With this background, tall fescue exerted more significant effect on the dry matter yield than perennial ryegrass. White clover showed significant superiority over all the other tested species, with regard to protein and energy contents. Otherwise, swards with red clover and alfalfa had a significantly higher legume contents and produced higher dry matter and N yields than the other swards. Plots grazed in different periods over winter showed a clear significant loss of grazable matter. The highest loss of dry matter which also was accompanied by a decrease in crude protein and energy content was observed in mixtures with Lucerne. Under mulching systems and early grazing high nitrate losses were measured. After ploughing, the early grazing systems resulted in lower spring wheat yields than grazing in January or cutting systems.

Introduction

Yield and forage quality of grass legume mixtures are affected by management factors like the type of defoliation system and the selection of seed mixture (Loges, 1998). In addition to use for silage and mulching of grass clover, a mixed harvesting and grazing system is also possible and typical. Compared with harvesting, pasture is cheaper (Jakob, 2003). From the economical point of view, applying extended grazing period, as long as possible, is always encouraged. By winter grazing costs for housing and forage conservation can be decreased.

On permanent pastures winter grazing can lead to problems, especially in maritime climates. Excrements can affect nutrient entries to ground and surface water (Buchgraber, 2006). A high stocking density brings irreversible sward damages.

These problems can be avoided or reduced, by practicing winter grazing only on grass clover swards that will be ploughed anyway in next spring.

The main objective of this study is to compare different grass forage legume mixtures regarding their yield ability, forage quality and ability for winter grazing.

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The possibility to support extensive cattle or sheep with grass legume mixtures by winter pastures was the main subject of the investigation.

Materials and methods

The current study is based on a multifactorial experiment carried out from 2005 to 2007, on the organic farm "Hof Ritzerau" in northern Germany. Grass clover swards with two different grass species (perennial ryegrass (*Lolium perenne*), tall fescue (*Festuca arundinacea*)) and three different forage legume species (white clover (*Trifolium repens*), red clover (*Trifolium pratense*) and lucerne (*Medicago sativa*)) were established and used for harvesting, mulching and as a mixed system with different grazing dates (Tab. 1).

Tab. 1: Levels of the different studied factors included in the experiment

factor	level	description
1. grass species	1.1 perennial ryegrass, Indiana *Lolium perenne* (PR)	most important grass species in northern Germany
	1.2 Tall fescue, Kora *Festuca arundinacea* (TF)	wintergreen, deep rooting grass species
2. legume species	2.1 White clover, Klondike *Trifolium repens* (WC)	typical forage legumes
	2.2 Red clover, Amos *Trifolium pratense* (RP)	
	2.3 Lucerne, Daisy *Medicago sativa* (LC)	
3. defoliation system	3.1 harvesting	3 cuttings
	3.2 mulching	3 cuttings
	3.3 mixed system	2 cuttings…
	3.3.1 grazing in October	… + grazing in October
	3.3.2 grazing in December	… + grazing in December
	3.3.3 grazing in January	… + grazing in January

At every date of use, plants were sampled for evaluating yield and eventually the rest of grazing. Forage quality parameters like crude protein (CP) and metabolizable energy content (ME) were measured by NIRS. In winter, nitrate leaching was measured using suction cups. The following spring wheat was harvested by a combine harvester.

Data were statistically analysed using the mixed procedure of SAS analysis. The students t-test ($P<0.05$) was used for mean comparison.

Results

To illustrate the productivity and quality parameters of the mixtures, first the sum of three applied cuttings per year are shown. The dry matter yield ranged significantly between 10 and 15 t ha^{-1} among three tested legume species (Tab. 2). Red clover and Lucerne produced higher yields than white clover. Regarding the yield composition, both the grass species and the legume species exerted significant effects on the legume portion. Tall fescue suppressed legumes more than perennial ryegrass. White clover was more negative affected than red clover and lucerne. It was also observed that a high legume portion was important to achieve a high crude protein content from the sward. This may explain the reason behind the very low protein content produced from the mixtures including white clover and including tall fescue. Both grass species had higher energy contents than red clover and lucerne fractions. Single energy content of white clover fractions was higher than those of grass species. Because of that a higher legume portion produces higher energy content only in mixtures with white clover.

Tab. 2: Yield and selected forage quality parameters in cutting systems.

seed mixture	WC PR	WC TF	RC PR	RC TF	LC PR	LC TF
yield [t ha^{-1}]	9.1^{b*}	9.7^{bc}	14.7^{a}	13.3^{ab}	14.2^{a}	13.2^{ab}
legume portion [%]	39.8^{c}	24.1^{d}	61.3^{ab}	49.1^{ac}	65.9^{a}	55.5^{ab}
crude protein [%]	15.8^{b}	14.7^{b}	18.5^{a}	16.4^{ab}	18.9^{a}	18.2^{a}
energy [MJ ME kg^{-1} DM]	10.6^{a}	10.2^{b}	10.1^{b}	10.1^{b}	9.3^{c}	9.1^{c}

To evaluate whether grass legume swards are suitable for winter grazing the stock of the third growth in October and January was taken (Tab 3). The dry matter yield in October was affected by legumes as in annual harvesting. From October to January the difference between the mixtures was decreased. No more differences between mixtures were recognized. In forage quality all mixtures, except white clover with perennial ryegrass, had crude protein content losses. The same mixture had the least losses of energy from October to January. Red clover and Lucerne mixtures had high energy losses. Especially, mixtures with Lucerne had the significantly lowest energy contents, lower than 10 MJ ME kg^{-1} DM.

Tab. 3: Yield and forage quality parameters in grazing the third growth in October and January.

seed mixture	WC PR	WC TF	RC PR	RC TF	LC PR	LC TF
yield Oct. [t ha^{-1}]	23.0^{b*}	27.1^{b}	47.2^{ab}	52.8^{a}	65.7^{a}	72.8^{a}
yield Jan. [t ha^{-1}]	20.2^{a}	17.7^{a}	18.8^{a}	35.5^{a}	32.4^{a}	31.4^{a}
crude protein Oct. [%]	24.8^{c}	18.9^{d}	31.5^{a}	27.7^{b}	33.1^{a}	32.8^{a}
crude protein Jan. [%]	27.8^{a}	13.7^{c}	26.3^{a}	17.9^{bc}	23.6^{ab}	20.9^{b}
energy Oct. [MJ ME kg^{-1} DM]	16.5^{a}	15.9^{b}	16.2^{ab}	15.1^{c}	15.2^{c}	15.0^{c}
energy Jan. [MJ ME kg^{-1} DM]	15.8^{a}	12.6^{b}	12.1^{b}	12.0^{b}	9.1^{c}	9.0^{c}

Tab. 4: Nitrate leaching and spring wheat yield after different defoliation systems on perennial ryegrass red clover mixture.

defoliation system	Harvest	Mulch	Grazing in Oct.	Grazing in Dec.	Grazing in Jan.
leaching [kg NO_3^--N ha^{-1}]	12.2^{a*}	20.6^{a}	30.8^{a}	9.1^{a}	14.5^{a}
spring wheat yield [t ha^{-1}]	3.7^{a}	3.5^{ab}	3.0^{b}	3.4^{ab}	3.8^{a}

* Means within the same column allowed by the same letters are not significantly different at 0.05 level of probability.

Under perennial ryegrass red clover mixtures differences in nitrate leaching under different defoliation systems was not statistical affected, but under mulching system and early grazing high losses were measured (Tab. 4). At the same time, after ploughing the sward, early grazing leaded to lower spring wheat yield than after the harvesting and the January grazing systems.

Discussion

In silage use systems, red clover and Lucerne had advantages against white clover; however lucerne mixtures had extreme large energy losses over winter. They are not able to support cattle or sheep in the late winter time (GfE, 2001). Tall fescue was detrimental to harvesting systems. In winter it was without any advantages compared to perennial ryegrass.

In northern Germany, the mixture perennial ryegrass with red clover is widespread. That's why influence of defoliation system on nitrate leaching and spring wheat yield is only shown after this mixture. The high nitrogen losses between 20 and 30 kg ha^{-1} under mulching and early pasture cause low wheat yields in next year. Later pastures prevent nitrogen losses and increase wheat yield.

Conclusions

Mixed systems with harvesting and winter pasture should prefer grass legume mixtures with perennial ryegrass and red clover. This mixture provides a high yield in summer and low material losses in winter.

Compared to cutting and grazing, mulching systems are without advantages and induce high costs. For arable farms it would be better to replace legume grass yield with organic fertilizers from a neighboured cattle farm.

Winter grazing on arable land is an alternative to grazing on wet permanent grassland, but cattle should come to arable land as late as possible without damaging permanent grassland, so nitrogen losses can be minimised and spring wheat yield is not decreased by a winter pasture in January.

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Nitrogen balances in Dutch organic greenhouse production

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Key words: greenhouse, modelling, nitrogen balance.

Abstract

The organic greenhouse production in the Netherlands is limited with regard to the number of growers, but plays an important role in EU organic greenhouse production. In the high-technology greenhouses a high production level is realized but nitrogen balances of this production system have been questioned. In order to document and improve the nitrogen balance, the production of seven greenhouses was monitored and soils were repeatedly analysed. The model "Bemestingsrichtlijn biologische kasteelten" (Fertilization Guide Organic Greenhouse Production) has been developed to simulate nitrogen availability and to fine-tune manure applications to crop demand. In the course of four years the overall nitrogen surpluses decreased sharply, but due to the observational character of the research no statistical analyses can be made. Part of the high surpluses in the first years can be explained by initial investments in soil organic matter. Calculation of the dynamic balance gives more possibilities to fine-tune farmers' fertilization strategies. Growers that followed the model-based advise for manure application, realized a substantial reduction of nitrogen surpluses.

Introduction

Although limited in number of growers, the Dutch organic greenhouse production is an important factor in Dutch and EU greenhouse production. Part of it is performed at a high technology level, resulting in correspondingly high nitrogen inputs and high production. The nitrogen balances of these production systems are undocumented so far. In a four-year monitoring project, the organic greenhouse production and fertilizer strategies of seven greenhouses were followed. During the project, a model was developed, tested and applied, aimed at the reduction of nutrient surpluses (nitrogen, phosphorus and potassium) of this production system. In the following text we focus on nitrogen only.

Materials and methods

Seven Dutch organic growers with intensive year-round cultivation of greenhouse crops participated in this monitoring project. From each greenhouse, one compartment was monitored from 2002–2005. During this period sweet pepper was cultivated most (43%) followed by tomatoes (39%) and cucumbers (18%). Total fresh- and dry mass of fruits, leaves and stems was determined throughout the growing period for each crop. Dry matter samples were analysed for nitrogen content. The total uptake of nitrogen for each crop was calculated. All compost, manure and additional organic

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fertilizer applications were registered, and total and mineral nitrogen contents were analysed if unknown. Additional organic fertilizers were applied as side dressings (e.g. feathermeal pellets or beet vinasse) during the growing season. During the growing seasons, soil mineral N was measured at approximately one-month intervals (8-11 measurements per year). Additionally, in 2004 (two growers) and 2005 (seven growers) a compartment of each greenhouses was divided in two parts with different fertilization strategies, one receiving fertilizers according to the current growers' practice, the other receiving fertilizers according to the outcome of the model calculation. Data were analysed in two ways:

1. Calculation of the input-output balance, defined as the difference between total N-input (N-contents of organic fertilizers) and total N-output (N-contents of harvested products and above-ground crop residues).

2. Calculation of the dynamic balance, defined as the difference between total mineral nitrogen, becoming available during the growing season (including N-mineralization of soil organic matter, organic fertilizers and above-ground crop residues), and total N-uptake by crops (including harvested products and above-ground crop residues). Available nitrogen was estimated, using model calculations of the "Bemestingsrichtlijn Biologische Kasteelten" (Fertilization Guide Organic Greenhouse Production). This model has been developed to support Dutch organic greenhouse production (Voogt, 2005).

Results

For all crops, the input-output and dynamic balances for nitrogen were calculated (Cuijpers et al., 2007). There was a large variation between the growers and between years and crops (data not shown). This, together with the limited number of participants (n = 7) complicates interpretations of the results.

For further analysis of these data, the average of the input-output balance and dynamic balance of all crops within one year is given (table 1). A clear declining trend is visible in the input-output balance, but must be nuanced by two factors. First, the character of the research was observatory, not experimentally, which impedes statistical analysis. Second, nitrogen surplus might be crop-dependent and each year the 7 growers cultivated a different ratio of sweet pepper, tomato and cucumber. In the dynamic balances the variation among the growers and among the years is too big to conclude that the surplus has diminished over the years.

Tab. 1: Total nitrogen crop uptake and nitrogen surplus in both input-output balance and dynamic balance (between brackets: lowest and highest value). Data given in kg ha^{-1} , n = 7

Year	Total crop uptake	Surplus Input-output balance	Surplus Dynamic balance
2002	**763** (452/1263)	**711** (215/2667)	**274** (-47/596)
2003	**638** (371/1012)	**460** (254/747)	**448** (182/684)
2004	**781** (382/1179)	**151** (-507/681)	**213** (-236/584)
2005	**765** (584/976)	**78** (-389/898)	**173** (-61/497)

In table 2, the improvements, achieved by application of the fertilization model are shown for both input-output balance and dynamic balance. In 2005, three out of seven growers adapted their fertilization strategies completely to the model strategy. In the other greenhouses the use of the model reduced nitrogen surplus in both input-output balance and dynamic balance, with exception of one grower. In this greenhouse compartment the model-directed manure strategy seemed to show nitrogen shortage and side-dressings were applied above the recommended amount. No yield effect was recorded due to reduced nitrogen applications.

Tab. 2: Reduction of applied and available nitrogen (kg/ha) as a result of the use of the fertilization model

Grower	Reduction in N-application Input-output balance	Reduction in N-availability Dynamic balance
A (2005)	0	0
B (2005)	0	0
C (2005)	176	17
D (2005)	1079	321
E (2004)	482	298
E (2005)	104	168
G (2005)	-301	-327
N (2004)	582	349
N (2005)	0	0

Discussion

In the input-output balances the input data can be considered as reliable. However, the output data are influenced by some methodological uncertainties. Calculation of the nitrogen quantities in fruits and other plant material is based on irregular measurements during the growing season. The amount of leaves, fallen or cut during growing cycles, were partly measured, partly estimated. Crop residue dry matter was based on measurements of only five plants at the end of the cropping period, as were nitrogen contents. All these factors increase the possible variation in outcome.

The dynamic balances contain more uncertainties than the input-output balances. The mineralization of organic matter and thus the release of nitrogen is calculated according to Janssen (1984) by means of the parameter *Initial Age* (IA), which is based on the C-turnover rate. The IA of organic inputs were based on incubation tests that were carried out on 42 different organic fertilizers in 2002 and 2004. The IA of soil organic matter was calculated based on incubation tests, carried out in 2002 and 2004) (data not shown).The model setup uses soil organic matter with an IA which is (in this case) derived from incubation experiments and it uses actual and historical manure applications. An overlap exists between IA of soil and historical manure applications. This was arbitrarily corrected, as was corrected for (a) length of growing period of the crops and (b) mineralization of nitrogen from fallen or cut leaves during growth. Even given these uncertainties, the dynamic balance offers more possibilities to fine-tune farmers' fertilization strategies and to gain insight in soil processes with environmental importance, like leaching or denitrification.

The average-year results of the in-out balances (table 1) show a clear decline in nitrogen surpluses, although the results must be interpreted carefully as was stated before. The decrease can partly be explained by unusual high applications of compost (200 tons ha^{-1} or more) and manure at the beginning of this 4-year period, motivated by the growers as an investment in soil organic matter. This is supported by a measured increase of soil organic matter (data not given). Such an application is done only once or twice, and will result in a long-term effect of increased nitrogen release out of soil organic matter. This will diminish the need for manure application in the following years. Modelling the soil organic matter dynamics with the NDICEA model (Van der Burgt et al., 2006) indicates that a yearly application of 50 tons ha^{-1} of compost will maintain soil organic matter in a range around 6%, a level which is considered to be sufficient. Interpreting the data, it should be taken into account that N-losses by denitrification, or by leaching were not part of the balance calculations. For situations with significant over-irrigation it could have the effect that the soil mineral N is reduced, both by higher denitrification rates and N leaching, stimulating the growers to additional side dressings.

Conclusions

Although observational data are not statistically analysed, the sharp decline in nitrogen surplus in the input-output balance is convincing and can be explained. The high nitrogen input in the first years is not lost; it is part of the build-up of soil organic matter.

The dynamic balance is a much more interesting instrument for analysing nitrogen balances than the input-output balance, even knowing the uncertainties linked to the dynamic balance and the more complicated way to construct it. Together with a (still to be validated) model, this can be a promising decision-support instrument for greenhouse growers to meet future challenges in further improvements of nitrogen balances.

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Mineral nitrogen in the course of a cash crop and two livestock rotations - first results from the long-term monitoring Trenthorst

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Key words: crop rotation, mineral nitrogen, production system, long-term monitoring

Abstract

The long-term monitoring Trenthorst, situated near Lübeck in a temperate maritime climate on loamy soils, was established in 2003 and compares two cash crop and three livestock farming systems. We studied the soil mineral nitrogen contents of one cash crop and two livestock farms, specialised in dairy cows and goats/oilseeds resp., with the hypothesis that the livestock farms show a more even course of Nmin in the rotation and a higher rotation mean. The rotation average of Nmin in the cash crop farm was not lower than the ones in the livestock farms. But in the course of the rotations differences became evident: compared to the livestock farms the cash crop farm showed higher Nmin-values after the first rotation year (mulched vs. cut grass clover) but lower values in the fourth and fifth year of the rotation. As a precise nitrogen supply via manure as in the livestock farms is impossible in a self-sustaining cash crop farm, the excess of nitrogen at the beginning and the lack of it towards the end of the rotation could not be balanced. A way to improve this might be the use of green manure crops for biogas production and the application of the residues as manure. But as no full rotation period has yet passed, a longer study period is necessary to confirm the results.

Introduction

The long-term monitoring Trenthorst was established in 2003 and comprises the six-year crop rotations of two cash crop and three livestock farms, specialised in dairy cows, pigs and goats and oilseeds respectively. Central aims of the experiment are 1) the comparison of a wide range of organic farming systems under practical farming conditions (in contrast to field experiments) with respect to the development of soil nutrient contents, plant- and grain nutrient contents, yields and biodiversity 2) the analysis of nutrient cycles in different farming systems 3) the comparison of different preceding crops, respectively, rotation positions of winter wheat and winter rape. To ensure sufficient options for a comparison of the farming systems, most crops are included in more than one rotation, and the first crops and the last crops in three rotations are identical. Two farms do not have a fixed crop rotation and as no full rotation period has passed yet, they are not included in this paper. To compare the nitrogen supply in the three remaining crop rotations (one cash crop and two livestock) we analysed the development of the soil mineral nitrogen content (Nmin) at the beginning of the growing season, as this is the parameter in the nitrogen cycle most directly related to yields and grain quality. We hypothesized that 1) the livestock farms show a more even course of Nmin contents in the rotation and a higher rotation average 2) winter wheat has a better nitrogen supply in the dairy cow than in the cash

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crop farm and 3) this leads to higher winter wheat yields and grain nitrogen contents in the dairy cow farm.

Materials and methods

The experimental farm Trenthorst is situated near Lübeck (53°46' N, 10°31' E) in a temperate maritime climate (Ø annual precipitation 739 mm, Ø annual temperature 8.8 °C) on loamy soils. The agricultural area of 480 ha is divided into five independent farms. Details of the three farms with an established stable crop rotation are given in table 1. The soil properties on these three farms are similar, although the fields of the goat farm tend to be less homogenous and to have heavier soils than the other two farms. Schaub et al. (2007) give a detailed description of the site conditions and study setup. In the cash crop farm, grass clover is mulched three times per year and the straw mostly incorporated into the soil. The livestock farms harvest grass clover and straw for forage, respectively bedding, and use only the manure of their own livestock. Nitrogen is transferred from grassland to the crop rotation via manure.

On each arable field, four or eight representative monitoring points were established, where all parameters have been measured annually since 2003. The results from these monitoring points are regarded as replications, as each farm consists of six arable fields and each crop is grown only once per farm and year. Data were analysed by univariate ANOVA and Tukey-HSD-test in SAS 9.1 (SAS Institute 2003). The Brown-Forsythe-test was used to test for homoscedasticity and Welchs ANOVA was used where necessary.

Soil samples were taken in three depths (0-30 cm, 30-60 cm and 60-90 cm) each year, before the start of the growing season in February or March, and the nitrate and ammonium content were determined.

Tab. 1: Crop rotation, area and livestock of three farms in the long-term monitoring Trenthorst

Farm	Arable/ grass-land [ha]	Stocking rate [LU*ha^{-1}]	Live-stock	Position in crop rotation / = mixed crop * = grass clover undersown					
				1	2	3	4	5	6
Cash crop	31/-	-	-	Grass clover[2]	Winter wheat	Oat	Pea	Winter rape	Triti-cale*[3]
Dairy cows	64/39	0.97	80 cows + calves	Grass clover	Grass clover	Winter wheat	Oat/ Field bean	Pea/ Barley	Triti-cale*
Goats	60/50	0.19	50 goats + lambs + young cattle[1]	Grass clover	Winter rape	Pea/ False flax	Winter wheat[4]	Lin-seed	Triti-cale*[3]

[1] = replacement animals of dairy cow farm [2] = White clover in 2005 [3]=Spelt wheat in 2003 and 2004 [4]=Summer wheat in 2003 and 2005

Results

Averaged over the years 2003 to 2006, only two differences in the course of the N_{min}-contents in the three crop rotations were noted: the cash crop farm had a higher N_{min}-

content than the goat farm in the second year of the rotation and a lower value than the dairy cow farm in the fifth year of the rotation. Nevertheless the course of the N_{min}-contents resembled the pattern that can be observed when one considers only the years after 2004 (Figure 1). From 2004 to 2005 the manure management on the dairy cows farm changed considerably: the cows, which until then had been kept as suckler cows, moved into the new cubicle house and were milked, the cows no longer had access to pasture and instead of solid manure slurry was produced. Averaged over the years after 2004, the cash crop farm had significantly higher N_{min}-values than the livestock farms in the second year of the rotation (after grass clover). In the third rotation year the three farms were on the same level, but in the fourth and fifth rotation year the cash crop farm showed significantly lower values than the dairy cow farm. In the last year of the rotation the N_{min}-contents of the dairy cow farm decreased to the level of the cash crop farm. Averaged over the entire rotation and the years 2005 to 2006, the N_{min}-contents of the three farms did not differ.

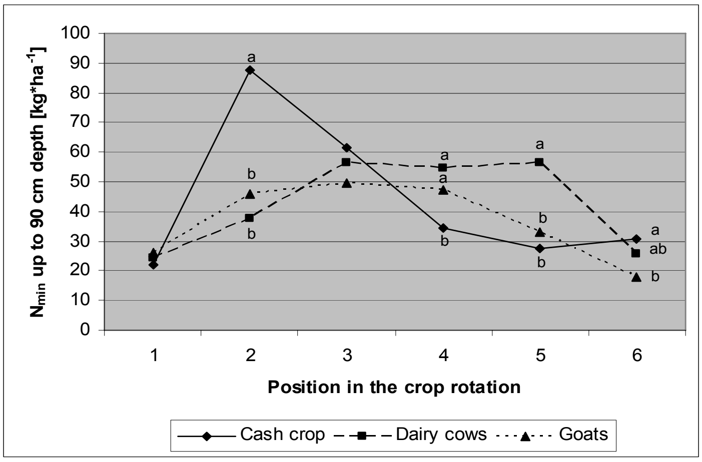

Figure 1: N_{min} in the course of three crop rotations in the long-term monitoring Trenthorst, means of the years 2005 and 2006 (different letters within position: significant difference (p=0,05))

The N_{min}-contents under winter wheat were significantly higher in the cash crop farm than in the dairy cow farm in the years 2004 and 2006 and averaged over the years 2003 to 2006. Nevertheless this higher N_{min}-value did not result in higher yields or grain protein contents: in 2005 and 2006 the winter wheat yields on the cash crop farm were numerically higher than on the dairy cow farm, but on average the dairy cow farm had a higher winter wheat yield. The wheat grain nitrogen content on the cash crop farm was numerically higher than on the dairy cow farm, but only in 2005 this difference was significant.

Discussion

Since only four years of the six-year rotation period can be analysed up to now and major changes in the dairy cow farm management took place after the first two study years, a longer study period is necessary to verify the findings.

The comparatively smooth course of the N_{min}-contents in the livestock farms can be explained by the harvesting of the grass clover as forage. This removes nitrogen and prevents a nitrogen accumulation as in the cash crop farm where grass clover is mulched (Loges et al. 2000). The distribution of farmyard manure leads to a more even nitrogen supply during the rotation. As this is not possible in a self-sustaining cash crop farm, the N_{min}-contents decrease earlier than in a livestock farm, although they are higher after the first year of the rotation. This high N_{min}-content after grass clover implicates an increased risk of nitrate leaching, especially on sandy soils. The use of clover grass for biogas production could remove the excess nitrogen and provide a cash crop farm with "transportable" nitrogen to fertilize crops at the end of the rotation. Stinner et al. (2005) reported a 10 % reduction of the average N_{min}-contents in the rotation and thus a decreased leaching risk when grass clover and intercrops were used for biogas production instead of being mulched.

The similar rotation average of N_{min} in the cash crop and the dairy cow farm is in accordance with findings of Schmidt et al. (2006), who reported a similar N availability in a stockless mulch and a livestock rotation. In contrast Entz et al. (2005) found higher available N in a grain-forage rotation compared to a green manure rotation. This might be due to the higher proportion of forage crops (50 % vs. 33 % in Trenthorst) in the rotation.

The higher N_{min}-contents under winter wheat in the cash crop farm in comparison to the dairy cow farm are somewhat surprising. The second year of grass clover apparently cannot compensate for the nitrogen removal via forage in contrast to the mulching of grass clover.

Conclusions

In comparison with the livestock farms, the cash crop farm showed higher N_{min}-values after the first rotation year (mulched vs. cut grass clover), but lower values in the fourth and fifth year of the rotation. The rotation averages of N_{min} were similar in the cash crop and the dairy cow farm. As no full rotation period has yet passed, a longer study period is necessary to confirm the results.

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Autumn sown catch crop understoreys as strategy to reduce nitrate leaching in winter cereals

Loges, R., Mauscherning, I., & Taube, F.[1]

Key words: intercropping, catch crops, winter cereals, nitrate leaching

Abstract

Under conditions with wet mild winters due to high nitrate leaching risk growing systems with high nitrogen (N) uptake efficiency in autumn are necessary, especially after pre crops with a high N release. In 2003 and 2004 a field trial was conducted in Northern Germany to investigate autumn N uptake and nitrate leaching in autumn sown winter wheat (Triticum aestivum L.) and winter oilseed rape (Brassica napus) grown intercropped with catch crops. Catch crops in pure stands were sown as control. In each system three catch crops common vetch (Vicia sativa), forage rape (Brassica napus) and oats (Avena sativa) were tested simultaneously. The experiment was run parallel after grass clover (high N status) and oats (low N status). N uptake, soil mineral nitrogen (N_{min}) and nitrate leaching of all stands were determined. Especially with winter wheat intercropping with catch crops increased N-uptake in autumn. In all stands forage rape and oats led to a higher N uptake than common vetch. In comparison to pure sown winter wheat, intercropping reduced N_{min} by more than 30 %. Nitrate leaching was highest after grass clover. Averaged over both pre crops intercropping of winter wheat and catch crops led to a reduction of nitrate leaching in a range of 38 to 60 %. Grown as intercrop to winter oilseed rape forage rape and oats decreased nitrate leaching compared to pure sown rape by 50 and 39 %, respectively. If cultivation of winter wheat after N intensive pre cop in winter mild climates is wanted, an intercropped production system with catch crops is a mean to reduce N leaching risks. Further investigations are necessary to clarify on yield performance of the main crops when growing together with catch crops.

Introduction

In organic farming winter wheat and winter oilseed rape is typically grown after good pre-crops such as grass clover as it pays well in terms of yield and quality. Especially under climatic conditions with wet mild winters much nitrate may be lost by leaching before spring, because winter cereals develop slowly and their N-uptake is smaller than the N amount mineralized from incorporated pre-crop residues. The benefit of catch crops in pure stand to reduce the soil content of mineral N and nitrate leaching over winter is documented by many studies (Meisinger et al. 1991, McLenaghen 1996, Francis et al. 1998, Justes et al. 1999, Aronsson 2000). Autumn sown catch crops grown as understorey to winter wheat could improve N-uptake of winter cereals and therefore lower the risk of unproductive N-leaching. After freezing off or incorporation between the main crop rows N release from catch crops residues could improve N availability for the cereal crop. Therefore catch crops were cultivated together with winter wheat and winter oilseed rape, respectively, in an intercropped growing system

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and compared to pure sown wheat and rape as well as to classic overwintering pure stand catch crops grown before a spring crop. The hypotheses of the investigation are that because of the temporal N retention by the accompanying catch crops over winter less nitrate losses occur and both environmental and nutritional effects of the overwintering main crops will be improved.

Materials and methods

Field experiments were carried out in Northern Germany (53° 40´ N; 10° 35´ E) at the organic managed experimental farm Lindhof (Kiel university) in 2003/04 and 2004/05 in a split plot design with three replicates. The site is characterised by Luvisols and Cambisols as soil types, a mean annual air temperature of 8,7°C and a mean annual precipitation of 774 mm. Winter wheat (*Triticum aestivum*) and winter oilseed rape (*Brassica napus*) were grown intercropped with catch crops with the aim to improve autumn N uptake and to avoid unproductive nitrate leaching. Pure sown wheat and oilseed rape as well as pure stands of catch crops were sown as control (Table 1). In each system three catch crops common vetch (*Vicia sativa*), forage rape (*Brassica napus*) and oats (*Avena sativa*) were established at the end of August, 2003 and 2004, respectively. The pure stands catch crops were sown at a row distance of 12 cm, while in the intercropped treatments a wide row spacing of 36 cm was chosen. Between the wider rows in half of the plots winter rape was sown at the same time, while in the remaining plots winter wheat was established five weeks later at the beginning of October. To analyse the influence of the soil N status the experiment was run simultaneously after two different preceding crops grass clover (high N status) and oats (low N status).

Total plant N uptake (shoot and roots), soil mineral nitrogen (N_{min}) in spring and autumn as well as nitrate leaching of all stands was measured. Leaching of nitrate was determined with ceramic suction cups. Leachate was sampled weekly between mid of November and mid of March during both winters and analyzed for NO_3 concentrations. The volume of leaching water was calculated by a general water balance model. Statistical analyses were carried out with the procedure Mixed of the SAS® Software (Vers. 9 SAS Institute 2001). Multiple comparisons of means were performed using the T-test with correction according to Bonferroni-Holm.

Tab. 1: Factors and factor levels of the field experiment

Factor	Factor level
1. Preceding crop	1.1 Three times mulched grass clover 1.2 Oats
2. Main crop	2.1 Winter wheat 2.2 Winter oilseed rape 2.3 Spring wheat
3. Catch crop	3.1 Without catch crop 3.2 Common vetch 3.3 Forage rape 3.4 Oats
4. Replications	3

Results

Catch crops in the intercropped system realised a comparable N-uptake to pure sown catch crops and were especially beneficial in combination with winter wheat, because of low biomass productivity of winter wheat (Tab. 1). The catch crops forage rape and oats showed a higher N uptake capacity than common vetch. Catch crops were able to reduce N_{min} in autumn by 32-45 % compared to the pure sown winter wheat. Averaged over the two main crops all catch crops showed higher soil N_{min} contents in autumn than in spring. Differences reached from 11.5 to 30.2 kg ha^{-1} and indicate nitrogen losses over winter. The differences were highest after the pure stands of winter wheat and oilseed rape, followed by the treatments common vetch. Pure sown winter wheat showed higher leaching losses than intercropped wheat. Averaged over both pre crops intercropping of catch crops and winter wheat led to a reduction of nitrate leaching in a range of 38 to 60 %. In each of the three systems forage rape and oats used as catch crops showed the highest reduction of nitrate leaching.

Tab. 2: Impact of main crop and catch crop on plant-N-uptake, soil mineral N in autumn and spring and on leached nitrate-N over winter
(averaged over 2 experimental years and 2 pre-crops)

Main crop	Catch crop	Plant-N-Uptake in Autumn- (kg N ha^{-1})	Autumn-Nmin (kg N ha^{-1})	Spring-Nmin (kg N ha^{-1})	Nitrate-N leached over winter (kg N ha^{-1})
Winter wheat	Without	28.1 c*	76.0 a	45.8 a	87.7 a
Winter wheat	Common vetch	66.5 b	51.8 b	34.7 ab	54.3 b
Winter wheat	Forage rape	92.4 ab	42.1 b	32.2 ab	45.8 bc
Winter wheat	Oats	88.9 ab	51.1 b	39.1 ab	35.0 c
Winter rape	Without	64.0 b	55.4 b	30.4 b	57.6 b
Winter rape	Common vetch	72.1 b	48.5 b	28.7 b	57.0 b
Winter rape	Forage rape	93.1 ab	38.8 b	25.8 b	28.6 c
Winter rape	Oats	112.0 a	37.2 b	23.2 b	35.0 c
Spring wheat	Without	79.2 b	46.1 b	31.4 ab	38.1 bc
Spring wheat	Common vetch	57.8 b	45.8 b	29.5 b	41.8 bc
Spring wheat	Forage rape	78.2 b	37.6 b	27.1 b	27.6 c
Spring wheat	Oats	75.1 b	35.2 b	23.7 b	28.7 c

*) same letters in one column are not significantly different P≤0.05

Tab. 3: Impact of pre crop on plant-N-uptake, soil mineral N in autumn and spring and on leached nitrate-N over winter
(averaged over 2 experimental years, 4 catch crops and 3 main crops)

pre crop	Plant-N-Uptake in Autumn- (kg N ha^{-1})	Autumn-Nmin (kg N ha^{-1})	Spring-Nmin (kg N ha^{-1})	Nitrate-N leached over winter (kg N ha^{-1})
Grass clover	89.1 a*	60.1 a	39.8 a	64.4 a
Oats	61.0 b	34.2 b	38.2 a	25.1 b

*) same letters in one column are not significantly different P≤0.05

Comparing the effects of the pre crop (Tab. 3.) plant-N-uptake and soil N_{min} in autumn was higher after grass clover confirming the hypothesed higher autumn N-release from incorporated crop residues. While after grass clover losses of soil N_{min} over winter occurred, net mineralization after oats led to higher spring compared to autumn N_{min}-values. On average over all treatments after grass clover much higher nitrate-N-leaching losses were determined compared to oats as pre crop.

Discussion

The in literature well described ability of catch crops to reduce nitrate leaching losses over winter is confirmed even when catch crops are sown late in northern latitudes with a time limited vegetation period. The before this study in literature less often discussed hypotheses that accompanying catch crops increase N-uptake and therefore decrease nitrate leaching losses in winter cereals could be verified. The investigation highlights again the high risk of nitrogen leaching losses growing winter wheat after good pre crops in winter mild climates. As due to economic reasons this is quite typical for organic wheat production, all measures have to be taken into account to guarantee an in all aspects environmental friendly production system. Intercropping winter cereals with autumn sown catch crops is a mean to reduce N leaching risks. Due to concurrence between catch crop and main crop with respect to other growing factors, further investigations are necessary to clarify on yield performance of the proposed growing system (Mauscherning 2008).

Conclusions

Growing catch crops is a mean to avoid unnecessary environmental risky leaching losses of the important growing factor nitrogen also under winter mild conditions in northern latitudes with a time limited vegetation period. If due to economic reasons in these climates cultivation of winter wheat after N intensive pre crops is wanted, an intercropped production system with catch crops as understorey is a mean to reduce N leaching risks. Further investigations are necessary to optimise yield performance and quality of the main crops when growing together with catch crops.

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Plant nutrition

Agronomic options for the management of phosphorus in Australian rain-fed organic broadacre farming systems

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Key words: phosphorus, manures, composts, P-efficiency, organic matter

Abstract

The paper is an overview of strategies for agronomic management of P in organic broad-acre farming systems within the Australian rain-fed cereal/livestock belt. It concludes that to raise and maintain adequate plant-available P in these systems the importation of organic manures or composts from off-farm will be required, although the immediate issue may be access to economically viable sources. Improving the P-use efficiency of the system by incorporating species into rotation or intercropping systems that are able to access P from less soluble sources has been a successful strategy elsewhere in the world and deserves further research effort in Australia. Agronomic management to maximise quantity and quality of pasture and crop plant residues undoubtedly builds labile soil organic matter and facilitates P cycling, but the strategy may be of limited benefit in low rainfall areas that do not have the capacity to produce large plant biomass inputs. Progress in selection and breeding for cereal genotypes that are more P-efficient and other plant genotypes that can access less labile P sources is gaining momentum but still remains a long term prospect.

Introduction

There has been relatively little reported research in Australia into the agronomic management and nutritional aspects of broadacre organic farming systems although there is far more information published for organic cropping systems in other parts of the world, such as Europe and Canada. Overall, the work has highlighted that, in common with other low-input systems, the maintenance of plant-available P is a major limitation. The problem is particularly extreme in stockless systems without access to manure and in mixed farming systems practiced on inherently infertile soils, as is the case for much of Australia (Penfold 2000).

In this paper, three broad strategies for agronomic management of P in Australian broadacre organic farming systems are considered. These strategies include (i) potential approaches for maximising the P use-efficiency of crops and pasture species in the system, (ii) practices for increasing soil P cycling to facilitate release and synchronous uptake of plant-available P, and (iii) import of allowable inputs that contain P.

Climate and soils of Australian rainfed broadacre agriculture

A key feature of Australian farming systems is the nature of the rainfall, in particular the low annual averages, high variability, and long dry or wet periods. Also, there is a wide range of soil types. Australian soils in the cereal/livestock belt are inherently low

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in soil organic matter (range 0.5 – 2%), as determined by the fixed factors of climate, depth, stoniness, mineralogy and texture. Australia, with some of the oldest, most weathered soils of the world, generally has soil P levels which are low by world standards. The total P content of Australian soils on average is 0.03%, compared with 0.04 - 0.10% for American soils and 0.05% for English soils.

Options for maximising P use-efficiency by crops/pastures

Utilisation of species or genotypes with high DM productivity or/grain yield per unit of P uptake

P use-efficiency by crops or pastures in simple terms can be defined as the amount of shoot biomass per unit of P present in the plant. It represents the integration of plant P uptake from soil and P translocation within the plant, processes that are both extremely complex.

The P efficiency ratio, expressed in terms of grain yield per unit of P in the plant shoot, attempts to describe the utilisation of P that a plant extracts from soil and fertiliser sources to produce grain. P efficiency ratios reported for field grown plants in dryland farming systems vary widely from 250 to 565 kg grain/kg P in shoots (Batten 1992). There is a growing consensus that sufficient genotypic variation of P efficiency within cereals exists to warrant breeding efforts. Indeed, a comprehensive Australian study that screened over 100 cereal genotypes demonstrated a wide variation in soluble P uptake efficiency (Osborne and Rengel 2002b) as well as in the capacity to use less soluble forms of P such as phytate and iron phosphate. Rye and triticale appeared more efficient than wheat at taking up and utilising P at low rates of P supply, and in being able to access less soluble forms of P.

There are reasons for seeking genotypes that achieve high yields of grain with low concentrations of P such as the negative association between loaf volume and high grain P and the positive correlation between low grain P and lower concentrations of the anti-nutritional factor phytic acid (Batten 1992). Nevertheless, high grain P may be an advantage for organic crops if seed is going to be kept for sowing on-farm, a factor which needs to be considered in overall management of P in the farming system. High seed P (up to 0.37% for wheat and 0.79% for annual Medicago spp.) has been associated positively in Western Australia with seedling vigour and significantly higher final dry matter production, both in the presence and absence of P fertiliser application, and also with higher wheat and lupin yields.

Increase the capacity for P cycling and release of available P

An approach consistent with the ethos of organic farming is to use agronomic strategies that increase soil organic matter, such as retention of crop residues and longer phases of pastures, and thus increase soil organic P. Without significant external inputs however, raising soil organic matter levels can be a very slow process especially in a semi-arid climate, as demonstrated from some farming systems research in South Australia where after eight years there was no significant increase in soil organic carbon under organic or biodynamic practices (Penfold and Miyan 1998), although paradoxically organic carbon did increase in the conventionally farmed treatment. Low plant-available P in farming systems may impact on N contribution from legumes in that if P is restricted then N fixation may also be reduced (Nguluu 1993) and residues will be reduced in P. It is therefore critical to a sustainable organic crop/pasture system in Australia to provide the legume phase with adequate P to generate the N to support the cereal phase of the rotation. There remains further scope for incorporating into the rotation crop species that are known to excrete P solubilising compounds including lupin, pigeonpea, chickpea, lucerne, white clover and cocksfoot (Li et al. 1997).

Import allowable and economically viable P inputs

Within the required standards for organic production in Australia there are mineral and organic options for P fertilisers. Reactive phosphate rock (RPR) and phosphate rock (PR) are allowable mineral P inputs to organic systems, but their value has been reported as limited (Ryan et al. 2004).

A more valuable P source is likely to be manures and composts. Recent changes in pig production systems from intensive shed to deep litter systems with pigs running on straw has increased the availability of pig manure for broad-acre application. Considerable expansion of the chicken meat industry, where the birds again live on straw or rice hulls, is further assisting in providing manures available for composting and use in organic production systems. On present estimates, there is enough manure generated from these systems in Australia to provide the phosphorus replacement requirements for over 1 million hectares of cropping land.

Transport costs associated with the movement of fertiliser products of low nutrient percentages (relative to chemical fertilisers) has traditionally been an impediment to their widespread use. However, recent increases in chemical fertiliser prices now show the nutrients contained in composts and manures to be relatively undervalued. With consideration for this discrepancy, calculations suggest chicken litter compost could be transported up to 300 kilometres and still equate with a similar amount of synthetic fertiliser delivered to the same distance. The efficiency of nutrient transport may be further enhanced by fortification of the compost with rock phosphate to produce phospho-compost - a process which is likely to also enhance the value of PR by increasing phosphorous availability following soil application (Pareek et al. 2004). Phospho-composting utilises the organic acids and humic substances produced by the bacteria and fungi in a compost pile to release P from PR, and a consequent chelating function performed on calcium, iron and aluminium (Zapata and Roy 2004).

Anaerobic Digestion – Energy from Compost

Within manures is embodied a considerable amount of energy in the form of C bonds which would normally become greenhouse gas. Using anaerobic digestion, methane is produced which can be used within the animal production unit for heating or fuel for transport or power generation. The residue from the anaerobic digestion can be used as a fertiliser, as it remains rich in N and P. One study in Germany applied fresh manures, composted manures, digested manures and N amended digested manures to crops in an 8 year rotation (Möller et al. 2006) and concluded there were no negative effects on nutrient availability following anaerobic digestion.

Pyrolysis has been proposed as an alternative to anaerobic digestion for energy and nutrient extraction from manures. The principle energy product generated by pyrolysis is oil and the sludge nutrients are recovered in the char. A study using sludge from a pilot plant in Western Australia confirmed the P was plant available but found the N was insoluble (Bridle and Pritchard 2004).

Conclusions

Without some radical changes in approaches to P management, sustainable broad-acre organic cropping in Australia is likely to remain constrained to areas with relatively high rainfall and soil P fertility. For those farms where soil P levels are low, the importation of P as manures or composts may be a feasible option to produce crops and pastures not constrained by P deficiency. Amending the imported products with additional rock phosphate could further enhance their viability. As energy and greenhouse gas pollutants becoming increasingly important issues, the capturing of these products via digestion or pyrolysis may ultimately become critical. In the meantime, work must continue towards increasing the P use efficiency of plants and enhancing soil biological health by using perennials and rotations to maximise P cycling.

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Comparison of effect of zinc-enriched pod of Phaseolus vulgaris and inner rice husk composts with zinc sulphate and zinc 14% chelate on zinc availability in maize plant in a calcareous soil

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Key words: Zinc-enriched compost, zinc sulphate, zinc chelate, maize, calcareous soil

Abstract

Mixtures of Zn salts and organic matter have been used successfully in controlling zinc deficiency in various crops. The aim of the present study was to optimize the effectiveness, on zinc availability in maize, of natural organic substances by enriching them with zinc sulfate. For this purpose pod of Phaseolus vulgaris and inner rice husk, as abundant organic wastes in the north of Iran, were incubated with increasing quantities of zinc sulphate. The effect of these zinc-enriched composts, zinc sulphate, and zinc 14% chelate on zinc availability in maize in a calcareous soil was studied in a greenhouse experiment. DTPA-extractable zinc of the soil, total zinc concentration, and chlorophyll of plant leaves were measured. Soil applications of all treatments, especially zinc-enriched composts, increased DTPA-extractable zinc more than control treatment, but this increase is not significant for zinc chelate. The plant analysis indicated that zinc-enriched composts of both organic matters significantly increased total zinc concentration in plant leaves more than control treatment, and their effects increased by increasing the level of enrichment until toxic level, even over that of zinc chelate. Non-enriched of both organic matters and zinc chelate had the most effect on leaf chlorophyll and significantly increased the amount of chlorophyll more than control treatment.

Introduction

Zinc deficiency is the most widespread micronutrient disorder among different crops (Westfall et al., 1971).It is more common in calcareous soils. Several organic and inorganic zinc compounds can be used to correct zinc deficiency, but crop response to zinc fertilization varies with the zinc fertilizer sources (Boawn, 1973). Several studies reported that, under greenhouse conditions, the application of nonchelated zinc fertilizers to calcareous soils is less effective than chelated forms of zinc (Hergert, et al., 1984).In comparison to inorganic zinc fertilizers, commercially available zinc chelates are 3 to 5 times as effective, but because of very high cost they are not always economically employable (James, 1992; Hergert, et al., 1984). The aim of this study was to produce two zinc-enriched composts from pod of Phaseolus vulgaris (PV) and inner rice husk (RH) by enriching them with zinc sulphate, then comparing the effect with zinc 14% chelate (Zn-EDTA) on zinc availability in maize (Zea mays L.) in calcareous soil in a greenhouse experiment. These organic matters seem to be especially favourable, because they are abundant in the north of Iran. The pod of

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Phaseolus vulgaris contain many active proteins, and rice husk has a large amount of lignin and cellulose and becomes particularly enriched with carboxyl and hydroxyl groups during decomposition (Bergmann, 1983), which might be able to form organic zinc complexes via chelatization.

Materials and methods

Pod of Phaseolus vulgaris (1000g) and inner rice husk (2000g) were incubated with increasing amounts (0, 1.36, 2.72 and 4.08 % weight) of net zinc as zinc sulphate source (or 0, 4, 8, and 12 % weight from zinc sulphate 34%) in three replications. The incubation was carried out during 80 days for Phaseolus vulgaris and 160 days for rice husk in a greenhouse at constant temperature (30ºC) and enough moisture (moisture > 60%). After the end of incubation, composts were dried (at 65ºC) and weighed. Organic carbon (Walky-black), Total N (Kjeldahl), and total zinc (dry ashing and HCL 2N) were measured (Table 1 and Table 2).

Tab. 1: Chemical analysis of pod of phaseolus vulgaris and inner rice husk

	O.C (%)	T.N (%)	C/N	Total Zinc(ppm)
Pod of Phaseolus vulgaris	69	1.151	59.94	40
Inner rice husk	77.14	1.163	64.32	30

Tab. 2: Chemical properties of produced composts

Composts	Weight loss (%)	O.C (%)	T.N (%)	C/N	Total zinc (%)
Pod of Phaseolus vulgaris	81.874	60.187	2.3	21.162	0.2136
PV+1.36%Zn	73.356	64.74	2.127	30.47	2.8359
PV+2.72%Zn	55.713	65.52	1.655	39.693	3.3565
PV+4.08%Zn	48.54	64.717	1.411	46.382	4.306
Inner rice husk	43.45	62	1.280	48.42	0.0985
RH+1.36% Zn	36	66.8	1.256	54.66	0.7493
RH+2.72% Zn	34.18	68.04	1.175	57.873	2.2197
RH+4.08% Zn	32.15	72.76	1.142	63.747	3.1762

This study was carried out on maize (as a susceptible plant to zinc deficiency) growing in a calcareous soil, in a greenhouse experiment in a completely randomized design with three replications. Physical and chemical properties of calcareous soil are presented in Table (3.). The amount of application of pod of Phaseolus vulgaris composts was 5g/kg soil (0.5%weight of soil), the amount of application of rice husk composts was 10g/kg soil (1% weight of soil), and the amount of application of zinc 14% chelate and $ZnSO_4$ treatment was 10 mg/kg soil of net Zn.

Tab. 3: Physical and chemical properties of the soil.

Deph cm	EC (ds/m)	pH (1:2.5)	T.N.V %	O.C %	P	K	Fe ppm	Mn	Zn	Cu	Texture
0-30	1	7.64	40	0.94	8	240	6.2	0.8	0.63	1.5	loam

Before harvesting, the leaf chlorophyll a and b and total chlorophyll concentration were estimated with a SPAD-502 meter (Minolta Co., Osaka, Japan) in fresh leaves. After 80 days, top organs of the plants were harvested and weighed. Leaves were washed with tap water and three times with distilled water, dried at 65ºC, and weighed. Total zinc and iron and manganese of leaves were measured by dry ashing and HCL 2N method and atomic adsorption spectrophotometry (Varian Spectr AA 220). In the experimental soil, DTPA-extractable zinc was determined by the method of Lindsay and Norvell (1978). These results are presented in Table 4.

Tab. 4: Effect of treatments on the averages of chlorophyll (Ch) a, chlorophyll b, chlorophyll a+b, and total zinc, iron, and manganese values of maize.

Treatment	DTPA Zn $mg.kg^{-1}$	Ch. a $mg.cm^{-2}$	Ch. b $mg.cm^{-2}$	Ch. a+b $mg.cm^{-2}$	T- Zn $mg.kg^{-1}$	T-Fe $mg.kg^{-1}$	T-Mn $mg.kg^{-1}$
F_0 (control)	0.57	0.021	0.007	0.029	35.19	28.43	76.2
F_1 ($ZnSO_4.H_2O$)	1.78**	0.027	0.008	0.036	77.22**	50.1	79.7**
PV[1](Phaseolus vulgaris)	5.71**	0.029 **	0.009	0.039**	90.6**	42.1**	77.1**
PV+1.36%Zn	12.67**	0.026	0.008	0.034	314.5**	52.4**	89.9**
PV+2.728%Zn	13.98**	0.026	0.008	0.034	392.3*	50.33 **	82.67
PV+4.08%Zn	14.48**	0.024	0.007	0.0317	532.2**	62.8**	94.3**
RH[2] (inner Rice husk)	5.89**	0.028	0.009	0.037**	99.6**	14.9**	73**
RH+1.36%Zn	12.87**	0.027	0.008	0.036	300.4**	42.8**	91.16 **
RH+2.72%Zn	13.64**	0.024	0.007	0.031	438.6**	38.5**	91.7**
RH+4.08%Zn	14.48**	0.022	0.007	0.028	550.8**	28.4**	105.4 **
Zn 14%chelate (Zn-EDTA)	0.86	0.030**	0.009 **	0.040**	141.3**	29.7**	79.4**

Results and Discussion

Results indicated (Table4) that soil application of all treatments, especially zinc-enriched composts, increased DTPA-extractable zinc more than control treatments, but this increase is not significant (α=0.01) for zinc chelate. In zinc-enriched composts of both organic matters with increasing percentage of enrichment, DTPA-extractable zinc of the soil increases. The plant analysis showed that zinc-enriched composts of both organic matters, significantly (α=0.01) increased total zinc concentration in plant leaves more than control treatments, and their effects increased by increasing levels of enrichment until toxic level, even over that of zinc chelate, just like DTPA-extractable zinc of the soil. Non-enriched composts of pod of *Phaseolus vulgaris* and rice husk and zinc chelate had the most effect on leaf chlorophyll and significantly (α=0.01) increased the amount of chlorophyll a, b, and a+b more than control treatment. However, in zinc-enriched composts of both organic matters, with increasing percentage of enrichment and increases of zinc concentration in the soil, the amount of chlorophyll decreases. Iron chlorosis symptoms appeared in these treatments. Wallace et al. (1976) reported that high amount of zinc resulted in Fe deficiency on soybean. Safaya (1976) reported a positive effect of applying zinc on Mn in plants. Mn and Fe had indicated antagonistic effect with each other too. Hewitte (1948) reported that manganese and heavy metals with similar chemical properties like iron might react with porphyrin compounds, thereby inactivating them for subsequent conversion to chlorophyll.

Conclusion

As a concluding remarks, the presented data showed that application of composts of pod of Phaseolus vulgaris and inner rice husk had same effect as zinc 14% chelate even, over than it. Zn-enriched composts treatments showed zinc toxicity. We suggest to use these products with Fe–fertilizers. Caused chlorose by rice husk compost was by rice husk compost stronger than Phaseolus compost. Contrary to zinc 14 % chelate, the compost of Phaseolus vulgaris or rice husk is not of high costs and farmers may produce it themselves.

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Nitrogen Utilization in Integrated Crop and Animal Production

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Key words: nitrogen utilization, nutrient circulation, integrated production

Abstract

The principles of organic production are based on integration between crop and animal production and self-regulated nutrient intensity. A comparison between specialized dairy and crop farm models and an integrated dairy and crop farm model showed 24 % higher total production per area and higher nitrogen utilization in the integrated system. The main factors were more efficient nutrient circulation, better utilization of legume crops and low intensity of nitrogen on non-legume crops.

Introduction

The main factors influencing nutrient utilization in agriculture are the production line (crop vs. animal production) and the degree of intensity and specialization of production. Organic production is based on integration between crop and animal production and self-regulated nutrient intensity. However, many organic farms are specialized in crop production based only on green manure and farm yard manure (FYM) from neighbouring farms. On the other hand, animal farms widely use purchased fodder. All of this may effect the utilization of nutrients, yet hardly any comparisons or analytical surveys between specialized and integrated (organic) farms can be found in literature.

The aims of this study were:
a) To model specialized organic crop and animal farms and an integrated farm
b) To identify the differences in nutrient balances and utilization between the models
c) To optimize nutrient utilization by means of integrating crop and animal production

Material and methods

A more detailed analysis was made of nitrogen (N) utilization on 9 organic farms in eastern Finland. The farmers were personally interviewed in 2004 and all the main nutrient flows were identified for the years 2002-2004. The assumption of a steady-state with balanced systems and reserve nutrients in the soil was applied. Biological N fixation (BNF) was assumed to account for 70 – 90 % of the total nitrogen content in the legume biomass (Kristensen et al. 1995, STANK 1998, Väisänen 2000). Red clover, white clover and alsike clover were grown in perennial mixture leys. Pea and annual vetch were annual legumes. (Seuri 2005).

Equal amounts of milk, beef and bread cereal were produced either on a specialized dairy farm (D) model and a specialized crop farm (C) model jointly or on an integrated dairy and crop farm (I) model. The share of fodder production was 80 % and bread cereal 20 % of the total yield, based on the average Finnish diet and use of arable land. BNF and atmospheric deposition (5 kg/ha annually) were the only external inputs of nitrogen (=primary nitrogen) in both systems. On farm C, all the harvested yield was

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sold (either to farm D as fodder or outside the system as bread cereal) and no FYM was used. On farm D, all the harvested yield was used as fodder. In addition, about 20 % of the fodder was purchased from farm C. All of the FYM was used only on farm D. On farm I, no fodder was purchased, but 20 % of total yield was sold as bread cereal.

Results

The major characteristics of the farm models are presented in Tables 1 and 2; more detailed N utilization is presented in Table 3.

Tab.1: Characteristics of three farm models: Specialized Dairy Farm (D), Specialized Crop Farm (C) and Integrated Dairy and Crop Farm (I). Both of the dairy farms (D & I) keep equal numbers of calves for replacement, all others are sold immediately after the suckling period. Replacement of the cows takes place after three milking periods.

	D	C	I
Crop rotation / (crops %)			
ley / green fallow	3 yrs. (60%)	2 yrs. (40%)	2 yrs. (40%)
cereals	2 yrs. (40%)	2 yrs. (40%)	2 yrs. (40%)
rape seed	-	1 yr. (20%)	-
cereal+peas	-	-	1 yr. (20%)
Legumes % / non-legumes %	60 / 40	40 / 60	60 / 40
Yield level (FU/ha & N kg/ha)			
ley /(green fallow)	3200 & 85	(green fallow)	3200 & 85
cereals	2200 & 42	2200 & 42	2000 & 38
rape seed	-	1800 & 42	-
cereal+peas	-	-	2000 & 52
Harvested N yield (kg/ha)	68	25	60
Animal density (AU/ha	0.71	-	0.43
Milk yield (kg/cow)	7350	-	7000

Tab. 2: Legume yields and BNF on farm models. C*, no legume yield is harvested, but ploughed in as green manure; only the first year ley exists (twice in 5-year-rotation) on farm C.

Crop	Farms D & C*	Farm I	Farms D, C & I
	Yield (FU/ha)	Yield (FU/ha)	BNF (N kg/ha)
First-year ley	3600	3400	120
Second-year ley	3200	3000	80
Third-year ley	2800	-	40
Cereal + peas	-	2000	40

The total average BNF is equal (48 kg/ha) in all the farm models. However, there is quite great variation between N intensity on non-legumes (=manure or green manure for non-legumes). The N intensity on non-legumes is highest on farm D (100 kg/ha), due to high amount of manure on a limited non-legume area (40%). Also on farm C the N intensity is higher (80 kg/ha) on non-legumes than on farm I (65 kg/ha). (Tab. 3).

Due to the lower N intensity on non-legumes, 10 % lower crop yield is assumed on farm I than on D and C (Tab. 1.).

Despite the lower yield level because of lower N intensity on non-legumes, the average total production is higher in integrated production (I) than in specialized production (D+C). More arable land, 24 %, is needed on the specialized farms than on the integrated farm to produce an equal "food basket" (milk, beef and (bread)cereal) (Tab. 3.). This is due to the green fallow on the specialized crop farm.

Tab. 3: N flows and balances in three model systems. Comparison by equal total production, I vs. D+C (sum of 0.57 ha D and 0.67 ha C equals 1 ha I); and by equal area (1 ha).

*Note: System boundaries are slightly different between EP and EA (**bolded** figures); e.g. purchased fodder in EP is not an input or output, but within system boundaries as it is purchased from farm C; in EA it is external input (farm D) and output (farm C).*

				Equal production (EP)			Equal area (EA)	
			I	D+C	D	C	D	C
	symbol	unit	(1 ha)	(1.24 ha)	(0.57 ha)	(0.67 ha)	(1 ha)	(1 ha)
Harvested N yield [1]	Y	(kg N)	60	56	39	17	68	25
N intensity on non-legumes [2]		(kg N/ha)	65	89	100	80	100	80
Deposition	p_1	(kg N)	5	6	3	3	5	5
BNF	p_2	(kg N)	48	60	28	32	48	48
Total fodder	F	(kg N)	51	47	47		82	
Fodder harvested	F_h	(kg N)	51	-	39		68	
Fodder purchased	F_p	(kg N)	-	-	**8**		**14**	
FYM (=F-A-L)	M	(kg N)	26	23	23		40	
FYM (fodder harvested)	m	(kg N)	26	-	19		33	
FYM (fodder purchased)	p_3	(kg N)	-	-	**4**		**7**	
Losses outside field [3]	L	(kg N)	13	12	12		21	
Animal products sold	A	(kg N)	12	12	12		21	
Crop products sold	C	(kg N)	9	**9**		**9 (+8)**		**25**
Primary N (= $p_1+p_2+p_3$)	P	(kg N)	53	**66**	**31**	35	**60**	53
Secondary N (=M-p_3)	S	(kg N)	26	**23**	**23**		**33**	
Circulation factor (P+S)/P		(-)	1.49	**1.35**	**1.75**	1	**1.55**	1
Farm gate balance p_1+p_2+Fp-C-A		(kg N)	32	**45**			**46**	28
output/input (C+A)/(p_1+p_2+Fp)		(-)	0.39	**0.32**			**0.32**	0.47
Field balance p_1+p_2+M-Y		(kg N)	19	**33**			**25**	28
output/input Y/(p_1+p_2+M)		(-)	0.76	**0.63**			**0.73**	0.47
PPB [4]= Y/P		(-)	1.13	**0.85**	**1.25**	0.47	**1.14**	0.47

1 See table 1.
2 FYM or green manure N for non-legumes
3 40 kg N/cow (incl. young cattle for replacement) (Grönroos et.al. 1998)
4 Primary production balance (Seuri 2005)

The nutrient balances describe the nutrient utilization, whereas comparison by area does not show any clear difference between the models. Comparison by equal total production indicates better utilization on the integrated farm than on the specialized farms jointly by all the indicator balances used (farm gate balance, field balance, PPB). The difference between primary N is 24 % (53 kg vs. 66 kg) for equal total production.

The major difference between these two production strategies is nutrient circulation. In the integrated system (I) the circulation factor of N is as high as 1.49. In the specialized system (D+C) it is clearly lower, 1.35. Another major difference is the poor field balance (0.47) in the specialized crop production compared to the field balance in the integrated system (0.76). This indicates the importance of utilization of legume yield. On farm C, no legume yield is utilized as a final output of the system, but only as a source of N for a non-legume cash crop.

Conclusions

N intensity is highly dependent on the proportion of legume crops in the crop rotation. However, with increasing proportion of legumes in the crop rotation, the risk of serious pathogen problems increases. Generally, the maximum proportion of legumes in crop rotation is around 60 %. Model D is based on this hypothetical maximum legume area. In addition, the amount of FYM is increased by 20 % using purchased fodder. Farm D has a slightly higher circulation factor and PPB than farm I, and the total yield is also slightly higher. Since the final products of these two farms are not equal, the comparison is misleading.

Model C is based on a minimum legume area, since legume crops are not cash crops at all. Hypothetically, a slightly lower N intensity on non-legumes could be possible. However, the risk of total crop failure and poor quality of yield in unfavourable weather conditions increases drastically. The poor PPB (0.47) reflects the weakness of the system: no nutrient circulation at all and no direct utilization of legume crops.

Model I is run with the lowest possible N intensity on non-legumes. However, the risk of total crop failure and poor yield quality can be controlled with help of (ruminant)cattle. The circulation factor is lower than in model D because of the 20 % cash crop area. However, legume crops are managed more efficiently resulting in the highest field balance (0.76). In order to produce the given “food basket”, this model is superior to the specialized alternative (D+C). According to the present data, this model has close to optimum N utilization. However, other nutrients must be replaced by completing nutrient recycling or from external sources.

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New Approaches to Phosphorus Regulation and Management

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Key words: Phosphorus, certification, research, farming system

Abstract

Phosphorus (P) conservation and the environmental, ecological and economic issues related to over-use and under-use of P on organic farms are addressed. Re-examination of Certification Standards is recommended to ensure the conservation and efficient use of P through adaptation of organic management to local conditions, ecology, culture and scale. Changes that will conserve P and minimise environmental risk are identified, along with the necessary research to make this possible.

Introduction

P export from organic farms is not an issue where soil is fertile, P export is low, and crop and livestock production are balanced by high internal recycling of nutrients, as in mixed farms of the Swiss Midlands (Maeder *et al.* 2002) - few farms can even aspire to this ideal. For others, P is a non-renewable input which is mostly derived directly, or indirectly, from declining stocks of rock phosphate (RP). Paradoxically, available soil-P is declining on some farms/regions causing economic and ecological concern, whilst increasing in others to the point of ecological concern. Here we overview the literature on P in organic farms and make a case-study of Australia to (i) explore whether the cornerstone values of organic production are being maintained, (ii) examine the case for changes in the Certification Standards, and (iii) identify research priorities.

The stocks and flows of P

Soil P dynamics are outlined by Smeck (1985) **-** the '*soil solution'* contains small amounts of dissolved organic and inorganic P. A greater proportion of the total P is chemically *sorbed* in soil or held in readily mineralisable organic forms. Sorbed P replaces plant uptake from the soil solution. In naturally fertile or over-fertilized soils the stock of sorbed P is large: in parts of Europe and North America good crops have been grown without P-fertiliser for decades by depleting sorbed P. Most soil P is in *sparingly soluble* minerals or inaccessible organic matter. Newly added dissolved P is sorbed within hours/days of application or being mineralized, and is eventually 'fixed' into slowly available forms – in Australian studies only 10-20% of applied P is used by plants in the year of application (Bolland and Gilkes 1998, Bünemann *et al.* 2005). Biological changes under organic management may increase access to less available forms of P (Jakobsen *et al*. 2005), plants may be selected for improved access to less-available P (Harvey 2008), and organically-grown plants may access more subsoil P than conventional crops (Cornish 2008). These processes only delay the requirement for P to be replaced by fertiliser or manure (Cornish 2008). If not, the plant-available fraction of P will be exhausted. All ecosystems need to replace the P removed.

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Most P absorbed by agricultural plants passes to humans, directly or via animal products. Animal waste is mostly returned to soil, but human waste has in the past mostly returned to surface water in sewage - a major stock of P denied to organic farmers. This policy removes humans from the ecosystem, depletes P from terrestrial ecosystems and contributes to nutrient enrichment of surface waters. All farmers 'trade' P by importing fertiliser, manure, compost and grain, and selling products. As a result of the global and regional P-trade, parts of Western Europe and North America have greatly elevated P concentrations in soil, including any organic farms with a positive farm P balance (Stockdale and Watson, 2002; Oberson and Frossard 2005). Elsewhere, concern is generally for declining soil P and productivity (Cornish, 2008). If no P is applied, the soil stock of P is depleted, which may be *desirable* if it reduces environmental risk, or *undesirable* if P deficiency reduces the protective cover of vegetation over erosion-prone soils and when it forces farmers into low profitability or food insecurity.

Environmental threat from excess nutrient use

Intensive agriculture in Europe is regulated to reduce the environmental risk from N or P inputs significantly exceeding outputs. It may take years for a positive P balance to increase risk over a farm, but localised areas can be at risk earlier. Risks emerge quickly in soil with low P sorption capacity. The issue is complex when manure is used for fertiliser. It is impossible to regulate the use of manure to manage both N and P together. Where manure is the main source of N for crops, more P is applied than necessary (Wells *et al*. 2002), increasing environmental risks. Separating animal and crop enterprises amplifies the problem, yet stockless grain farms and intensive animal enterprises may both be certified. Both face significant issues: ecologically responsible disposal of animal waste; or for farmers who depend on imported manure for N, reduced need for manure achieved ultimately by including more legumes in rotations.

Environmental threat from insufficient phosphorus fertiliser use

Soil P may be low, as with subsistence farmers in parts of Africa (Oberson, unpublished) and India (Cornish, unpublished), and in developed economies such as Australia (National Land and Water Audit, 2001). P export without replacement further lowers concentrations of available P, reduces N-fixation by legumes, and cuts plant productivity. P is transferred from grazed to cropped areas and from there to humans either directly in grain or in meat from animals fed on the grain. In poor rural communities nutrient transfer to near the homestead impoverishes grazed land and increases grazing pressure and land degradation, whether organic or not.

Fertilizer use, phosphorus deficiency, and economic viability

Manure is not always available to organic farmers. In lesser-developed countries manure is in short supply if it is used for fuel, and although individual land holdings may be small, animals range over 'common' areas so manure collection is not feasible (Bationo *et al*. 2007). Manure collection is also not possible in some developed regions with low-moderate rainfall as in Australia where crops are produced on large mixed farms. In Europe and North America stockless farms have limited access to manure although most of them have enjoyed sufficiently high fertility to raise crops organically without P-fertiliser. However, P concentrations are falling, questioning the sustainability of this practice. Conventional soil testing may not provide answers. Failure to use fertiliser in each of these situations has serious economic consequences. The major fertilisers used in organic farming are based on reactive phosphate rock (RPR) which requires acid soil and sufficient rainfall to be effective.

This excludes much of the world where available soil P is low and fertiliser is needed, including southern Australia where RPR is ineffective in organic crops (Dann *et al*. 1996). This, combined with poor supplies of manure or compost, makes soil P management very difficult for a large grain-producing area. The farmers have tried many P fertilizers, yet productivity is low (Cornish 2008). Their over-optimistic use of fertiliser is uneconomic, inefficient and not in accord with basic principles of organic farming. Yet animal and cropping enterprises are integrated and much of the grain is retained on-farm, thus recycling nutrients in strict conformity with organic principles. **The Standards** do not accommodate the economic imperative to lift productivity from impoverished soil in which allowable forms of P are ineffective or unavailable. This is not a healthy ecosystem, and nor is it sustainable, even if good organic practice is otherwise observed. Soluble P added to soil with *high P sorption capacity* and *low solution P* is rapidly incorporated into bio-geochemical cycling. The soluble P feeds the soil, which in turn feeds the plant. Adding soluble P when necessary to maintain soil health seems, to us, to adhere to the organic maxim: “feed the soil, not the plant”.

It is important for organic farming to maintain the principles of minimising imports by maximising opportunities for recycling; maximising efficiency of resource use; and supporting plants through the soil ecosystem. It is also important that the soil ecosystem itself be ‘fed’. Our present knowledge and fertilizer options leave some important situations, exemplified in the foregoing overview and Australian studies, where soluble P remains the only option for feeding P to the soil ecosystem in a way that it can support economic levels of plant production.

Nutrient deficiency reduces water-use efficiency

In water-limited environments, water is the most precious resource after land, and yet nutrient deficiency often sets an upper limit to yield. Farmers have *some* control over nutrients but *little* control over water. With low nutrient inputs, stable production is achieved, but at the cost of a low level of productivity. Production in natural ecosystems in such environments varies inter-annually in response to varying rainfall. Stable but low level yields are not a sign of sustainability.

Organic Certification Standards

Farming systems evolve in a more complex socio-economic environment than when Standards for organic production were first conceived. For example, it could not have been anticipated that changing ‘culture’ and scales of production would lead to the stockless or intensive animal farms now accommodated within the Standards, without ensuring that subsequent problems of nutrient enrichment or depletion are managed. Organic principles embrace the idea of “adaptation of organic management to local conditions, ecology, culture and scale”, but there are many examples of failure to adapt or develop systems that (i) adequately conserve or recycle P, (ii) reflect the unavailability of organic-P sources despite sound organic practice, (iii) reflect gross differences in soils between regions and (iv) differences in the capacity of soils to retain P against environmental losses. The application of Organic Standards has focused on details, whilst in some ways blurring the fundamental aims.

We recommend overhauling the Standards to reassert the core values and objectives of organic farming. Greater sophistication in their interpretation and application is needed, informed by science, to match the heterogeneity in farming systems, regions, soils and cultures. *Accumulation and decline in P must both be addressed, including* *an allowance for soluble P where it is the only option for feeding P to the soil ecosystem.* Here, the same flexibility is needed that in Europe allows (i) soluble potassium as K_2SO_4 to be used and (ii) accommodates both stockless farms and intensive livestock farms, against all ecological principles. Greater attention is needed in the Standards to nutrient recycling, plus monitoring and evaluation of trends in soil P and the balance of P at the farm gate.

Research and extension

Priorities are to quantify P cycling processes and develop suitable soil tests for organic farms; to improve plant access to reserves of soil P where they are high; to develop strategies for farmers to manage the transition from P sufficiency to deficiency; and to improve the availability of RP. Cultural change should allow the unsustainable blanket ban on human waste to be reconsidered and foster research to make it safe. Other ways to recycle nutrients need to be identified and promoted along with opportunities to reduce P inputs where they are needlessly high. Farmers should also be alerted to the potential costs of over depleting soil P. Fertility management products, and techniques involving paid services (e.g. the 'Albrecht' system) need proper evaluation.

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Economic aspects of the application of different organic materials as N-sources in organic production of lettuce

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Key words: lettuce, fertilization, yield, profit

Abstract

In a field experiment on a farm registered for organic production, we studied the effect of the application of different organic materials (OM): farmyard manure (FYM), guano (G), soybean seed (S), forage pea seed (P) on lettuce yield. Besides yield, we also analyzed the economic profitability of the application of different OM. Fresh lettuce yield was significantly higher with OM treatments than with the treatments without fertilization. The highest yield was obtained with the FYM treatment (43.7 t ha^{-1}), and the lowest with the application of P (42.0 t ha^{-1}). The highest additional profit was obtained with the FYM treatment (1123 EUR ha^{-1}) and the lowest with the application of P (475 EUR ha^{-1}).

Introduction

Organic production does not allow the application of mineral fertilizers obtained industrially so the lack of mineral forms of nitrogen (N) early in the spring is often a factor which limits the yield of early crops, even on naturally fertile soils. The application of organic fertilizers with higher contents of N (>1.5%), i.e. a narrower C/N ratio (<20), and their mineralization in the soil can release significant amounts of N in a mineralized, available form and so satisfy the needs of crops for N (Amlinger et al., 2003; Bavec et al., 2006). The aim of this paper is to study the effect of the application of different OM (organic N fertilizers) on lettuce yield and profitability.

Materials and methods

In a field experiment set up on a farm certified for organic production, during the year 2007 we studied the effect of the application of different OM on one set of lettuce (*Lactuca sativa sub.sp. sekalina*) yield. Besides the yield, we also analyzed economic profitability of the application of OM. The experiment was set up applying random block system with four replications. The treatments were: rotten farmyard manure (FYM), guano (G), ground soybean (*Glycine hispida*) seed (S), ground forage pea *(Pisum sativum)* seed (P). OM fertilization doses were calculated with the following formula:

$$Nf = (Ntg-Ni-Npot) / k \quad (1)$$

When values for Ntg, Ni and Npot are entered into Equation 1, we get:

$$Nf = 40 \text{ kg N ha}^{-1} / k \quad (2)$$

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Nf – amount of N applied through different OM (kg N ha^{-1}); **Ntg** – amount of N required for the projected lettuce yield (120 kg N ha^{-1}); **Ni** – mineral N content in the soil at the time of sowing (32 kg N ha^{-1}); **Npot** – amount of mineral N which will be released by the mineralization of organic matter in the soil during lettuce vegetation (48 kg N ha^{-1}); **k** – coefficient of the availability of total N applied through different OM (potentially mineralizable N). Npot and k values were calculated with a previously performed incubation experiment (unpublished data) and are given in Tab. 1.

Tab. 1: Basic data on OM and applied amounts of N in experimental plot

Treatments[1]	N total (% DM[2])	P total (% DM)	K total (% DM)	C/N ratio	K[3]	OM applied (kg ha^{-1})	Nf [4] (kg ha^{-1})
FYM	2	1.06	2.14	10.41	0.268	7421	148
G	15.32	0.14	0.07	2.89	0.670	391	60
S	6.65	1.08	1.18	7.50	0.377	1593	106
P	4.08	0.83	0.68	10.17	0.334	2912	119

[1] FYM, farmyard manure; G, guano; S, soybean seed; P, forage pea seed; [2] DM, dry matter; [3] k, coefficient of the availability of total N applied (potentially mineralizable N); [4] Total amount of N applied through different OM

Organic materials were applied immediately before sowing. The area of the experiment plot was 5.4 m^2, between-row spacing was 0.3 m and within-row spacing 0.25 m. Lettuce was sown on 18 March and harvested on 12 May. After sowing lettuce was covered with agril foil which was removed after four weeks. Soil humidity during vegetation was maintained at the level of 60-70% of field capacity, with “Tifon” irrigation system. Basic characteristics of the chernozem on which the experiment was set up: pH 7.52; 0.17% $CaCO_3$; 1.92% C; 11 mg $100g^{-1}$ Al-P_2O_5 and 26.8 mg $100g^{-1}$ Al-K_2O.

Results

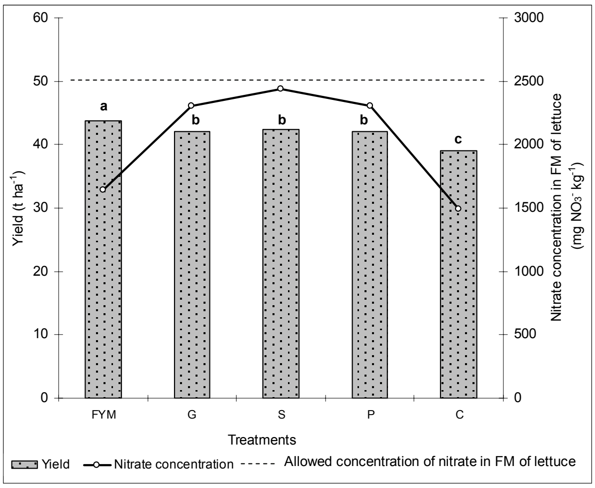
Economic profitability of the application of FYM and G was calculated using their market prices (Tab. 2). For the calculation of economic profitability of the application of S and P we used the data on production costs (The Association of Cooperative Farms of Serbia) for the projected yield of 2.2 t ha^{-1} (S) and 3.0 t ha^{-1} (P).

Tab. 2: Costs of the production of S and P and market prices of FYM and G in 2007

Costs	FYM	G	S	P
Total costs of production/purchase[1]	16	250	265	265
Costs of OM preparation and incorporation (EUR ha^{-1})	50	50	70	70

FYM, farmyard manure; G, guano; S, soybean seed; P, forage pea seed; [1] For FYM and G EUR t^{-1}; for S and P EUR ha^{-1}

Fresh lettuce yield was significantly higher with OM treatments than with treatments without fertilization (Figure 1). With FYM lettuce yield was significantly higher both than the control and than other fertilization treatments. Among G, P and S treatments there were no significant differences, because the same amount of potentially mineralizable N was applied.



FYM, farmyard manure; G, guano; S, soybean seed; P, forage pea seed; C, unfertilized plot; FM, fresh matter; Yield followed by different letters was significantly different at P<0.05

Figure 1: Fresh lettuce yield and profit made compared to the control

At harvest concentrations of NO_3^- in the fresh matter of lettuce was within the limits of maximum allowed concentrations (Commission Regulation (EC) No 466/2001). Tab. 3 shows additional profit calculated on the basis of market prices of lettuce (0.38 EUR per kg), reduced by harvest, packing and sale costs (0.1 EUR per kg of lettuce) and by the cost of the application of OM. The calculation does not include the costs of the production of lettuce because they were the same for all treatments. The profit therefore is the additional profit made through the application of OM.

Tab. 3: Economic indicators of the application of different OM

Treatments[1]	Differences in yield compared to control (kg ha^{-1})	Price of 1 kg N from different OM (EUR kg^{-1})[2]	N total applied (kg ha^{-1})	OM application costs (EUR ha^{-1})[3]	Additional net profit on fertilized plots (EUR ha^{-1})
FYM	4608	0.8	148	168	1123
G	2954	1.62	60	147	680
S	3204	1.9	106	271	626
P	2899	2.25	119	337	475

[1] FYM, farmyard manure; G, guano; S, soybean seed; P, forage pea seed; [2] Calculated on the basis of the production costs (S, P) and market prices (FYM, G); [3] Calculated on the basis of the price of N unit and costs of preparation and OM soil incorporation

FYM had the lowest price of N unit, which is 2-3 times lower than the other OM (Tab. 3). The costs of the application of S and P were approximately two times higher than the prices of FYM and G. As a result of the highest price and lowest yield, the lowest additional profit was made with P treatment. The highest profit was made with FYM treatment.

Discussion

Significantly higher lettuce yield with FYM treatment can be explained by the fact that the application of FYM has a positive effect on physical and chemical characteristics of the soil (Cuvardic et al. 2006), and with the fact that its application introduced significantly higher amounts of P and K into the soil than was the case with other treatments (Tab. 1). Nitrogen use efficiency in the field corresponded to C/N ratio (r^2 = 0.95) and coefficient k determined by incubation experiment (r^2 = 0.80). Nitrogen use efficiency was in the range from 12.16% (FYM) to 28.33% (G). With all applied treatments except FYM the application costs were proportional to the price of N unit. High costs of FYM application when compared to the price of N unit are a result of relatively low content of total N and a low availability coefficient (k). When we compare S, P and G treatments, among which no significant differences in yield were recorded, G proves to be the most economical OM, which had lowest application costs and highest additional profit.

Conclusions

The application of studied OM resulted in a significant increase in lettuce yield, ranging from 2.9 (G) to 4.6 t ha^{-1} (FYM), compared to the control and additional profit ranging from 475 (P) to 1123 EUR ha^{-1} (FYM). If mineralization potential and the content of mineral N in the soil during sowing are taken into account when fertilization norms are being determined, profit can be made even when expensive fertilizers such as S and P are used. The highest profit was made with FYM treatment and lowest with P treatment which had the highest price of N unit.

Acknowledgments

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Element composition and quality of lettuce (*Lactuca sativa* var. Biweri), grown with sheep-manure composts

Radics, L.[1], Pusztai, P.[1], Biró, B.[2], Biró, Zs.[1], Németh, T.[2] & Monori, I.[3]

Key words: compost, manure, phosphorus, nitrogen, lettuce

Abstract

Two representative Hungarian soil-types (slightly humus sandy and loamy saline) were used to study the effect of various compost-products, made from sheep-yard manure and phosphorous amendments on the biomass-production of lettuce (Lactuca sativa var. Biweri) in a pot-experiment. Two types of phosphorous amendments, such as raw-phosphate with high- or a phosphorous rock with low solubility were used as amendments during the twelve-week composting process. Pots of five-hundred g weight were used and considering the ecophysiological demand of the lettuce, low (30 t/ha) optimum (60 t/ha) and provocative (120 t/ha) levels of manure compost were applied to the soils. Yield of lettuce and mineral content analysis were done by ICP and soil-analysis by TVG. Statistical differences were shown (LSD5%) following ANOVA. An increasing yield of lettuce was recorded simultaneously by the compost doses up to the provocative level at both soil-types. Effect of composts was found to be the best at the low-fertility sandy soil with slight humus content. Among the compost-types, the low-releasing-phosphorous-rock was the most appropriate also on the sandy soil. Summarizing the results, sheep-manure-composts could be the prospective amendments for the low-fertility soils.

Introduction

It is common to improve the soil fertility with different types of artificial and natural fertilisers in the farming practice (Biró et *al*. 2005). Composting has become an everyday routine in manure treatments nowadays to keep the original nutrient value, improve the physical characteristic and to speed up the biological degradation, while reducing the nitrate-nitrogen losses (Füleky, 1999).

It is expected that composts enriched with different amendments can provide advantages (ie. higher yields) or disadvantages because of some plant chemical ingredients (e.g. higher nitrate content) depending of the actual type of the compost, dosage and not least of the soil type. Our experiment was targeted on getting information on these parameters. Typical Hungarian soil types were selected and used for the test with different dosage of sheep manure based compost mixed and amended with different substances. All the rules of organic farming regulation were strictly kept when the amendments, manure and management were selected (Radics, 2001).

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Materials and methods

Two representative, but in their main characteristic different Hungarian soil-types (low humus sandy soil and loamy saline one) were used to study the effect of various compost-products. Sheep manure was composted for 3 month. This compost was completed with phosphorous amendments to measure the effect of different compost mixtures on the biomass-production of the lettuce in a pot-experiment.

Originally the research involved nine compost types. We've also examined the effect of some compost types, which were ameliorated with selected phosphates. Phosphorus is one of the most crucial nutrients in the soil because of its low availability. During the composting process we used a highly soluble raw-phosphate (K4) and a high phosphorous content rock (K7) of low solubility (Zapata, 2004). The added phosphate provided more continuous nutrient supply. The particular amount, the mixture content and the technology itself are under procedures for obtaining patent protection, so that it is not public yet. Two controls were used: sheep manure compost with zero P amendment (K1) and pure soil without any compost as null control (K0). After completing the compost mixtures, soil and compost samples were dried, ground and filled into the pots. To find the optimal amount of compost three different doses were tested according to the needs of lettuce as it was cited in literature. Low level was 30 t/ha equivalent, optimum level was 60 t/ha equivalent and provocative level was 120 t/ha equivalent dosage. The total weight of soil and compost sample mixture was 500g in pots and was placed in a light room (Penning, 1989).Fresh weight of shoots, length and width of leaves of lettuce were measured after 10 weeks and dried to a constant weight on 65 °C before the plant nutrient content was analysed (ICP). Soil samples were scrutinized with standardised general and full analyses (TVG**). Data were analysed by one-way ANOVA with t-test.

Results

The total nitrogen content of lettuce leaves is shown on Figure 1.

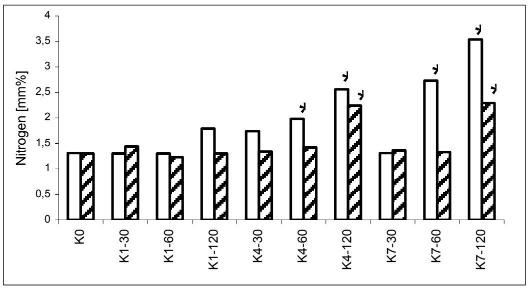

Figure 1: Total nitrogen content in the leaves of lettuce on slightly humus sandy and (solid white) loamy saline soils (stripped) depending on different compost doses. Significant differences from zero phosphorus amendment (K1-x) are labelled with *.

. Standardized General Full Chemical Plant Analysis

** Standardized General Full Chemical Soil Analysis

Mineral content analyses of lettuce showed that the total nitrogen content of lettuce was practically equal on both examined soil types. Compared to the control treatment (pure sheep manure, K1) the highest dose showed significant difference in most cases.

But, on sandy soil plots, the treatment with medium dose compost with raw-phosphate amendments also gave significantly higher nitrogen content of lettuce.

Each treatment had significantly higher phosphorus content in lettuce leaves compared to the control treatment (no added phosphorus, K0) on sandy soil plots except the smallest dosage of phosphorous rock. The smallest dosage could only be significantly higher in raw phosphate amended mixture on saline soil plots. Phosphorous rock was more effective to provide nutrients for lettuce than raw phosphate.

Phosphorus content in the leaves of lettuce is shown on Figure 2.

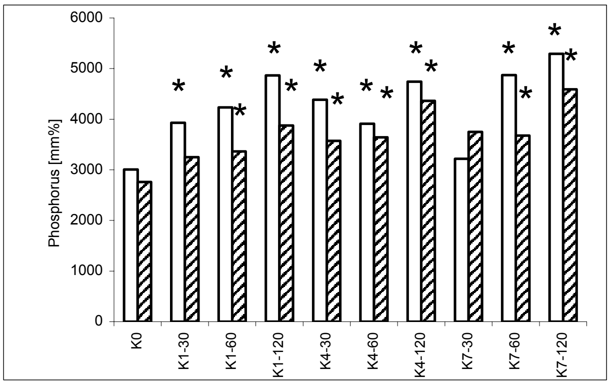

Figure 2: Phosphorus content in the leaves of lettuce on slightly humus sandy and (solid white) loamy saline soils (stripped) depending on different compost doses. Significant differences from zero phosphorus amendment (K1-x) are labelled with *.

The phosphorus content is significantly higher in lettuce leaves compared with the control treatment (K0) in almost all doses on sandy soil tests. The only exception was the smallest dose of phosphorous rock compost treatment.

Low-dose treatments could only have significant effects on plant phosphorus content if the treatment was raw-phosphate enriched compost in loamy saline soil test.

Comparing compost mixture varieties, phosphorous rock treatment effectively increased phosphorous content of lettuce. Presumably phosphorous with slow solubility is ideal because it provides steadier availability during the growing season. Increment of phosphorous content was less on loamy saline than on sandy soil, but differences were still well detectable.

Discussion

Mineral content of lettuce strongly increased under high doses of compost on sandy soil. The total nitrogen content was 2-3 times higher in the lettuce leaves in these cases. This phenomenon indicates that there is a potential risk of the nitrate-accumulation especially on sandy soil as it could be found in the literature (Biró et al. 2005, Fodor et al. 2006).

Changes of phosphorous content were similar to the ones of the nitrogen content. It was verified that phosphorous amended compost could provide more soluble phosphorous to the soil and to the crops compared with not treated compost.In the case of loamy saline soil, significant nitrogen-growth was also observable in the soil at the end of the growing season, but in the lettuce leaves only. The highest dose of both compost forms caused a significant difference. Accordingly, the risk of nitrate and nitrite uptake is lower compared to sandy soils.

Summarising economical, environmental and food-quality aspects low and medium doses of compost seems to be expedient. When you determine doses at establishment of a new crop production system, basic physical, chemical and biological characteristics of the soil and quality of the applied compost should be considered too, as other authors referred it also (Radics, 2001; Seléndy, 1999; Füleky, 1999, Várallyay, 2002).

Conclusions

Summarizing the results, the sheep-manure-composts could be a promising amendments for the low-fertility soils and it is recommended to use as compost for lettuce. At the higher doses, however, beyond the optimal level for organic agricultural conditions, there could be a potential risk of nitrate-accumulation, which needs to be considered at the frequent application. However, it is expected that the results are the same under field conditions, it is necessary to extend the experiment to outdoor trials to get information about the true effect in the circumstances of a farm production.

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Potentials of beneficial micro-organisms

Plant-probiotic microorganisms for a sustainable buffer of input reduction in organic and low-input tomato production systems

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Key words: Organic tomato; Input reduction; Plant-probiotic microorganisms; Sustainable production; Farmer participation.

Abstract

A consortium of plant-probiotic microorganisms is under investigation in open field conditions, at the ICEA-certified Organic Farm "La Carioncella", for its ability to ensure durable soil fertility while buffering nutritional inputs reduction. The primary objective of our QLIF-WP333 three-years-long project is to produce scientific data to help farmers in managing soil probiotics, as a way to reduce inputs, production costs, while keeping quality and sustainability of organic and low-input tomato production systems.

Introduction

The root surface and the close rhizosphere are habitats where microbial activity is maximum, due to several modification of soil environment: release of bioactive compounds from the roots, soil aggregate formation, roots respiration, *etc*. Population density and diversity of microorganisms that are in close relation with plant roots were recently evidenced to be finely regulated by each plant genotype (Picard *et al*., 2008). This finding is especially important for organic and low-input agriculture. In fact, rhizospheric plant-growth-promoting prokaryotes and eukaryotes (now called PPM, for Plant-Probiotic Microorganisms) do positively and directly affect plant production through several mechanisms, such as biological nitrogen fixation, solubilization of organic nitrogen, phosphorous, iron and oligoelements, enhanced water supply, synthesis of plant hormones and plant hormone regulators (Picard and Bosco, 2008). PPM can also indirectly promote plant growth by antagonizing the action of phytopathogens, pests and weeds (Lugtenberg *et al*., 2002). As the diversity of terrestrial plants is dependent from the diversity of their co-evolved soil probiotics (van der Heijden *et al*., 1998), sustainable innovations in organic and low-input agriculture will need to take into account the biological need of plants to co-operating with PPM. Our present research aims to achieve a better understanding on how plant-probiotic micro-flora management could buffer future reduction of external inputs, while keeping tomato fruit quality and system sustainability.

Materials and methods

Plant materials consisted of tomato (*Solanum lycopersicum* L.) 'Riogrande', an industrial processing cultivar, chosen by the organic farmer because it already produced good yield, quality in his own farm during the past ten years. Microbial inputs

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(M) consisted in an experimental consortium of PPM (Bosco et al., 2007), containing the arbuscular mycorrhizal fungi (AMF) *Glomus mosseae* GP11, *G. viscosum* GC41, *G. intraradices* GB67, as well as plant-growth-promoting-rhizobacteria (PGPR) like *Pseudomonas* sp. PN01, *P. fluorescens* PA28, *Bacillus subtilis* BA41, *Streptomyces* sp. SB14, three Italian strains of free-living nitrogen-fixing bacteria (BUSCoB Culture Collection), and the antagonistic saprophytic fungus *Trichoderma viride* TH03. Compost inputs consisted in a commercial green compost (1.8% total N, 30% total C) produced by Nuova Geovis S.p.A. near Bologna.

Trials were performed with the active participation of the farmer at the Carioncella organic farm, in northern Italy, which holds the AIAB-ICEA certificate since 1993. In 2007, tomato seedlings were re-planted into the same four replication blocks established in 2006. Each block was randomly divided into main-plots and sub-plots as summarized in Table 1.

Tab. 1: Experimental combinations of compost (C) and microbial (M) inputs

	Year	Main-plots					
		1		2		3	
Sub-plots	2006	C0M0(-)		C1M0(-)		C2M0(-)	
	2007	C0 (+)	C0 (-)	C1 (+)	C1 (-)	C2 (+)	C2 (-)
	2006	C0M1(-)		C1M1(-)		C2M1(-)	
	2007	C0 (+)	C0 (-)	C1 (+)	C1 (-)	C2 (+)	C2 (-)
	2006	C0M2(-)		C1M2(-)		C2M2(-)	
	2007	C0 (+)	C0 (-)	C1 (+)	C1 (-)	C2 (+)	C2 (-)

C: compost inputs equivalent to zero (C0), 100 kg per ha (C1), 200 kg per ha (C2).
M: microbial inputs equivalent to zero (M0), 40 kg per ha (M1), 80 kg per ha (M2).
(+): nursery-inoculated tomato seedlings; (-) non inoculated seedlings.

<u>Evaluations</u>

In 2007 growing season, tomato fruits representing 18 different treatments (Table 1) were harvested from all the subplots and analyzed. Total and marketable fresh weight (Kg) per subplot were recorded. Fruit average weight (g) and size (longitudinal and transversal diameters) (mm) were determined. All yield data were subjected to one-way analysis of variance (ANOVA) to compare the different treatments. In order to show whether the 2006 treatments had any continued effect on 2007 yield, all data of 2006 subplots (Bosco *et al*., 2007) were compared with those of 2007 non inoculated subplots. A representative sample of marketable fruits (2 Kg) per subplot of the last harvest was analysed for quality parameters such as soluble solids (°Brix), titratable acidity (mEq 100 g^{-1}), firmness (Kg cm^{2-1}), and pH. Soluble solid concentration of the clarified tomato juice was determined using a hand-held Atago PR1 refractometer which provides values as Brix degrees (Brix range 0-32% at 20 °C). Acidity was determined by titration with sodium hydroxide 0,1 mol l^{-1} and values were expressed in mEq of citric acid per 100 g. The pH was determined using a Metrohm Model 654 pH-meter. Firmness was measured by using a pressure tester (Forge Gauge, Lutron FG-5000-A) fitted with a cylindrical plunger of 6 mm in diameter. ANOVA was used to compare quality parameters between treatments. Mycorrhizal colonisation of tomato roots was monitored by a microscopic method (McGonigle *et al*., 1990;) on roots sampled at two dates (8^{th} and 10^{th} weeks after planting), and analysed with ANOVA.

Results

Significant differences (*p<0.05)* according to the Duncan's multiple range test were detected between tomato fruit yields of 2007 non-inoculated subplots and 2006 inoculated ones. The medium amendment of compost in the 2007 growing season more positively influenced yield than the high compost amendment of 2006 season. The quality of marketable fruits was not significantly different between 2007 treatments. Mycorrhizal index was significantly different (*p<0.05)* between 2006 M inputs in the roots corresponding to the first 2007 sampling. In particular, the low PPM input (M1) positively influenced the mycorrhizal index in comparison to the control (Fig. 1). In the same way, compost inputs enhanced mycorrhizal colonisation (non significant). The mycorrhizal colonisation was significantly higher in the second sampling, but the differences between treatments lost their significance (Fig. 1). It is interesting to note that the mycorrhizal index of plants non-inoculated in 2007 wasn't significant different from the index of those sampled in 2006 PPM-inoculated subplots.

a

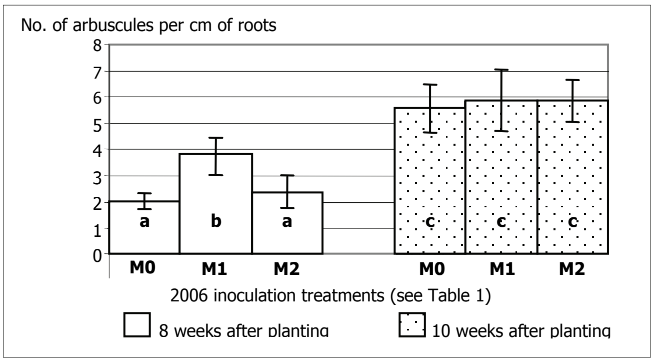

Figure 1: 2007 root mycorrhizal colonisation due to 2006 microbial (M) inputs: the columns sharing the same letter(s) do not differ significantly.

Discussion

Plant-probiotic microorganisms are emerging as a sustainable production factor for future agriculture. However, few experimental works have been done to assess their actual impact on organic and low-input tomato fruit yield and quality. By comparing results from our 2006 (Bosco et al., 2007) and 2007 field plots, we could evidence that plants non treated in 2007 did produce significant higher yields than plants grown in 2006 treated plots, even if tomato was re-planted after tomato (experimental low-input conditions) in an organic managed farm. In 2006-treated plots, the 2007 reduction of compost input (C1) did not reduce yields, nor fruit quality, suggesting a long-lasting, buffering effect by the first-year PPM treatment. This is in agreement with (and could be explained by) the observed stability of mycorrhizal index between roots sampled in 2007 and 2006 growing seasons. However, a third experimental growing season is desirable and already started to verify this explanation.

Concusions

As the moderate PPM input (M1) in 2006 had its positive impact on the second growing season, and could buffer the 2007 reduction of compost inputs (C1), without reducing tomato fruit yield and quality, we are now concerned with the actual cause of such an effect. Further research into microbial parameters, such as community diversity and structure evaluation, should help to understand the interactions of natural soil microflora, external inputs of plant-probiotic microorganisms, reduced inputs of fertilizers, and tomato fruit yield, quality, production costs, system sustainability.

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Tools for innovative organic breeding arise from rhizosphere microbial ecology

Bosco, M.[1] & Picard, C.[1]

Key words: Plant genotype; below-ground potential; Organic breeding; Plant-probiotic micro-organisms.

Abstract

Research on soil microbial ecology is beginning to elucidate how and how much beneficial soil micro-organisms (i.e. plant-probiotics) contribute to plant integrity and plant environmental fitness. The differences so far highlighted among crop varieties show highly positive interactions with plant-probiotic microflora (PPM), and upgrade the role of soil PPM at the level of other essential factors for sustainable plant breeding. Current research efforts, aimed to rapidly achieve crop varieties fitting for low-input and organic production systems, finally take into account the capacity of each individual variety to efficiently exploit indigenous PPM.

Introduction

In natural environments, the nutrients uptake of plants, as well as their health, is greatly regulated by the presence and activity of beneficial micro-organisms, *i.e*. those known to enhance plant growth by fixing atmospheric nitrogen, solubilizing phosphorus, nitrogen, iron and other nutrients, by producing bioactive compounds that stimulate root proliferation and by suppressing root diseases. These beneficial micro-organisms are now called "plant probiotics" (Picard and Bosco, 2007), and include mycorrhizal fungi, antagonistic fungi and the large group of Plant Growth Promoting Rhizobacteria (PGPR). The term "probiotic" has been borrowed from another ecosystem, the gastrointestinal tract, where probiotic bacteria and yeasts can exert health-promoting properties, such as solubilizing nutrients, producing vitamins *in situ*, reducing the symptoms of diarrhea and of inflammatory bowel diseases. The common idea for plant- and gastrointestinal- probiotics is that in both cases a beneficial micro-flora minimizes a range of biotic and abiotic stresses.

Despite the fundamental role of plant-probiotic micro-flora (PPM), its interactions with plant-root systems have been largely ignored in agro-ecosystems. In fact, modern agricultural soils are almost universally maintained at high fertility, and the selection of most of the current crop varieties has been made under these conditions. Furthermore, resistance toward soil-borne pathogens has been in general ignored. Possibly as a consequence, modern breeding programs may have yielded cultivars highly dependent on fertilizer and pesticide supply, and that have diminished capacity to form synergistic microbial associations. For example, modern strawberry cultivars, selected under utilization of methyl bromide soil fumigation, resulted to be non-adapted to the sublethal effects of organisms in non-fumigated soils (Fort *et al*., 1996). Similarly, Hetrick *et al.* (1995) found that older cultivated wheats, developed prior to 1950 and thus before the widespread use of inorganic fertilizers in breeding programs, were more reliant on mycorrhizal symbiosis than modern wheat varieties. This is in

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agreement with Engelhard *et al*. (2000), who found that wild rice species and older rice varieties were preferred over modern rice cultivars by endophytes of roots such as *Azoarcus* spp. Confirming the hypothesis of the loss of beneficial root microbial associations during modern breeding programs in highly fertilized systems are the rare cases of varieties selected in low fertilized soils, such as the current Brazilian cereal and sugar cane genotypes. In fact, these cultivars can especially benefit from associative N_2 fixation (Baldani *et al.,* 2002), allowing the reduction or complete elimination of N fertilization for these crops.

All these findings highlight the fact that it may be difficult to select cultivars for lower-input agriculture from the elite cultivars currently used in conventional agriculture. In order to increase or maintain the rate of production despite less input of H_2O, N, P, Fe or pesticides, it seems thus primordial to breed new crop varieties able to obtain their nutrient supply and their root protection mainly from an efficient association with PPM.

Materials and methods

Host variation in responsiveness to beneficial micro-organisms generally has been expressed as microbial root-colonization density and diversity, as well as effective plant growth stimulation and protection (Tanksley and McCouch, 1997). Concerning atmospheric nitrogen fixation, root nitrogenase activity and quantification of plant N derived from the atmosphere have also be taken in consideration, both for rhizobial-legume symbiosis and plant associations with free-living microorganisms. Specifically for legumes, number of nodules was also a quantitative trait measured to assess host reaction (Herridge and Rose, 2000). Finally, the mycorrhizal responsiveness was defined in terms of Pi uptake and mycorrhizal dependency (MD) (Tawaraya, 2003).

Results and Discussion

Independent of the beneficial association studied, it has been established that host genotype has a substantial impact in determining the extent of microbial colonization. For example, it has been shown that there is significant genotypic variation in the responsiveness of legume cultivars to *Rhizobium*. In fact, a range of bean, soybeans as well as of Lucerne (Hungria and Phillips, 1993) genotypes differed in relative nodulation. Furthermore, high variability in nitrogen fixation was observed among crop legume genotypes, varying from 0 to 97% of crop nitrogen derived from nitrogen fixation (Herridge and Rose, 2000).

Concerning the mycorrhizal association, the majority of information on variability in MD was obtained in studies with the cereals *Zea mays* (maize), *Hordeum vulgare* (barley) and *Triticum aestivum* (bread wheat) (summarized by Smith and Read, 1997). For example, diversity in MD level was observed among wheat genotypes by Hetrick and colleagues (Hetrick *et al*., 1995). Interestingly, it was reported that diversity in capacity of wheat to sustain AM colonization was associated with yield responses, varying from zero to positive or negative values (Xavier and Germida, 1998). Furthermore, MD is often negatively correlated with root morphological traits, such as root length, root dry weight, root hair length and density of root hairs, traits known to improve the ability of the non-mycorrhizal plant to acquire Pi directly from the soil (reviewed in Tawaraya, 2003).

Finally, differential capacity to support associative PGPR has been clearly established among cereal species as well as among genotypes within cereal species. Maximal nitrogenase activity was reported to be dependent upon maize genotype (Ela *et al*., 1982). By comparing 69 rice lines from diverse backgrounds, Shrestha and Ladha (1996) demonstrated that nitrogen fixation differed significantly amongst the various lines, ranging from 1.3 to 20%. Those with high nitrogen fixation were mostly traditional varieties. More recently, Azevedo *et al*. (2005) observed that the genetic structure in populations of root-associated diazotroph colonizing rice, maize or sorghum was indeed plant-species dependent. Furthermore, Picard *et al*. (2008) gave recently clear evidence that maize genotype influences the size of PGPR communities involved in nitrogen fixation and plant protection, as well as the diversity of the AMF colonizing population.

Interestingly, all these variations among cultivars in interactions with PPM seem to have resulted from evolution over generations (Engelhard *et al*., 2000). More importantly, it was evidenced that root colonization by PPM could be an inherited trait (Smith *et al*., 1999), probably related to heterosis (Picard *et al*., 2008). Moreover, at least for the rhizobium-legume symbiosis, the specificity of the beneficial association also resembles a gene-for-gene system. In fact, the strain- and host-genotype-specific interactions are characterized by unique patterns of signal release and response (Pueppke *et al*., 1998).

Knowledge of the available genetic variability should be utilized for implementing a selection procedure adapted for low input environments. This selection can be carried out with conventional breeding procedures, i.e. by the direct detection of effective root association with beneficial micro-organisms, or can be integrated with the use of molecular marker tool. In that light, more and more studies were conducted to identify quantitative trait loci (QTLs) underlying the plants ability to establish a favourable rhizosphere microbial community. For example, by analyzing 197 recombinant inbred lines (RIL) in a mapping population of maize, Kaeppler *et al*. (2000) demonstrated that host variation on AM colonization was associated with two QTL. In the same manner, three quantitative trait loci in tomato associated with suppression of root infection by *Pythium torulosum* in response to introduction of the rhizobacterium *Bacillus cereus* strain UW85 explained 38% of the phenotypic variation observed (Smith *et al*., 1999).

Conclusions

From recent findings we understand that future efforts for breeding sustainable varieties must consider the below-ground genotype potential of each crop, often misunderstood. In particular, the scientific community of soil microbial ecologists supports very strongly the idea that a lot of new knowledge will be produced in the near future. Innovations in sustainable crop varieties will undoubtedly pass through the exploitation of plant-probiotic micro-organisms, by developing and testing, at laboratory, field, and biostatistic levels, a brand new breeding strategy targeted to crop varieties that rely the most part of their productivity, environmental fitness on PPM.

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How effective are 'Effective Microorganisms'? Results from an organic farming field experiment

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Key words: Effective microorganisms, biofertilizer, soil fertility, soil biology

Abstract

The effectiveness of 'Effective Microorganisms' (EM) was investigated in a four years field experiment (2003-2006) at Zurich, Switzerland. The experiment was designed to enable clear differentiation between effects of the microorganisms in the EM treatments (Bokashi and EMA) and its substrate (sterilized treatments). Crop yields and soil microbiological parameters as soil respiration and microbial biomass were determined. The EM treatments showed no effect on yield and soil microorganisms which were caused by the EM microorganisms. Observed effects could be related to the effect of the carrier substrate of the EM products. The sampling time showed stronger effects on soil microbial biomass and soil respiration compared to the effect of the treatments. Hence 'Effective Microorganisms' are not able to improve yields and soil quality in mid term (4 years) in arable farming under temperate climatic conditions as in Central Europe.

Introduction

Biofertilizers are defined as substances containing living microorganisms which promote growth by increasing the supply of primary nutrients to the host plant (Vessey, 2003). In addition microorganisms that promote plant growth by control of deleterious organisms are defined as biopesticides (Banerjee et al., 2005). Both strategies are of particular importance in organic farming systems. Hence several products are on the market and listed in the regulations of governmental or farmer association's regulations on organic farming. For instance, in Switzerland about 60 preparations containing microorganisms are admitted for application in organic farming (FIBL-Hilfsstoffliste 2007; www.fibl.org).

However, there is poor evidence on the effectiveness of many preparations such as the Japanese 'Effective Microorganisms' (EM), which is widespread all over the world in organic and sustainable agricultural systems. It consists of 80 species of 'beneficial coexisting microorganisms' and contains lactic acid bacteria, phototrophic bacteria, *Actinomyces* and yeasts (Higa, 2001). It is recommended for crop production, to improve soil fertility, manure quality, crop yields, plant quality and health. But in the peer-reviewed scientific literature only a few references on the effects of EM with contradictory results can be found (Javaid, 2006; Khaliq et al., 2006;). No results are available for temperate climates and field conditions.

Our aim was to evaluate the effects of different preparations of 'Effective Microorganisms' (EM) on crop yields and on microbial parameters characterised by mass and activity of the microbial community during four years of field application under organic management.

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Materials and methods

A field experiment (randomised block design, 4 replicates) was established at Agroscope Reckenholz-Tänikon Research Station ART in Zurich, Switzerland, from 2003 to 2006 on an organically managed field (medium eutric Regosol, mean temperature 8.5°C, mean rainfall 1042 mm). Treatments of the EM preparations EMA as spraying agent and Bokashi as organic fertilizer were applied (Table 1). Treatments without EM and parallel treatments with autoclaved EM preparations, to separate the effect of the microorganisms from its substrate, served as controls (Table 1). Bokashi and the first EMA spraying were applied at sowing. The further EMA sprayings were spread during the vegetation period until flowering and after the cutting of lucerne.

Tab. 1: Treatments of the EM field experiment

No	Treatment[1]	EMA spraying[2]	EM-Bokashi[4]	Manure[4]
1	control	3 x H_2O	-	-
2	sp	3 x[3]	-	-
3	sp au	3 x au[3]	-	-
4	sp+bok	3 x	2.9 t ha^{-1}	-
5	sp+bok au	3 x au	2.9 t ha^{-1} au	-
6	sp+bok+m	3 x	2.9 t ha^{-1}	10 t ha^{-1}
7	sp+bok+m au	3 x au	2.9 t ha^{-1} au	10 t ha^{-1}

[1] bok = Bokashi; sp = spraying; m = manure; au = autoclaved
[2] 110 litre EMA ha^{-1} per application
[3] in 2003 additional pickling of potato seed stock with EMA
[4] fresh matter basis

Potatoes were cropped in 2003 followed by winter barley in 2004, lucerne in 2005 and winter wheat in 2006. Crop yields, soil microbial biomass C by chloroform fumigation extraction (CFE) and soil basal respiration were determined. Soil samples (0 – 20cm) were taken in March 2005, in October 2005 immediately before (autumn 05 I) and after sowing of winter wheat (autumn 05 II) and in March 2006.

Results

Crop yields

Potatoes showed no significant differences in yield in 2003. From 2004 to 2006 yields of the EMA spraying treatments 2 and 3 (sp, sp au; table 2) showed no differences to the untreated control. However yields differed considerably in treatments with additional Bokashi application. Winter barley yields in 2004 were increased compared to the control between 23% in treatment 6 (sp+bok+m) to 36% in treatment 4 (sp+bok), but the comparatively high differences were not significant. Differences of winter wheat yield to the control in 2006 ranged between 13% in treatment 6 (sp+bok+m) and 23% in treatment 7 (sp+bok+m au). But significant differences were only found between the control, treatment 3 (sp au) and treatment 7 (sp+bok+ m au) (Table 2). The additional application of manure to spraying combined with Bokashi application did not cause any distinct yield effects. The lucerne yields in 2005 showed a similar pattern but differences between the treatments were small. The statistical evaluation, comparing the factor living EM with sterilised EM (treatment 2, 4, 6 vs. 3, 5, 7) resulted in no significant difference.

Soil respiration and microbial biomass

Soil respiration (SR) did not differentiate between the untreated control and the EMA spraying treatments 2 - 3 (fig. 1A) on each sampling date. But SR increased in the treatments with additional Bokashi application (Treatment 1, 2, 3 vs. 4, 5, 6, 7). These differences were not consistent throughout the treatments with Bokashi application and during sampling dates. In autumn 05 II treatments 4, 5 and 7 differed significantly from 1 - 3, but not treatment 6. In spring 06 treatment 4, 6, and 7 differed significantly from 1 - 3, but not treatment 5. In analogy to crop yields the comparison of living EM with sterilised EM (treatment 2, 4, 6 vs. 3, 5, 7) resulted in no significant difference.

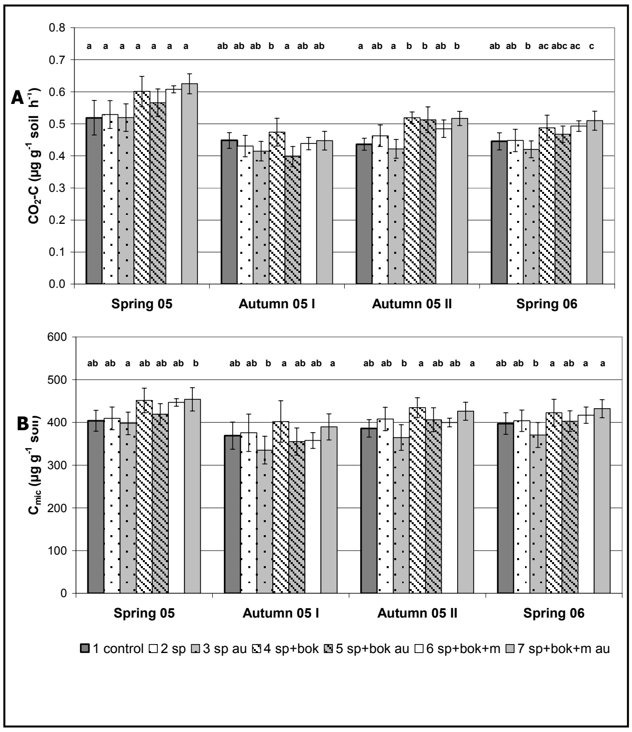
Tab. 2: Yields of main crops from 2003 – 2006. Differing letters in columns show significant differences of means (Tukey, p<0.05), [1]Summ of 4 cuts.

No	Treatment	Potatoes 2003	Winter barley 2004	Lucerne 2005[1]	Winter wheat 2006
		(t FM ha^{-1})	(t FM ha^{-1})	(t DM ha^{-1})	(t FM ha^{-1})
1	control	27.4 [a]	2.95 [a]	14.0 [a]	2.97 [a]
2	sp	33.3 [a]	3.30 [a]	14.6 [a]	3.16 [ab]
3	sp au	30.6 [a]	2.88 [a]	13.8 [a]	2.95 [a]
4	sp+bok	27.0 [a]	4.00 [a]	14.5 [a]	3.53 [ab]
5	sp+bok au	26.9 [a]	3.80 [a]	14.4 [a]	3.48 [ab]
6	sp+bok+m	30.3 [a]	3.63 [a]	15.1 [a]	3.36 [ab]
7	sp+bok+m au	29.0 [a]	3.75 [a]	14.7 [a]	3.64 [b]

The results of soil microbial biomass C were similar to soil respiration. No significant differences were found between the untreated control and treatment 2 and 3. Significant differences were only found between treatment 1 – 3 and 4 – 7 (Fig 1B). The differences were not consistent throughout the treatments with Bokashi application and during sampling dates. Treatments with living EM were not significantly different from the sterilised treatments (treatment 2, 4, 6 vs. 3, 5, 7). Distinct effects of sampling date were observed. Soil respiration and microbial C differed significantly at spring 05, autumn 05 I and autumn 05 II, but not between autumn 05 II and spring 06 (SR p< 0.000; CFE-C p<0.000).

Discussion and conclusions

Significant differences of EM treatments to the untreated control were only found between treatments with Bokashi application. EMA spraying alone had no effects on either crop yields or soil microbial parameters. Differences can be explained by the considerable amounts of nutrients of 401 kg N, 16 kg P, 33 kg K and 7 kg Mg ha^{-1} a^{-1} which were applied with Bokashi. However, the effects of additional manure application were small. No differences were found between EM treatments and the sterilized EM control treatments. Hence the observed effects could solely be related to the carrier substrate of Bokashi. The microorganisms in the EM preparations caused no effects. Overall the effects on soil microbial parameters were small and the sampling date showed greater differences as the treatments and fertilization effects. Our results are in good agreement with the findings of Priyadi et al. (2005) who found no effects of EM application on corn yields in Indonesia. Khaliq et al. (2006) found no EM effects by applying EM alone on seed cotton, but concluded an improved fertilizer effect combining NPK and organic matter applications with EM. However, these studies did not use sterilised treatments and thus the inter-pretation whether substrate or micro-bial effects are responsible for the observations is difficult.



We conclude from our results that the 4 years application of 'Effective Microorganisms' in the temperate climate of Central Europe under organic farming management caused no significant effects on crop yields and soil microbial parameters. Observed effects could solely be related to the nutrient inputs of the carrier substrate Bokashi, while the microorganisms had no effects. Effects of sampling time exceeded effects of treatments.

Figue 1: Soil respiration (A) and microbial biomass C (B) of soils at differing sampling dates. Autumn 05 I = before EM application, Autumn 05 II = after EM application; (Tukey, p<0.05)

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Influence of organic farming on arbuscular mycorrhizal fungal populations in a Mediterranean agro-ecosystem.

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Key words: arbuscular mycorrhizal fungi, glomalin-related soil protein, spore population, biodiversity, organic farming.

Abstract

Arbuscular mycorrhizal fungi (AMF) are key components of the soil microbiota, fundamental for soil fertility, plant nutrition and functioning of agroecosystems. Data on the interactions between organic practices and AMF populations are limited and inconsistent. Here we compared AM fungal communities and glomalin-related soil protein (GRSP) content occurring in a recently converted organically farmed soil with those occurring in a conventionally managed soil. The results show that the two farming systems did not significantly differ in AM fungal spore populations and glomalin-related soil protein. We hypothesize that in our experimental system, which was converted from conventional to organic farming only recently (5 years), there may not have been enough time to allow the establishment of differentiated AM fungal populations.

Introduction

Soil microbial communities are considered a vital factor for the functioning of agroecosystems and success in organic farming (Gosling et al., 2006). Glomeromycotan fungi form arbuscular mycorrhizal (AM) symbioses with most crop plants and are fundamental for soil fertility and plant nutrition and health. Since different species and isolates of AM fungi (AMF) show differences in plant growth responses and quality, any change in their populations may result in changes of agro-ecosystem productivity (van der Heijden et al., 1998). AMF are strongly affected by anthropogenic activities (Giovannetti and Gianinazzi-Pearson, 1994), and intensive agricultural practices, such as crop rotation fertilization pest control and tillage impact AMF, reducing population biodiversity (Helgason et al., 1998; Daniell et al., 2001). Organic agriculture has been shown to increase AMF root colonization and propagule numbers (Galvez et al. 2001; Oehl et al. 2003), although low input practices used in such management system do not always allow the level of biodiversity to increase, even after a long time (Franke-Snyder et al., 2001). Hence, understanding the structure and the dynamics of AMF populations as affected by diverse agricultural practices represents an important prerequisite for the success of organic farming. This

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work was intended to describe the AM fungal communities occurring in field trials comparing conventional and stockless organic farming.

Materials and methods

The experimental plots are located in the CIRAA (Interdepartmental Centre for Agri-environmental Research "E. Avanzi", University of Pisa) experimental centre near Pisa (Italy), and are a part of the long-term experimental system MASCOT (Mediterranean Arable Systems COmparison Trial). MASCOT was established in Autumn 2001 as a long-term comparison between organic and conventional management system for a typical rotation of coastal Tuscany, characterized by the absence of livestock, and including sugar beet, common wheat, sunflower, pigeon bean, and durum wheat. In spring 2006 sugar beet was replaced by maize.

In the conventional management, crops were minerally fertilized with 602 kg ha^{-1} N , 487 kg ha^{-1} P_2O_5, 346 kg ha^{-1} K_2O distributed over the five years of rotation. In organic management all crops were supplied with 30 kg ha^{-1} N, 30 kg ha^{-1} P_2O_5, 0 kg ha^{-1} K_2O each year. Additionally, in the organic system, red clover was interseeded in common and durum wheat and used as a green manure for subsequent crops.

The five crops in the rotation were allocated to five fields and managed organically or conventionally (each group of five fields represents a system within a block; each crop is present every year). Systems were replicated three times according to a randomized complete block design. Additional information on the agricultural practices used in the organic and conventional systems can be found in Bàrberi and Mazzoncini (2006).

Soil samples consisted of seven random cores collected from each of three plots under organic and conventional management after the harvesting of maize. Samples were collected in the second half of June 2006 in the plots. AM fungal spores were extracted from 50 g soil samples by wet-sieving and decanting, down to a mesh size of 50 µm. Spores and sporocarps were examined under a dissecting microscope and the numbers and types of AM fungal spores were recorded. Only intact, healthy spores were counted. Spore identification was performed under the light microscope, after mounting the spores in polyvinyl alcohol lacto-glycerol (PVLG) on microslides. We determined species richness and calculated the frequency of occurrence. Relative abundance was calculated as the number of spores of each species divided by the total number of spores. We also calculated the Shannon diversity index and the Pielou evenness index.

Results

Nine species of AMF were found in the experimental sites, eight belonging to *Glomus* and only one to *Scutellospora*. Some differences in species occurrence and frequency were observed: *S. calospora* spores were more frequent in the organic plots than in the conventional ones, and *G. rubiforme* spores were more frequent in conventional plots. (Fig.1).

Species richness and other diversity indexes in the two agricultural systems did not differ statistically.

The organic and conventional farming systems did not show statistical differences in EE-GRSP, whose values were 172.5 to 170.3 □g g^{-1} soil, respectively.

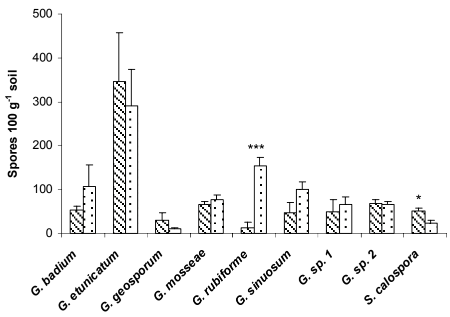

Figure 1: Distribution of fungal spores per AM fungal species, in organic (hatched bars) and conventional (dotted bars) plots. *, *P*<0.05; *, *P*<0.01**

Discussion

The analyses of AM fungal spores of the experimental plots show a quantitative and qualitative uniformity of AM fungal populations in the conventional and organic farming systems, 5 years after the beginning of the experiment. Our data are in agreement with previous reports showing only slight differences in AM fungal populations between conventional and organic farming systems a few year after conversion (Purin et al., 2006). Slight differences in the levels of diversity between the two systems were found after 15 years of cultivation (Franke-Snyder et al., 2001). By contrast, in a long-term comparison trial in central Europe, higher species richness and diversity of AMF were reported (Oehl et al., 2004), while other authors found an increase of AM fungal inoculum in organic farmed soils (Bending et al., 2004). Overall we assessed the occurrence of nine AM fungal morphospecies. Such level of biodiversity is lower than that found in other organically farmed soils, while it is consistent with data from conventional agriculture (Oehl et al., 2003).

A few differences were also recorded in GRSP concentrations, in agreement with previous observations concerning conventional versus organically managed soils (Purin et al., 2006; Wright et al., 2007). Our present data contradict previous findings obtained in a 50-year-old corn monocrop subject to conventional high-input agriculture, where GRSP concentration was 7.5-fold lower than in an organically grown grassland (Bedini et al., 2007).

On the basis of the present results we can hypothesize that in our experimental system, only recently converted from conventional to organic farming (5 years), there was not enough time to allow the establishment of differentiated AM fungal populations. Further investigations are needed to understand whether other factors, such as residual phosphate from previous conventional management, or organic farming management practices such as tillage for weed control and the use of copper-based fungicides, may be detrimental to AM fungal populations.

Conclusions

Our data on the characterization of AM fungal spore populations and on GRSP content of two differentially managed field trials, 5 years after conversion from conventional to organic farming, represent the reference point for future assessment of putative AM fungal population shifts.

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Biological profitability of maize inoculation with selected rhizosphere micro organisms (*Pseudomonas fluorescens* and *Glomus intraradices)* under Water Deficit Stress

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Key Words: Maize, *Pseudomonas fluorescens*, *Glomus intraradices*, Phosphorus, Water Deficit Stress

Abstract

This research focused on evaluating the usefulness of an arbuscular mycorrhizal fungus (Glomus intraradices) and a plant growth-promoting rhizobacterium (Pseudomonas fluorescens) to maize growth under water deficit stress. Field experiment was conducted at Soil and water research institute, Karaj Station, Iran, during 2006 growing season. Biological positive effects of the micro organisms on plant growth, nutrient uptake, grain yield and yield components in maize plants was recorded in the treatment receiving mixed inoculums of G. intraradices and P. fluorescens. Maize shoot P content, grain yield, yield components, harvest index, grain N and P, soil available P, root colonization percentage and water use efficiency increased significantly with the G. intraradices inoculation and P. fluorescens, alone or in combination under water deficit stress. The highest profitability was observed in the combined treatment of inoculation with G. intraradices and P. fluorescens, which synergistically increased plant growth compared with other treatments.

Introduction

Co-inoculations of beneficial rhizosphere microorganisms into soils, reducing the inputs of environmentally deleterious agro-chemicals required for optimal plant growth, are gaining increased attention in sustainable agroecosystems (Barea *et a*l., 1997). There are several groups of beneficial rhizosphere microorganisms. Inoculation with AM fungi is an effective method of enhancing the ability of the host plants to become established and to cope with stress situations such as nutrient deficiency, drought and soil disturbance (Caravaca *et al*., 2003a). In fact, several authors have indicated that mycorrhizal fungi may improve the performance of seedlings, by stimulating water uptake (Auge, 2001) or increasing nutrient uptake by the plant, particularly N and P (Jeffries et al., 2003). Beneficial free-living soil bacteria are usually referred to as plant growth-promoting rhizobacteria or PGPR (Kloepper et al., 1989). Particularly, the so-called mycorrhiza helper bacteria are known to stimulate mycelial growth of mycorrhizal fungi or to enhance mycorrhizal formation (Toro *et a*l., 1997). The microbiologically solubilised phosphate could, however, be taken up by a mycorrhizal mycelium, thereby developing a synergistic microbial interaction (Barea *et al*., 1997). The combined inoculation of selected rhizosphere microorganisms has been recommended for maximising plant growth and nutrition (Probanza *et al*., 2001). The study of the antagonistic or synergic effects of the different microbial inoculants when co-inoculated is a crucial step in the development of effective host-microorganism

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combinations. It has also been reported that dual inoculation with *G. intraradices* and *Bacillus subtilis* promoted the establishment of the introduced AM fungus and increased plant biomass and tissue P accumulation (Toro *et a*l., 1997).

Materials and Methods

This experiment was conducted at the Karaj station of Soil and Water Researches Institute of Iran, with a loam soil during 2006 growing season. Soil available P and K content were 6.2 and 170 mg/kg respectively. Also organic C and N content were 0.34 and 0.07 percent respectively. The experiment design consisted of four randomized complete blocks in a split-factorial arrangement having 15 treatments in every block. The main-plots consisted of three water regimes, which were achieved by scheduling cumulative pan evaporation in mm. The irrigations were scheduled for various treatments, when the cumulative pan evaporation readings reached at 70, 100 and 130 mm. The sub-plots included of the application of microbial inoculants [*G. intraradices; P. fluorescens* strain 173; *G. intraradices + P. fluorescens* strain 173 (50%-50%)] and not [triple super phosphate; without fertilizer (control)]. Each plot consisted of 4 rows, 7 m long and 75 cm apart. Chemical P treatment received some super phosphate fertilizer to increase soil available P up to 15 mg/kg. No P given in AM and Pf treatments. Water treatments began after maize 8-leaves stage. In this stage, plants were exposed to intensities of water deficit stress (severe, moderate and no water deficit). Specific strain of *P.fluorescens* (strain 173) was isolated from the rhizosphere of wheat (*Triticum aestivum* L.) by Soil Biology Laboratory in Soil and Water Researches Institute of Iran. The inoculum of *G. intraradices* consisted of AM propagules. This inoculum was uniformly mixed into the apatite (in order to facilitate incubation), which was prepared by Mycorrhiza Laboratory in mentioned Institute. Maize seeds were inoculated according to Sharma *et al*. (2003) and then placed in the furrow. In end of maize growth season grain yield, yield components, harvest index, grain N and P, soil available P, root colonization percentage and WUE were determined.

Results

- Conversely, *G. intraradices* (AM) and *P. fluorescens* (Pf) bio-inoculants enhanced the maize grain production regardless of intensities of water deficit stress. The dual inoculation showed significant difference in grain yield of maize when compared with fertilizer and control (uninoculated) treatments. Inoculation with AM + Pf and AM increased the grain yield compared with other treatments. The highest increase in 100-grain weight, of row number per ear and grain number per row was recorded in AM + Pf treatment. In the presence of AM+Pf and AM treatments, yield components enhanced significantly compared with P fertilizer and control, when plants were exposed to water deficit conditions. The water deficit treatment significantly ($P<0.05$) decreased yield components of control (uninoculated) and P fertilizer treatments. There was no significant differences between Water deficit stressed AM + Pf and AM treatments and well-watered and fertilized plants. Single inoculation with Pf had more effect compared with fertilizer and control treatments too. Harvest index was also higher in plots supplied with co-inoculation that this difference was significant. The water deficit treatments decreased HI for inoculated and non-inoculated plants, but HI values were higher in co-inoculants. The HI values for water deficit stressed AM+Pf and AM plants were comparable to well-watered treatments. Phosphorus concentration in plant tissue were increased in plants by inoculation with AM+Pf and AM under well-watered and water deficit stress condition. The inoculation with AM+Pf significantly ($P<0.05$) increased the P contents of maize plants and had higher than control and P fertilizer plants under varying intensities of water deficit stress. P uptake by plant was also more with the application AM under moderate stress in our study. The concentration of P in control plants was significantly ($P<0.05$) lower than that in plants grown under treatments AM+Pf and AM (table 1). The dual inoculation of Pf and AM resulted in a significant increase of grain P and N concentration (table 1). The inoculation with AM and Pf had a more stimulating effect on the assimilation of P and N in comparison with fertilizer and control treatments. However, AM performed better than P fertilizer, but was less than AM + Pf in stimulating N and P uptake.

- The highest soil available P was associated with plants grown under AM+Pf co-inoculation treatment. This value was significantly ($P<0.05$) higher than that of plants grown under all other treatments under similar conditions. Our study showed that inoculated maize plants by AM + Pf are much more efficient in taking up soil P than non-inoculated plants. All inoculation treatments significantly improved available P content of soil (table 1).

Tab. 1: Maize shoot and soil P content in phosphate fertilizer (P), *G. intraradices* (AM), *P. fluorescens* (Pf), co-inoculation (AM+Pf) and no fertilizer (Control) plants exposed to varying intensities of water deficit stress (70, 100 and 130 mm cumulative pan evaporation)

-	-	-	- Parameters			-
- Treatments	- Grain P (%)	- Grain N (%)	- Plant's tissue P (%)	- Soil available P content (mg/kg soil)	- Root Colonization (%)	- WUE - (Kg ha mm-1)
P + 70	0.3525 c	1.725 cd	0.2675 ab	4.7 d	1.84 fg	33.77 bcd
AM + 70	0.61 ab	1.975 ab	0.3375 ab	6.12 b	65.13 ab	42.55 ab
Pf + 70	0.5575 ab	1.86 bc	0.315 ab	5.56 bc	62.01 ab	37.63 abc
AM + Pf + 70	0.645 a	2.138 a	0.3475 a	8.72 a	79.5 a	43.23 a
Control + 70	0.12 ef	1.09 h	0.1 cde	1.8 fg	1.732 fg	17.2 f
P + 100	0.205 de	1.452 ef	0.2325 abc	2.62 ef	1.643 fg	27.21 d
AM + 100	0.515b	1.742 bcd	0.27 ab	4.76 cd	50.08 bc	34.81 abcd
Pf + 100	0.34 c	1.717 cd	0.2575 ab	2.82 e	41.12 cd	32.68 cd
AM + Pf + 100	0.535 ab	1.847 bc	0.305 ab	5.04 cd	60.17 b	36.31 abc
Control + 100	0.1175 ef	1.048 h	0.09 de	1 gh	0.8725 g	15.6 f
P + 130	0.1225 ef	1.145 gh	0.21 bcde	2.32 ef	1.29 fg	17.49 ef
AM + 130	0.3025 cd	1.55 def	0.2475 ab	2.72 e	20.94 e	31.75 cd

Pf + 130	0.1975 de	1.358 fg	0.225 abcd	2.42 ef	19.52 ef	26.45 de
AM + Pf + 130	0.3075 cd	1.67 cde	0.255 ab	2.775 e	30.28 de	32.05 cd
Control + 130	0.0725 f	0.98 h	0.075 e	0.9 h	0.545 g	15.12 f

Means with different superscript letters are significantly different at $P<0.05$ according to LSD test

- The trend of grain P and N accumulation under different treatments of water deficit stress was similar to well-watered conditions. The lowest P and N concentration of grain was detected in plants grown in uninoculated and unfertilised treatments. Treatment of AM+Pf , AM and Pf inoculation resulted in a significant increase in P and N uptake to different degrees of water deficit stress when compared with the control, respectively (table2). The percentage of root colonization was significantly higher in the treatments containing co-inoculants than AM and Pf treatments. The highest increase in the percentage of root colonization was recorded by co-inoculated treatments. Our results showed water deficit stress decreased the percentage of root colonization (table 2). The WUE of inoculated treatments was higher than non-inoculated treatments in moderate and severe intensities of water deficit stress. In spite of no significant difference between inoculation treatments, inoculation with AM+Pf and AM under well-watered conditions increased WUE compared with other treatments (table 2).

Conclusion

In summary, AMF and PGPR bio-inoculants improved drought tolerance of field grown maize plants as a consequence of enhanced nutritional status especially of P. AMF and PGPR bio-inoculants response was more pronounced under water deficit stress than well-watered conditions. The data revealed that mentioned bio-inoculants enable the host plant to withstand varying of water deficit stress under field conditions. Indeed, these bio-inoculants were adapted to their environment in terms of soil characteristics, plant genotype and climate. Meanwhile, this research must be proactive and the field trials must be established across a broad range of soil and

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Role of forage legumes mixed cropping on biomass yield and bacterial community composition

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Key words: Mixed cropping, legume crops, free-living N_2-fixing bacteria, rhizosphere bacteria population, *Azotobacter* spp

Abstract

*Intercropping berseem clover (Trifolium alexandrinum L.) may increase forage yield and free-living N2-fixing bacterial species community. Berseem clover was mixed with Persian clover (Trifolium resupinatum L.) at ratios of 1:0, 3:1, 1:1 and 1:3 and with Persian clover/ annual medic (Medicago regidula cv. Regidula) at ratio of 1:1:1 at Field Crops Department, Faculty of Agriculture, Tarbiat modares university, Tehran, Iran in 2007. Mixed ratio had significant effect on total forage yield. Total forage yield was greatest with a 1:1:1 ratio of clovers to annual medic. Total intercrop yields with clovers/ annual medic at 1:1:1 plants m–2 was 214.37g m–2 DM yields. Mixed cropping increased rhizosphere microorganisms viz. bacteria, free-living N_2-fixing bacteria and Azotobacter counts. Free-living N_2-fixing bacterial species and Azotobacter populations of 96 g-1 soil*103 cells and 24 g-1 soil*102 cells, respectively, obtained from mixed cropping with 1:1:1 clovers to annual medic ratios.*

Introduction

Forage legumes can be important components of sustainable crop rotations. Forage legumes access atmospheric N2 through symbiosis with a group of soil bacteria collectively called rhizobia and so require minimal N fertilizer inputs. When part of this `free' N is made available to a subsequent crop, the use of legumes in a rotation can lead to a reduction in fertilizer-N use. Berseem clover (*Trifolium alexandrinum* L.) is an annual leguminous forage or cover crop species well adapted to semi-arid conditions of the Mediterranean areas. It is a high-yielding, nutritious, cool-season forage crop thought to have originated in the Middle East (Knight, 1985). It is grown in pure stands or in mixtures with annual grass species for over winter grazing and for harvested forage in the spring (Martiniello, 1999; Stringi et al., 1987). Intercropping gives a greater stability of yield over monoculture (Willey and Reddy, 1981). Besides, mixed or intercropping is widely practiced by the farmers because it often gives higher cash return and total production per hectare than growing one crop alone (Kurata, 1986) and ensure greater resource use efficiency (Herrara and Harwood , 1974). Although the study of mixed or intercropping benefits and rhizosphere microbial dynamic is well established, recent research has revealed a third interaction (cropping system) that appears to be significant in terms of overall soil microbes. The objective of the present study was to measure the rhizosphere microbial changing associated with monoculture and mixed cropping of Persian/berseem clovers and annual medic to evaluate the potential mixed cropping on forage yield and soil microbes.

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Materials and methods

Field experiment was conducted at the at Field Crops Department, Faculty of Agriculture, Tarbiat Modares University, Tehran, Iran (about1323 m Alt, 35° 48' N Lat) in 2007. The soil type at site was silty clay loam. The field plots were maintained under transitioning to organic production. Experiments followed tilled fallow, and fields were disked and harrowed before seeding. The experimental design was a randomized complete block and stand ratios of 1:0 3:1, 1:1, and 1:3 0:1 of Berseem clover: Persian clover (BP), respectively, and stand ratios of 1:1:1 of clovers to annual medic (M) were treatments. Plots were 3 by 5 m and there were three replications. The mixedcropping design was based on the replacement principle. Samples were cut from an inner plant area of 2 m2 by hand at 5 to 7.5 cm above soil level. Shoot samples were oven dried at 70 ˚C until daily checks indicated no further decreases in weight.

Colony form unit (CFU) numbers of various groups of rhizosphere micro-organisms viz. bacteria, N2-fixing bacterial species and Azotobacter were estimated by plate counts of aliquots from serial 10-fold dilutions. The root systems of 10 plants were gently separated from the bulk soil and the soil adhering to the roots was considered rhizosphere soil. Rhizosphere soil was shaken in Ashby's liquid medium minus carbon source, and suitable dilutions were plated on N-deficient medium to give a count of Azotobacter. TSA and Jensen's agar used for plating of two groups of microbes, micro-organisms viz. bacteria, N2-fixing bacterial, respectively. Three replicate plates were inoculated from each dilution and one dilution series was prepared per soil suspension. The plates were incubated at room temperature in the dark and the colonies emerging were counted. The morphology of the colonies on the plates was checked and the numbers of CFU were counted.

All measured variables were assumed to be normally distributed and statistical analyses by ANOVA were performed using SAS software (SAS, 1990). The significance of difference between treatments was estimated using the LSD range test with a 0.05 if a treatment was significant.

Results

Berseem clover was roughly 3.1 times taller than Persian clover regardless of the stand ratio. The average rates of plants height were 17 and 54 cm for Persian and berseem clover, respectively. The average rates of annual medic plants height was 41.3 cm in mixed and sole cropping. Clover ratios significantly increased total fresh weight (TFW) and total dry weight (TDW). As berseem clover:persian clover ratios change from 1:0 to 1:3 TFW and TDW yield decreased from 843.3 to 753.3 and 160.63 to 97.0 g m–2 , respectively (Table 1). Clover mixed cropping with annual medic significantly ($P<0.001$) increased both TFW and TDW. Total forage Dry weight m-1 was greatest with a 1:1:1 ratio of berseem/ Persian clovers to annual medic. The greatest TFW and TDW of 1383.3 and 214.37 g forage m-1 were in the berseem clover:persian clover:annual medic ration treatment of 1:1:1 (Table 1). Result indicated that rhizosphere in Persian sole cropping compared to berseem and annual medic sole cropping has a greater Colony form unit (CFU) numbers of Free-living N2-fixing bacteria and Azotobacter (Table 1). Result showed that the effect of mixed cropping affected bacteria, N2-fixing bacteria and Azotobacter colony forming unit (CFU) numbers. CFU counts of bacteria, N2-fixing bacteria and Azotobacter were increased with mixed cropping compared with monoculture of berseem clover species and annual medic. bacteria, N2-fixing bacteria and Azotobacter CFU counts were the greatest with 1:1:1 clovers/annual medic ratios (86×105, 96 × 103 and 24 × 102 CFU g-1 rhizosphere soil, respectivily) (Table 1).

Tab. 1: fresh weight (g m^{-1}), dry weight (g m^{-1}), CFU, MPN of free – living nitrogen fixation bacteria and Azotobacter spp.from the rhizosphere of Persian clover (P), berseem clover (B) and annual medic (M) in sole and mixed cropping system

Treatments	Total Fresh weight (g $^{-1}$m)	Total Dry weight (g $^{-1}$m)	Bacteria (CFU) (g-1 soil* 10^5)	MPN of N2 fixers (×10^3 cells)	Population of azotobacter (x10^2 cells)
B(1:0:0)	843.3^d	160.63^b	50^c	61^c	10^c
P(0:1:0)	520^c	101^c	79^b	91^a	20^a
M(0:0:1)	$746.7c^d$	153.18^b	25^e	40^e	30^f
BP(3:1)	1063.3^b	175.43^{ab}	50^c	61^c	10^c
BP(1:1)	$933.3b^c$	164.97^b	20^e	26^f	71^e
BP(1:3)	$753.3c^d$	97.0^c	36^c	51^d	93^b
BPM(1:1:1)	1383.3^a	214.37^a	86^a	96^a	24^a
MS	226787.3	5113.3	1914.04	1976.38	165.21
F. value	10.29	7.72	209.35	181.24	191.87***
significant	***	***	***	***	***

*** Significant for P<0.001

Discussion

In agreement with other studies (Evans, 1960; Grimes and Quasem, 1992; Kurata, 1986), intercrooping improved the growth of both berseem and Persian clovers. Both clover species had a greater herbage dry weight m-2, which may have made both clovers more competitive for light, water and nutrients when grown in the mixture with another clover species. Persian clover just produce three leaflets with long petiole that grow upright, 25-35 tall when this species of clover developed as a summer or spring annual. Therefore high supply of carbon serving in tap root in absence of the stem permit Persian clover to has a greater exudation of organic substance from the root (data not shown). The influence of plant assimilation on microbial communities has been defined in relation to the rhizosphere (Hiltner, 1904) and microbial activity stimulated by the leakage and exudation of organic substance from the root (Grayston 1997). The experiment indicated that various legumes had different influence on composition of microbial population. Plant diversity may had a greater potential on biochemical diversity of root exudates and therefore select for more diverse microbial communities. It is known well that root exudation changes the population of rhizosphere bacteria. Therefore sufficient supply of carbohydrates of plant, special root, may be able to have a greater effect on soil micro-organisms. Persian clover and berseem clover display a simple structure consisting of central tapering main root, which bears a number of branching fibrous root (Taylor,1985) but tapering main root of Persian clover is much thickened compared with berseem clover and annual medic and then has a greater supply of carbohydrates than two other legume.

Conclusions

The present experiment shows that biomas production and the population of the rhizosphere bacterial were affected by both plant species and kind of cropping system. We conclude that probably various root exudations of the different plant species caused the alteration of the composition of microbial population. Studying the diversified agricultural production systems association with soil micro organism would provide more information to obtain improved crop, increased productivity and development of sustainable management of soil fertility.

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Mycorrhization of winter wheat cultivars in organic farming

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Key words: Arbuscular mycorrhiza, root colonisation, root length density, plant morphology, drought tolerance

Abstract

The root length density, arbuscular mycorrhizal (AM) colonisation and the total AM root length density of 12 winter wheat cultivars have been studied at seven sites in eastern Austria under organic farming. Root length density did not differ between the cultivars whereas AM colonisation and total AM root density did. Site effects were more pronounced than cultivar effects. All three traits generally were on a higher level in calcaric Phaeozems than in Cambisols. The AM colonisation and total AM root density decreased with increasing plant height and were positively correlated with crop yield. On calcaric Phaeozems, root length density in the subsoil was obviously more important for drought tolerance than AM colonisation in the topsoil.

Introduction

In organic farming, the choice of adapted cultivars and healthy seedlings are very important. Although management is quite different from conventional farming e.g. with respect to use of fertilisers and chemical plant protection, mostly the same cultivars are used in Austria and other countries. Appropriate cultivars are characterised by characteristics like their adaptation to the soil fertility management of organic farming, a high and stable yield, and an effective nutrient uptake under low-input conditions. Root characteristics like high root length or surface area, and symbioses between crop plants and micro-organisms help achieving these aims. Arbuscular mycorrhizal (**AM**) fungi play a key role in water uptake, availability of sparingly soluble nutrients like phosphorous (P), and crop health in low-input farming systems (Jeffries et al. 2003). For many crops, however, it is not sufficiently known if cultivars differ significantly in their ability to establish a symbiosis with AM fungi. Regarding their above mentioned functions, mainly the total AM root length density is ecologically relevant.

The objectives of this study were to compare root length density, AM colonisation, and AM root density of 12 winter wheat cultivars under field conditions in organic farming, and to test relations with plant morphology, crop yield, and drought tolerance.

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Materials and methods

Mycorrhizal colonisation was assessed in field trials in 3 replicates at 7 sites in eastern Austria. The sites represent acidic and calcaric Cambisols from the pre-alpine region and calcaric Phaeozems from the pannonian dry region. Available P contents in the Ap horizon were in a medium range (Table 1). Soil samples were taken in spring 2006 and 2007 during shooting of winter wheat with an auger from the topsoil at 0 – 30 cm depth. Roots were washed out of the soil and stained (Vierheilig et al. 1998). Root length density (**RLD**) was assessed with the gridline intersect method (Tennant 1975). AM colonisation (**MYC**) of the roots was assessed by microscopy (McGonigle et al. 1990). Multiplying RLD and MYC yielded AM root length density (**MYC_RLD**).

Crop yield was assessed as mean values of the 3 replicates at each site. At two of the sites (Sitzendorf and Oberweiden) additional experiments determined yield depression through induced drought stress generated by sheltering the plots from rain. Experimental traits were tested for cultivar and site effects by a 2-way analysis of variance and Tukey test.

Tab. 1: Site characteristics

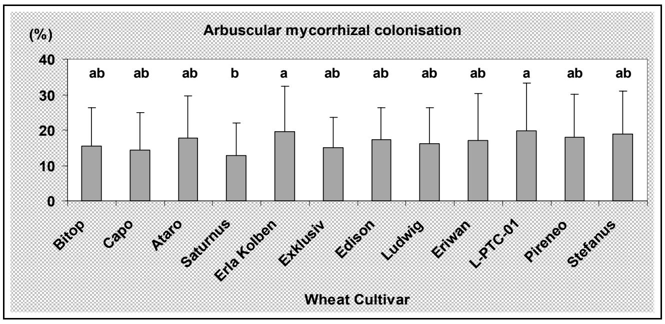
Site \ Trait	Precipitation (mm)	Soil type	pH_{CaCl2}*	P_{CAL}* (mg kg^{-1})
Moidrams	610	Ca	4.4	88
Gießhübl	938	Ca	7.1	17
Edelhof	610	Ca	6.0	69
Sitzendorf	508	Ph	7.4	63
Dörfles	540	Ph	7.5	118
Oberweiden	543	Ph	7.4	53
Obersiebenbrunn	532	Ph	7.6	92

P_{CAL}: available, calcium acetate lactate-extractable phosphorous; *: in the Ap horizon, 0 – 30 cm; Ca: Cambisol; Ph: Phaeozem; n.a.: not analysed.

Results

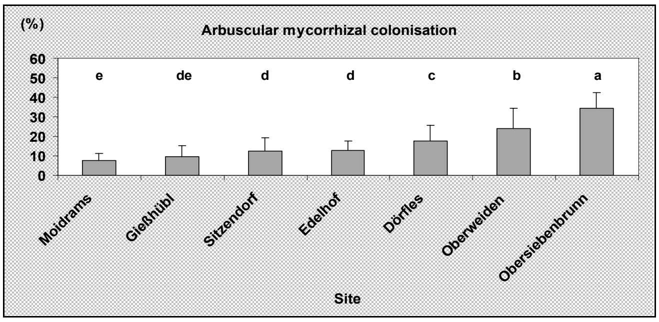
The RLD in the topsoil did not differ between cultivars and amounted to 3 – 4 cm cm^{-3} on average (data not shown). AM root colonisation ranged from 14 to 20 % on average (Fig. 1). Highest degrees of AM colonisation were found in both old (Erla Kolben, cultivar registration in 1961) and new (L-PTC-01, not yet registered) cultivars. AM root length density varied around 0.5 cm cm^{-3}. It was least for Bitop and highest for Stefanus, the other cultivars did not differ from one another (data not shown). The standard deviation was high for all traits of the wheat cultivars due to significant site effects. AM root colonisation (Fig. 2, Table 1), RLD and MYC_RLD (data not shown) in general were lower on Cambisols than on calcareous Phaeozems.

AM root length density was correlated ($P < 0.01$) to RLD and AM colonisation. Both MYC and MYC_RLD decreased with increasing plant height and were correlated ($P < 0.01$) to crop yield (Table 2). The relative yield depression through induced drought stress on two of the Phaeozems increased with increasing AM colonisation and MYC_RLD (Table 2).



Mean values with the same letter are not significantly different (*P* < 0.05).

Figure 1: Arbuscular mycorrhizal root colonisation of the 12 tested wheat cultivars in the topsoil in 2006. Average values of 7 sites.



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Mean values with the same letter are not significantly different (*P* < 0.05).

Figure 2: Arbuscular mycorrhizal root colonisation in the topsoil at 7 sites in 2006. Average values of the 12 tested cultivars.

Discussion

For AM colonisation and AM root length density, only two groups of cultivars could be distinguished. Site effects, however, were considerable. In a study of Yao et al. (2001), mycorrhizal dependency was very low but varied significantly among wheat genotypes and was presumably affected by the carbohydrate partitioning between shoot and root. The general negative effect of soil available P contents on AM colonisation was not apparent. This was most probably due to an overriding pH effect on the study sites where pH values varied over a wide range (Table 1).

Taller plant genotypes presumably allocate more carbohydrates in shoot compared to root growth and vice versa. Carbohydrate partitioning in favour of the roots in shorter plants obviously furthered AM root colonisation in the studied genotypes. The increasing relative yield depression through induced drought stress with increasing AM colonisation seems contradictory to other studies showing a drought alleviating effect of AM colonisation (Jeffries et al. 2003). First results of Schweiger (2007) indicate that root length density in the moister subsoil may be decisive for drought tolerance of wheat cultivars on the calcaric Phaeozems of this study. In our study it was obviously more important for drought tolerance than AM colonisation in the topsoil. The specific combination of traits in the studied genotypes could have overcompensated for a generally existing drought alleviating AM effect.

Tab. 2: Correlations (Pearson) between root length density, AM colonisation, AM root density, plant height, grain yield, and yield depression through induced drought stress.

Trait	N	RLD	MYC	MYC_RLD
MYC	**84**	0.252 (0.021)	-	-
MYC_RLD	**84**	0.538 (0.000)	0.928 (0.000)	-
Plant height	**72**	-0.282 (0.016)	-0.328 (0.005)	-0.404 (0.000)
Grain yield	**84**	0.087 (0.429)	0.385 (0.000)	0.387 (0.000)
Relative yield depression	**24**	0.564 (0.004)	0.686 (0.000)	0.776 (0.000)

Abbreviations see text. Significance level in brackets.

Conclusions

Differences in AM colonisation and AM root length density between the 12 tested wheat cultivars were only small but related to plant yield. Site effects were mainly due to differing soil acidity. Wheat P responsiveness to AM colonisation should be assessed to understand the agronomic importance of differences in AM colonisation.

Highest degrees of AM colonisation were found irrespective of the age of the cultivar. AM root length density decreased with increasing plant height.

Acknowledgments

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Preliminary Findings on the Arbuscular Mycorrhizal Colonization of Organic Wheat

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Key words: Spring wheat, arbuscular mycorrhiza, heritage wheat, phosphorus

Abstract

Arbuscular mycorrhizal fungi aid many crop plants in the uptake of phosphorus, which is one of the most limiting nutrients in organic crop production. Genotypic variation for mycorrhizal colonization exists in wheat cultivars. Mycorrhizal colonization and yield were studied in 5 modern wheat cultivars and 5 older wheat cultivars to investigate if differences in colonization exist between the cultivars. Cultivars that may be better suited for organic production are identified.

Introduction

Modern wheat varieties that have been bred under conventional management systems may not be the best suited varieties for organic production. Although modern crop varieties are high yielding under optimal conditions, some researchers have reported that modern varieties suffer greater yield losses than ancestral varieties when grown under stressful conditions (Mason and Spanner 2006).

In many regions of the world phosphorus (P) is one of the most important nutrients limiting crop production (Zhu *et al.* 2001). Due to increased nutrient deficiencies in organic systems, arbuscular mycorrhizal fungi (AMF) are important for the uptake of nutrients, especially P.

It has been reported that genotypic variation for mycorrhizal colonization exists between cereal cultivars (Baon *et al.* 1993; Zhu *et al*. 2001; Kaeppler *et al.* 2000). Dependency upon mycorrhizal colonization also varies between crop cultivars. Hetrick *et al.* (1992) found landraces have a greater benefit from mycorrhizal symbiosis then modern cultivars, suggesting mycorrhizal dependence is stronger in older populations of wheat. It has been hypothesized that selection of germ plasm under fertilized conditions may have reduced that frequency of genes that promote mycorrhizal associations (Hetrick *et al.* 1992).

The objective of this study was to determine if selecting wheat varieties under conventional management has reduced their ability to colonize with AMF. A second objective of this study is to identify cultivars that may be better adapted to organic conditions due to higher levels of mycorrhizal colonization.

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Materials and methods

This experiment was conducted at two long term organic locations, Glenlea and Carman, Manitoba, Canada. The experiment was established in the spring of 2007. The experimental design is a randomized complete block, with four replicate blocks at each site. Soil samples were collected in early spring and showed 9 ppm or 77 kg/ha of available P at Glenlea, and 14 ppm or 155 kg/ha of available P at Carman. The seeds of five older and five modern bread wheat varieties (*Triticum aestivum* L.) were obtained (Table1). Plot size was 3 x 0.6 m at Glenlea and 4.5 x 0.6 m at Carman. Both locations were seeded in early May and were harvested in late August using a plot combine. To estimate root colonization by AMF 3 soil cores plot^{-1} were obtained at the 4 leaf stage. The soil cores were bulked to give one sample per plot. Roots were washed by hand, root mass was measured, then the roots were stored in 70% ethanol. A random subsample of roots was cleared with 10% KOH, then stained using chlorazol black E. The magnified intersections method (McGonigle *et al.* 1990) was used to score 100 root intersections for colonization by hyphae, arbuscules, vesicles, and spores. All data were statistically analyzed using the mixed model (P<0.05) with the SAS statistical package.

Results

Percent colonization by arbuscules varied from 5.75% (Neepawa) to 11.25% (Mida) at Glenlea and from 12% (Neepawa) to 21% (McKenzie) at Carman (Table 1). Although colonization did not appear to follow a trend at Glenlea, percent colonization generally decreased from the most recently released cultivars to the oldest cultivars at Carman. At Glenlea there was no statistically significant (P>0.5) difference between the modern and older cultivars. As shown in Figure 1, at Carman the modern cultivars had a significantly higher (P<0.5) level of colonization then the older cultivars.

Tab. 1: Year of release, percent colonization by arbuscules, and yield (kg/ha) for the 10 wheat cultivars at Glenlea and Carman, Canada, in 2007.

Cultivar	Year of Release	Arbuscular Colonization		Yield (kg/ha)	
		Glenlea	Carman	Glenlea	Carman
FBC Dylan	2006	9.75[z]	19[z]	1381.60cd[y]	2306.54a[y]
5602 HR	2004	8	13.25	1859.06a	2053.67a
McKenzie	1997	8.5	14	1793.30ab	1729.13b
AC Barrie	1994	6	14.5	1137.05d	1112.86e
CDC Teal	1991	8	19.5	1477.90bc	1424.46cd
Neepawa	1969	5.75	12	1350.52cd	1317.63cde
Selkirk	1955	7.75	13.25	1313.64cd	1210.09de
Mida	1944	11.25	11.25	1283.27cd	1588.88bc
Marquis	1918	8.25	10.25	1442.80cd	1218.29de
Red Fife	1886	9	13	1892.00a	1515.68bc

[y]Means within the same site year followed by the same letter within a column are not significantly different (P>0.05) according to Fischer's protected LSD.
[z]Means are not significantly different (P>0.05) according to Fischer's protected LSD.

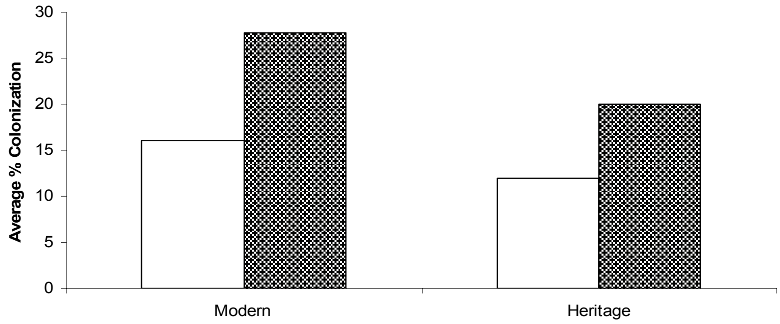

Figure 1: Average % colonization by arbuscules (white) and by hyphae and arbuscules (dark) for modern varieties (1991-2006) and for heritage varieties (1886-1969) at Carman, Manitoba, Canada.

There was no general yield trend at Glenlea, while yields generally decreased with year of release at Carman. Yields ranged from 1137.05 kg/ha (AC Barrie) to 1892 kg/ha (Red Fife) at Glenlea and from 1112.86 kg/ha (AC Barrie) to 2306.54 kg/ha (FBC Dylan) at Carman (Table 1).

Discussion

Variation in mycorrhizal colonization was observed at both locations. The results at Carman are in agreement with the findings of Zhu *et al.* (2001), where the modern cultivars had higher colonization than the older cultivars in the study. All cultivars were found to be mycorrhizal in this study. In general, mycorrhizal colonization is known to increase the uptake of P per unit weight of root (Baon *et al.* 1993). Colonization was shown as arbuscular colonization because it is thought that most nutrient exchange occurs at the arbuscules (Peterson *et al.* 2004). Although it may seem that cultivars with higher colonization by arbuscules should have the ability to take up more nutrients this may not be the case.

Hetrick *et al.* (1993) found no relationship between the degree of root colonization and the degree of benefit from AMF symbiosis. Some researchers have found that efficiency or response to mycorrhiza is greater in older cultivars than modern cultivars (Hetrick *et al.* 1993; Zhu *et al*. 2001). Therefore, although modern cultivars were found to have higher levels of colonization than older cultivars at Carman, more research is needed to assess the benefit the cultivars are receiving from symbiosis with AMF.

It was hypothesized that heritage cultivars may be better suited for organic production. At Glenlea, a site which had high weed and disease pressure, Red Fife (1886), a heritage variety, had the highest yield. At Carman the highest yielding cultivar was FBC Dylan (2006), an organically bred variety. The high yields may be associated with mycorrhizal colonization since FBC Dylan had high colonization at Carman and Red Fife had moderately high colonization at Glenlea. AC Barrie, a variety commonly grown by conventional farmers in Canada had the lowest yield at both sites under organic management.

Conclusions

The objective was to identify cultivars that may be better suited to organic conditions due to higher levels of mycorrhizal colonization. No significant differences in arbuscular mycorrhizal colonization were found between cultivars, although there were significant yield differences at both locations. The yields of the individual cultivars provide an opportunity to identify cultivars that were better suited to organic conditions in this year, although yields were different between sites. More research needs to be done to determine the benefit the cultivars are receiving from mycorrhizal colonization.

Acknowledgments

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Soil fertility in Mediterranean organic farming systems I

Poliennal results on soil N management and maize N nutrition by green manuring

Benincasa, P.[1], Tosti, G., Boldrini, A., Tei, F. & Guiducci, M.

Key words: green manure, maize, nitrogen, fertilisation

Abstract

*Several field trials were carried out in 5 years in Central Italy to study the effect of green manuring on soil N management and N availability for grain maize as a succeeding crop. Hairy vetch, field bean, rapeseed and barley were grown in autumn-winter as pure crops or mixed in leg-non leg couples. Maize was sown in early spring just after green manure incorporation. The amount of N supplied by green manures, as well as the maize N uptake and the estimated N effect (i.e. the N taken up by maize that actually derives from green manure N) depended on species used, but with a high between-year variability. The N effect at harvest over 3 years was found to depend on the amount of incorporated biomass (DW) and its N content (N%) according to a multiple linear regression (Neff = -3.9*DW + 47.8*N%, R^2 = 73%).*

Introduction

Winter catch crops of legumes and non legumes, pure or mixed, can be grown to both prevent soil N leaching and incorporate N (either N absorbed from the soil or legume N derived from atmosphere via symbiotic fixation, Ndfa) to the soil for spring-summer cash crops (Odhiambo and Bomke, 2001; Thorup-Kristensen et al., 2003). However, the predictability of green manure N fertilisation efficacy is low, since the amount and release of incorporated N varies much year by year. This paper reports data from 5 years of experiments aimed to study green manure N accumulation and N availability for succeeding grain maize.

Materials and methods

Several field trials were carried out in the 5 years 2001/2002-2005/2006 in Central Italy (165 m a.s.l.) on clay-loam sub-alkaline soils with 1.2-1.5% SOM, quite high N fertility, low available P and high exchangeable K contents. Depending on the year, some or all of the pure crops of hairy vetch (V), field bean (F), rapeseed (R) and barley (B), and the mixtures leg-non leg (Table 1) were sown in autumn and incorporated in early spring, just before the soilbed preparation for irrigated grain maize as succeeding crop. Plot size (50 to 80 m^2) and replicates (3 to 4) varied year by year. Seed rates (kg ha^{-1}) were 300 for F, 90 for V, 10 for R, 200 for B in pure crops and half for each species in mixtures. In any year, the experimental design included bare soil plots in winter where then maize was not fertilised (unfertilised control, N0) or fertilized with urea at 300 kg N ha^{-1} (mineral control, N300). For green manures we measured aerial biomass and N accumulation (Kieldahl method) at incorporation date. For maize from green manure plots we measured the N uptake ($Nupt_{GM}$) at shooting, flowering and final harvest and estimated the N effect (Neff), i.e. the amount of

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uptaken N that actually derives from incorporated green manure N (Thorup-Kristensen et al., 2003). In fact $Nupt_{GM}$ includes, besides N released from green manure biomass, also soil mineral N at maize sowing (Nmin) and N released from soil o.m. during maize growth. We assumed as the best estimate of Neff: Neff= $Nupt_{GM}$ – $Nupt_{N0}$ + Nmin; where $Nupt_{N0}$ is the maize N uptake of the unfertilised control (a pooled estimate of Nmin + N mineralised from soil o.m.). Since we did not measure Nmin, we assumed N accumulated in barley at incorporation as the best estimate of Nmin, provided N-leaching was risible in our clay-loam soils when autumn-winter was not too rainy (Thorup-Kristensen et al., 2003). Actually, we calculated Neff only for the first 3 years, because in 2005/2006 the much rainy and cold autumn-winter compromised barley growth and N uptake and thus the estimate of Nmin, while in 2004/2005 the unespectedly high soil N fertility ($Nupt_{N0}$= 233 kg ha^{-1}) masked the effect of treatments.

Results

Data in table 1 show a great inter-annual variability. As an average, N accumulation was highest in legumes, lowest in non legumes, and medium to high in mixtures, mainly due to differences in N% content of dry matter. At any growth stage, the maize N uptake in the 5 years (table 2) and N effect in the first 3 years (table 3), in most cases (except for in one year after V and V+B) were high after legumes and N300, low after non legumes and N0 (lowest after barley), intermediate after mixtures. One-year data for Neff at each crop stage were related to the amount of incorporated dry biomass and to its N% content according to multiple linear regressions with R^2 always higher than 91% except for the 2nd year (R^2= 84% at shooting, 67% at flowering and 68% at harvest). However each of those relationships did not fit well to data from other years. Weak common relationships plotted over all 3 years data were found at shooting (R^2=45%) and flowering (R^2= 52%), while the regression found at harvest (Neff= -3.9*DW + 47.8*N%) fit pretty well to observed data (R^2= 73%) (Fig. 1).

Tab. 1: Poliennal ranges and means for biomass and N accumulations and N% content in d.m. of pure crops and mixtures grown for green manuring.

Green manure	Years	Dry matter (t ha^{-1})		N % content in d.m.		N (kg ha^{-1})	
		range	mean	range	mean	range	mean
Field bean (B)	3	4.5÷8.6	5.9	3.22÷3.95	3.54	150÷295	208
Hairy vetch (V)	5	4.2÷9.3	5.9	3.05÷4.72	3.89	166÷370	229
Rapeseed (R)	3	2.6÷9.1	5.6	1.39÷2.15	1.77	44÷127	95
Barley (B)	5	2.1÷8.8	5.3	1.13÷1.49	1.27	28÷111	67
F+R	3	5.6÷9.2	7.2	2.81÷3.79	3.32	205÷261	241
V+B	5	3.6÷8.1	6.1	1.89÷2.98	2.62	99÷241	162
F+B	1	6.7	-	2.74	-	181	-
V+R	1	9.0	-	3.23	-	289	-

Tab. 2: Poliennal ranges and means for maize N uptake at 3 growth stages after green manures and in controls (N0= unfertilised; N300= urea at 300 kg N ha^{-1}).

Green manure and controls	Years	Maize N uptake (kg ha^{-1})					
		Shooting		Flowering		Harvest	
		range	mean	range	mean	range	mean
Field bean (B)	3	73÷92	81	141÷168	152	259÷281	267
Hairy vetch (V)	5	52÷104	87	76÷231	150	162÷326	244
Rapeseed (R)	3	35÷64	54	82÷132	115	126÷181	155
Barley (B)	5	20÷45	31	46÷95	68	99÷155	123
F+R	3	65÷81	76	105÷160	146	196÷269	225
V+B	5	29÷96	71	48÷198	120	126÷262	192
F+B	1	77	-	143	-	190	-
V+R	1	106	-	214	-	246	-
N0	5	15÷62	40	50÷152	101	104÷233	164
N200	5	52÷105	82	141÷255	189	252÷316	282

Tab. 3: Poliennal ranges and means for maize N effect at 3 growth stages in green manure treatments.

Green manure	Years	N effect (kg ha^{-1})					
		Shooting		Flowering		Harvest	
		range	mean	range	mean	range	mean
Field bean (B)	2	46÷99	72	85÷86	85	151÷177	164
Hairy vetch (V)	3	-8÷108	57	16÷148	83	102÷222	161
Rapeseed (R)	2	7÷71	39	26÷49	37	22÷48	35
Barley (B)	3	-40÷39	-3	-13÷12	0	12÷56	38
F+R	2	37÷89	63	50÷77	63	92÷101	97
V+B	3	-31÷103	38	-11÷115	54	66÷153	102
F+B	1	84	-	60	-	82	-
V+R	1	113	-	131	-	137	-

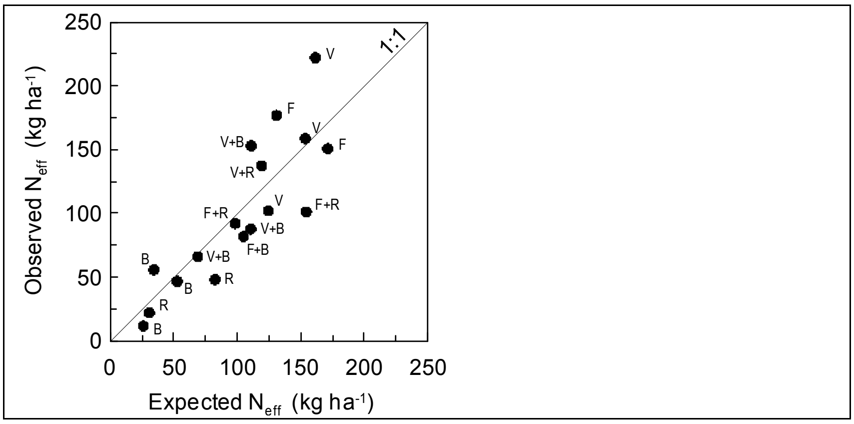

Figure 1: Observed vs expected Neff from the relation Neff = -3.9*DW + 47.8*N% (R^2=73%). Letters: V= hairy vetch, F= field bean, R= rapeseed, B= barley.

Discussion

Notwithstanding the great between-year variability, green manure species showed a clear effect on soil N management. Legumes supplied a high amount of easily releaseable N that could meet the high crop N demand of irrigated grain maize at any growth stage. Indeed, in most experiments, maize N uptake and grain yield were not statistically different from that of the mineral control (N300) (data not shown). It is worth to notice that amounts in table 1 do not take into account roots. Of legume N, the 50-83% was estimated (by difference between N accumulation in legumes and in barley) (Muller and Thorup-Kristensen, 2002) to be Ndfa and therefore added ex-novo to the system. The amount of N absorbed by non legumes is environmentally considerable as it is N temporarily withdrawn from the risk of winter leaching. However that N could not meet maize N requirement in terms of both total amount and timing of release, due to the low N concentration (and thus the high C/N ratio) in biomass. The negative values of Neff mainly recorded after barley indicate that barley caused a high pre-emptive competition (i.e. the depletion of soil Nmin) during its growth and a high soil N immobilization after its incorporation. Indeed, in most experiments maize N uptake and grain yield after barley were lower than in the unfertilised control (N0) (data not shown). However, a negative Neff was also recorded in one year in V+B and even in V at shooting, indicating that even with legumes pre-emptive competition can be high and counteract partially/temporarily the nutritional benefits of green manuring. Mixtures were generally very efficient in accumulating biomass and N, especially with unfavourable (i.e. cold and rainy) seasons, thanks to the ecological complementarity of mixed species, and in most cases the N they supplied and released was able to meet maize needs. Despite the between-year variability of Neff, the common relationship found for Neff at final harvest allows a good predictability for the N actually available from green manuring. Unfortunately, the fit of common relationships is not good at early stages, when the predictability of Neff would be more important, as maize growth and yield depends mainly on the nutritional status at that time. The better fit at final harvest is justified, because the effects of annual soil and climate conditions on green manure biomass decomposition and on maize growth could integrate and compensate over a longer time.

Conclusions

Results suggest that green manure N fertilisation efficacy for irrigated grain maize can be foreseen with good approximation on the basis of parameters (amount of incorporated biomass and its N% content) that are easy to be determined. This should help make of green manuring a more precise and reliable fertilisation technique.

Acknowledgments

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Effects of green-manure and organic fertiliser on organic maize (*Zea Mays L.*) in south Tuscany

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Key words: green manure, organic fertiliser, maize, Mediterranean organic farming

Abstract

Green-manure in Mediterranean stockless organic farms is a useful tool to improve nitrogen availability, reduce production cost and conserve soil fertility. A 2-year on farm research was carried out in Tuscany (Italy) to evaluate the effect of 3 different green manures (Hordeum v. + Avena s. mixture, Trifolium s. + Avena s. mixture, Vicia faba var. minor) and 2 levels of organic N fertilization (0 and 120 Kg N ha-1) on maize in 2004 and 2005. Green manures were ploughed into the soil in April 2004 and organic fertiliser was applied before sowing; neither green manure nor fertilizers were applied in 2005 to evaluate the residual effect of the treatments. The effect of the distribution of organic fertilizer was not efficient in comparison to green-manure. Field-bean increased maize productivity in both the years thanks to an increase in N availability as suggested by its total N uptake that exceeded the uptake of maize after control by 19.5 and 14,3 Kg N ha^{-1} in the first and second year. In our experimental conditions, with low organic matter and nitrogen content in the soil, the use of grasses as green-manure caused temporary immobilisation of N and maize yield reduction.

Introduction

Italian organic farms, as typical of Mediterranean areas, are often managed without animal husbandry. Even though the exclusion of animal husbandry turns into simplification of farm management, stockless farming systems often suffer from insufficient nitrogen availability to crops. For these reasons organic nitrogen fertilisers application is very common under Mediterranean conditions. Generally farmers prefer to use these fertilisers instead of to introduce green manure in their crop rotations. In this context, the use of green manure together with adequate residue management and crop rotation could be useful to conserve or increase soil fertility, promote nutrient cycling at farm scale and reduce the external inputs (Melero et al., 2006). The aim of this study, partly funded by ARSIA, was to evaluate the effect of 3 different types of green manure crops interacting with 2 levels of organic fertilization on the productivity of maize in 2004 and to assess the residual effect on the same crop repeated in the following year (2005).

Materials and methods

The field experiments were carried out at a farm located in Grosseto province (Tuscany, Italy), under organic management since 1989. The soil has the following characteristics: sand 57%, silt 25%, clay 18%; pH 6,1, organic matter 1,8%, total N 0,9

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‰, available P 8,3 ppm. The experimental plots (15x25m) have been realized within a farm field that has followed a 7 year crop rotation (alfa-alfa 3y - hard wheat – annual mixed grass – field bean - maize). The management of soil fertility includes recourse of commercial organic fertilisers. The field trial was laid out in a strip-plot block design with two replicates; the main factor was the green-manure specie (*Hordeum vulgare+Avena sativa* mixture, *Trifolium suarrosum+avena sativa* mixture, *Vicia faba var. minor*, control without green manure) and the secondary factor was the nitrogen fertilization: 0 and 120 kg N/ha distributed before seeding using a commercial fertilizer based on vegetable and animal organic matter material. The green-manure crops were sown the 2/10/03 after a harrowing at the following seed density: barley+oat at 100+50 Kg ha^{-1} respectively, clover+oat at 100+35 Kg ha^{-1} respectively and field faba at the rate of 200 Kg ha^{-1}. The burial of green-manure crop was done on 23/04/04 using a disk-harrow and subsequent ploughing at 35 cm deep. The sowing of maize (cv *Campanero*) took place on the 26/04/04 with an investment of 7 plant m^{-2} (70 cm inner row). Mechanical weeding has controlled weeds. None protection treatment was done, while 1500 m^3 of irrigated water was provided in 5 times. The maize was harvested the 15/10/04. At the following spring, the maize was sown the 28/04/05 after preparation of sowing bed and grown without any input of fertilizer. The green manure biomass production (DM) and N content (%) was determined before their burial; maize total biomass, grain and residue production (DM) N content were measured. Analysis of variance (ANOVA) was applied to crop yield, N concentration and uptake data using SAS statistical procedures. A strip plot design was used and least significant differences (LSD) were calculated at P≤ 0.05 to evaluate difference between means.

Results and discussion

The characteristics of green-manure crops before incorporation are shown in table 1.

Tab. 1: Green-manure crop characteristics as determined in spring 2004

	biomass (DM t ha^{-1})	N concentration (%)	N content (Kg $ha^{-1)}$)	C/N
barley + oat	9.0	0.8 *b*	72.6 *b*	49.8 *a*
clover + oat	9.3	0.8 *b*	71.6 *b*	51.9 *a*
field bean	7.4	1.6 *a*	116.7 *a*	25.4 *b*
	n.s.	*(*)*	*(*)*	*(*)*

(*) significant for P<0.05

The biomass production was not different among green-manure crops even if mixtures had a tendency to be more productive. Field bean showed a statistically higher nitrogen concentration that directly affected the N content (116 kg ha^{-1}) and the C/N ratio that was more balanced respect to the mixture. The poor results of clover+oat have to be related to the poor stand and development of the clover. The results of maize production in relation to green manure species and nitrogen fertilization in 2004 are shown in table 2. The interactions between the two factors (green-manure and nitrogen fertilizers) did not highlighted differences statistically significant between treatments. However, maize grain yields and residues productions, was positively influenced by the field bean green-manure at both levels of nitrogen fertiliser, especially at N0. Looking at the mean effects, nitrogen fertiliser had no significant influence on maize production, nitrogen concentration and uptakes. On the contrary, the effect of green-manure was decisive and meaningful for all these parameters, except for the average nitrogen concentration in maize cob. Compared to control, field bean green-manure increased maize total biomass and grain production of about 30%

and 37% respectively, while it has not produced significant increases in tissue N concentration, except for crop residues. The total N uptake of maize after field bean was much higher than the other treatments. Respect to control, the difference in N uptake was 19,5 kg N ha^{-1}. The other green-manure (barley+oat and clover+oat) have had a negative effect on maize productivity, N concentration and uptake; this effect was more evident in the barley+oat mixture. Comparing total N uptake of maize after mixtures with control (-15,9 and 22,8 kg N ha^{-1} for clover+oat and barley+oat respectively), it is possible to assume that, in our experimental context, more grass species are included in the green-manure mixture more nitrogen availability is reducing for maize. The reason for these results could be identified in the high C/N values of the green-manure biomass, which has prevented a rapid attack by the soil micro-organisms, reducing N availability for the cultivation of maize during the demanding phases of its development cycle. These assumptions are confirmed by the results of the second succession harvested in 2005 (Tab. 3).

Tab. 2: Effects of green-manure and fertilisation on maize in 2004

	DM (t ha^{-1})			N concentration (%)			N content (Kg/Ha)		
	R	G	tot	R	G	cob	R	G	tot
N0xG1	1.7	2.4	4.1	0.6	1.3	0.5	10.5	31.8	42.3
N0xG2	1.9	2.6	4.5	0.6	1.4	0.6	11.7	37.5	49.2
N0xG3	3.3	4.1	7.4	0.8	1.5	0.5	24.9	59.8	84.7
N0xC	2.6	2.8	5.4	0.7	1.7	0.6	18.7	46.4	65.1
N120xG1	1.8	2.5	4.2	0.6	1.4	0.4	10.4	35.5	45.9
N120xG2	2.3	2.7	4.9	0.6	1.4	0.5	14.2	38.5	52.7
N120xG3	2.9	4.0	6.9	0.8	1.7	0.5	21.0	67.2	88.2
N120xC	2.5	3.1	5.7	0.7	1.6	0.5	17.8	50.8	68.6
	ns	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
N0	2.4	3.0	5.4	0.7	1.5	0.5	16.4	43.9	60.3
N120	2.4	3.1	5.4	0.7	1.5	0.5	15.8	48.0	63.9
	ns	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
G1	1.7 *d*	2.5 *c*	4.2 *c*	0.6 *b*	1.4 *c*	0.5	10.4 *d*	33.7 *c*	44.1 *c*
G2	2.1 *c*	2.6 *bc*	4.7 *c*	0.6 *b*	1.4 *bc*	0.5	13.0 *c*	38.0 *c*	51.0 *c*
G3	3.1 *a*	4.1 *a*	7.2 *a*	0.8 *a*	1.6 *ab*	0.5	22.9 *a*	63.5 *a*	86.4 *a*
C	2.6 *b*	3.0 *b*	5.5 *b*	0.7 *a*	1.6 *a*	0.6	18.3 *b*	48.6 *b*	66.9 *b*
	(*)	*(*)*	*(*)*	*(*)*	*(*)*	*ns*	*(*)*	*(*)*	*(*)*

(R:residues; G:grain; G1:barley+oat; G2:clover+oat; G3:field bean; C:control; * signif. for $P<0.05$)

In the second year, the lack of positive interaction between green-manure and organic nitrogen fertilisation was confirmed as well as the lack of any positive effect of organic fertilisation on maize. According to the previous year results, the only treatment that has provoked significant effects on maize was the green-manure confirming the existence of a "residual effect". In particular, only field-bean has shown to be able to increase maize production, N concentration and uptakes in comparison with the control and the other mixture. Looking at the total nitrogen uptake, the difference between maize after field bean and the control was 14,3 kg N ha^{-1}. Considering that in the previous year this difference was 19,5 kg N ha^{-1}, it is possible to conclude that field-bean has increased nitrogen availability by about 34 kg N ha^{-1} respect to control; 58% of this amount has been used by maize the first year and 42% in the second year. The total N uptakes of the other green-manures were not different from the control while in the first year they had a lower result. This evidence would reinforce the hypothesis of N reduced availability in the short-period when high C/N biomass are incorporated into the soil.

Tab. 3: Residual effects of green-manure and fertilisation on maize in 2005

	DM (t ha^{-1})			N concentration (%)			N content (Kg/Ha)		
	R	G	tot	R	G	cob	R	G	tot
N0xG1	3.7	3.5	7.2	0.6	1.3	0.5	22.9	45.1	68.0
N0xG2	3.5	3.4	7.0	0.6	1.3	0.5	21.3	44.4	65.7
N0xG3	3.8	3.7	7.5	0.8	1.4	0.4	28.6	52.2	80.8
N0xC	3.0	2.9	5.9	0.7	1.4	0.4	21.0	41.4	62.4
N120xG1	3.7	3.6	7.4	0.6	1.5	0.5	22.5	54.2	76.7
N120xG2	3.4	3.4	6.8	0.6	1.6	0.5	21.5	53.2	74.7
N120xG3	3.8	3.6	7.4	0.8	1.7	0.5	28.5	60.9	89.5
N120xC	3.2	3.1	6.4	0.7	1.6	0.5	22.1	49.0	71.1
	ns	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
N0	3.5	3.4	6.9	0.7	1.4	0.5	23.5	45.8	69.2
N120	3.5	3.4	7.0	0.7	1.6	0.5	23.7	54.3	78.0
	ns	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
G1	3.3 *bc*	3.3 *b*	6.7 *b*	0.6 *c*	1.4 *b*	0.5	20.5 *b*	46.3 *b*	66.7 *b*
G2	3.5 *ab*	3.4 *b*	6.9 *b*	0.6 *c*	1.4 *b*	0.5	21.4 *b*	48.9 *b*	70.3 *b*
G3	3.7 *a*	3.6 *a*	7.3 *a*	0.8 *a*	1.6 *a*	0.5	28.1 *a*	56.6 *a*	84.7 *a*
C	3.2 *c*	3.1 *c*	6.3 *c*	0.7 *b*	1.5 *a*	0.5	22.9 *b*	47.5 *b*	70.4 *b*
	(*)	*(*)*	*(*)*	*(*)*	*(*)*	*ns*	*(*)*	*(*)*	*(*)*

(R:residues; G:grain; G1:barley+oat; G2:clover+oat; G3:field bean; C:control; * signif. for $P<0.05$)

Conclusions

The results show the high value of the green-manure for the soil fertility of Tuscan stockless organic farms. The green-manure, in fact, is able to improve the availability of nitrogen for cash crops in succession even in the absence of fertilization. The effect of the distribution of organic fertilizer was not efficient in comparison to green-manure, showing small increases of production even at the highest level. In our experimental conditions, characterised by low organic matter and nitrogen content in the soil, the use of grasses as green-manure caused temporary immobilisation of N. The proper choice of the green-manure species adapted to the local environment is very important for organic farming both from the scientific and the technical point of view.

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Natural biofertilizers for organic agriculture: productivity and nutrient uptake of *Medicago sativa* inoculated with different arbuscular mycorrhizal fungi

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Key words: arbuscular mycorrhizas, *Glomus mosseae*, *Glomus intraradices*, phosphorus uptake, nitrogen uptake

Abstract

Arbuscular mycorrhizas are symbiotic associations that play a key role in plant nutrition by absorbing and translocating mineral nutrients from soil to host plants. Arbuscular mycorrhizal fungi, which are considered natural biofertilizers, show diverse levels of performance, depending on the ability of different isolates to promote plant growth and health. Here we investigated the performance of geographically different isolates of two fungal species, Glomus mosseae *and* G. intraradices*, by assessing plant growth responses and P and N uptake in* Medicago sativa*, in order to select the most efficient fungi for this host plant. The four selected* Glomus *isolates significantly increased shoot dry weights and shoot N and P content of mycorrhizal plants, but their performances were different. In particular,* G. intraradices *IMA6 significantly differed from* G. mosseae *IMA1 in inducing larger growth responses relative to all parameters measured.*

Introduction

Arbuscular mycorrhizas are symbiotic associations established between fungi belonging to the Phylum Glomeromycota and the roots of most land plants. They play a key role in plant nutrition, since plants receive mineral nutrients, such as P, N, S, K, Ca, Fe, Cu, and Zn, that are absorbed and translocated by extraradical hyphae of these fungi, which spread from mycorrhizal roots into the surrounding soil. Thus, arbuscular mycorrhizal (AM) fungi are considered natural biofertilizers (Smith & Read, 1997). However, AM fungi show diverse levels of performance, depending on the ability of different isolates to promote plant growth by improving mineral nutrition and by increasing tolerance to biotic and abiotic stresses (Giovannetti & Avio, 2002; van der Heijden et al., 1998; Avio et al., 2006). Therefore, selection of mycorrhizal endophytes based on their physiological characters represents a fundamental step for practical utilization of AM fungi. Here we investigated the symbiotic performance of four geographically different isolates of two globally distributed AM fungal species, *Glomus mosseae* and *G. intraradices*, by assessing plant growth responses and P and N uptake in *Medicago sativa* (lucerne), a mycotrophic plant species highly dependent on mycorrhizal symbiosis, particularly in nutrient-poor soils.

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Materials and methods

The AM fungi used were: *G. mosseae* (Nicol. & Gerd.) Gerdemann & Trappe, isolate IMA1 from UK and isolate AZ225C from USA, and *G. intraradices* Schenck & Smith, isolate IMA5 from Italy and isolate IMA6 from France. The plant species used was the forage legume *Medicago sativa* cv. Messe.

Seeds of *M. sativa* were planted into 600 ml plastic pots containing a mixture (1:1) of a sandy loam soil and Terragreen (a calcinated clay). The mixture was steam-sterilized to kill naturally occurring AM fungi. Pots were inoculated either with 90 ml of crude inoculum (mycorrhizal roots and soil containing spores and extraradical mycelium) of one of the four fungal isolates, or with 90 ml of a sterilized mixture of them (non-mycorrhizal control). All the pots received 120 ml of a filtrate obtained by sieving a mixture of the four inocula and of agricultural soil from a *M. sativa* field, through a 50-μm diameter pore sieve, to ensure a common microflora for all treatments. After emergence, seeds of *M. sativa* were thinned to 10 per pot. Plants were grown in the greenhouse, supplied with tap water as needed and with a weekly fertilization of half-strength Hoagland's solution (10 ml per pot). The experiment was a completely randomized design with 5 inoculum treatments (fungal isolates and the control) and 5 replicates. Three months after emergence, plant shoots were harvested by cutting them 1 cm above the soil level, and *M. sativa* dry weights determined after drying at 95° C for 48 h. Percentage of AM colonisation and total root length were assessed on half of each root system after root staining, using the gridline intersect method.

P concentrations of shoots were measured after sulphuric/perchloric acid digestion using the photometric method. Tissue N concentrations of shoots were assessed using the Kjeldahl method. The total P and N contents were calculated by multiplying P and N concentration values by dry weights.

Analysis of variance (ANOVA) was performed with SPSS 11.0 software after the necessary transformations, and differences between means were determined by the appropriate test. Tukey's B procedure was used for comparing means.

Results

The four *Glomus* isolates successfully established mycorrhizal symbioses with *M. sativa*, while no colonization was observed in the uninoculated plants. Shoot dry weights (SDW) were significantly higher in mycorrhizal plants, and since nutrient concentrations were also higher in inoculated plants, shoot N and P contents of inoculated plants increased by much more than did SDW (Fig. 1). In fact, the mean increase of SDW in mycorrhizal plants was 105%, while increases of N and P content were 135% and 216%, respectively. Although all AM fungal isolates used in this study produced positive growth responses in *M. sativa*, they affected the host differently: *G. intraradices* isolate IMA6, which was the best-performing fungal endophyte, produced increases in shoot dry weight and N and P content that were consistently higher than with *G. mosseae* isolate IMA1 (Fig. 1).

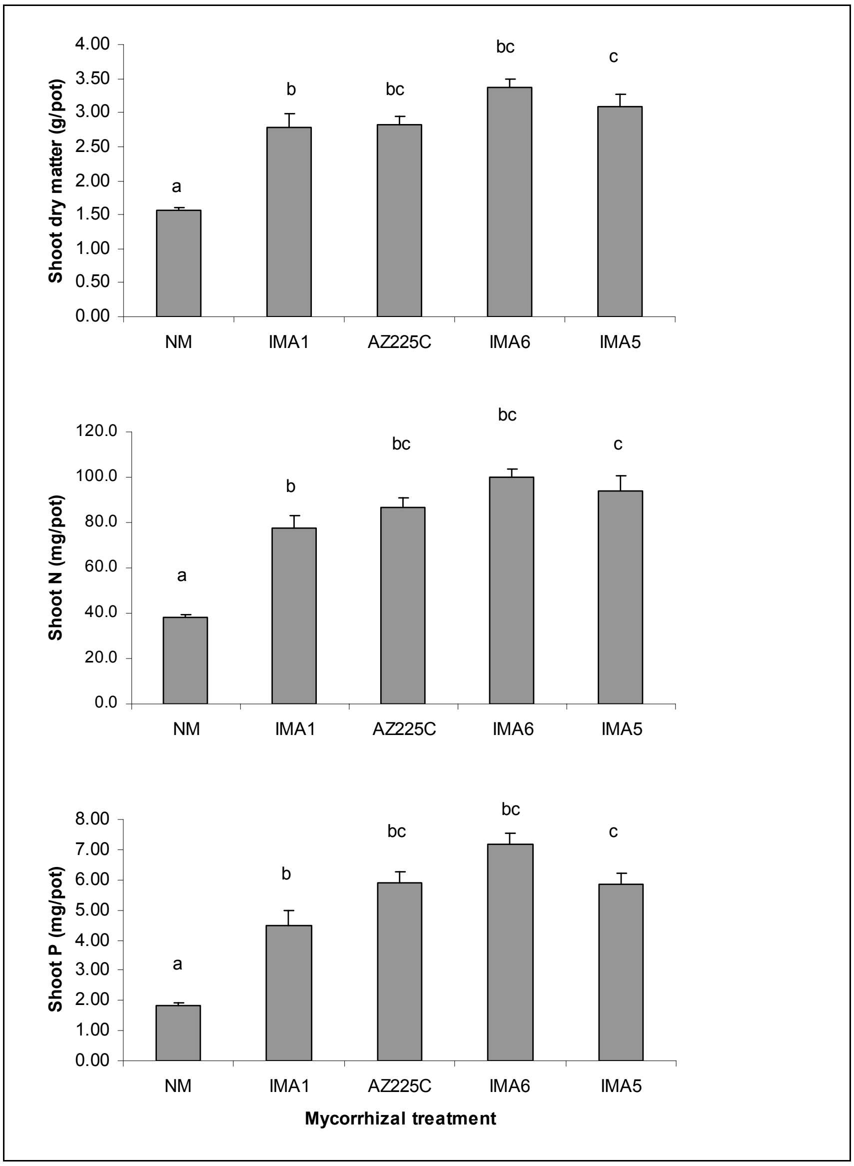

Figure 1: Shoot response variables of *Medicago sativa* inoculated with isolates of *Glomus mosseae* (IMA1 and AZ225) and *Glomus intraradices* (IMA6 and IMA5) or not inoculated (NM). Different letters above bars indicates significant difference, P < 0.05. Error bars show ± SEM.

Discussion

This work shows that different AM fungal isolates differ in their ability to increase the growth and P and N nutrition of *M. sativa* plants, thus contributing to enhanced nutritional quality of this forage crop. In particular, a *G. intraradices* isolate (IMA6) showed a better symbiotic performance than a *G. mosseae* isolate (IMA1). Interestingly, the latter isolate, in a previous comparison with the same isolate of *G. intraradices* on a different lucerne variety, was the less-performing endophyte (Vasquez et al., 2001). The isolates of *G. intraradices* and *G. mosseae* used in this work have different patterns of extraradical mycelial growth, as measured by hyphal length and density or by the number of anastomoses (Avio et al., 2006). Interestingly, *G. intraradices* IMA6 produced the highest values for all parameters related to extraradical fungal growth (Avio et al., 2006). These data are in agreement with the suggestion that size and developmental patterns of soil-exploring mycelium are important factors in AM fungi efficiency (Jakobsen et al., 1992), although other fungal traits may play a role, such as spatial distribution of hyphae or uptake efficiency of hyphal Pi transporters (Smith et al. 2000; Munkvold et al., 2004).

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How Perennial Grass has Modified Distribution of Organic Carbon in a Peach Orchard in Emilia-Romagna Region (Italy)

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Key words: Organic Carbon, Humification Parameters, DRIFT, TG-DTA

Abstract

In this study, the distribution of the total and humified organic carbon in a peach orchard tilled-irrigated on the row and perennial grassed on the inter-row space after 16 years of cultivation were evaluated. The TOC has shown differences not statistically significant in the 0-20 cm horizon, whereas the difference in the row vs. inter-row 20-40 cm horizon was significant. The highest content of humic substances was found in the 0-20 cm of the inter-row with perennial grass vs. row tilled soil: the absence of tillage increases the accumulation of humified compounds. DRIFT and TG-DTA analysis pointed out only some small structural variation in the humic fraction of the samples taken from the layer at depth 20-40 cm.

Introduction

Cultivation practices in agricultural systems have remarkable influence on dynamic of soil organic carbon (Francioso et al., 2000; 2005a; Gioacchini et al., 2006). Sowings, perennial grass species and irrigation, among the others, are the major factors affecting the dynamic of the organic carbon in orchards. Perennial sods prevent soil erosion, improve traffic conditions, enhance water infiltration into the soil, suppress pests, interact with beneficial organisms, modify orchard temperatures and light conditions for improved fruit quality, reduce dust and mite infestations, and provide substrate or food and habitat for a multitude of soil-borne organisms. The adoption of different soil management can contribute to the soil carbon sequestration and distribution in soil profile (Lal, 2002) to mitigate the greenhouse effect (Lal, 2003). Perennial grass species can contributes to the formation of a soil horizon reach in organic carbon in the top layer (Wedin et al., 1995).

Aim of this study was to measure the distribution of the total and humified organic carbon in a peach orchard tilled-irrigated on the row and perennial grassed on the inter-row space after 16 years of cultivation using chemical analysis, infrared spectroscopy and thermogravimetric (TG) and differential thermal analysis (DTA).

Materials and methods

Soil samples (Typic Xerochrept) were taken in a 16-years peach orchard farm located in Roncadello (Forlì-Cesena province), Emilia-Romagna Region (Italy). Samples were collected in August 2005, after harvest, from plots at two depth (0-20 and 20-40 cm) along the row (tilled soil) and in the inter-row space (perennial grassed with different

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Graminaceae species). Soil samples were air dried, crushed to pass a 2 mm sieve and stored in sealed bags. In the last decade the mean annual fertilisation added was 40 kg N ha^{-1} of organic N fertiliser. The main physical-chemical characteristics of the soil were: pH (in water) 7.24; texture: sand 25%; silt 35%; clay 40%; total calcium carbonate ($CaCO_3$) 110 g kg^{-1}; cation exchange capacity 25 $cmol_c$ kg^{-1}; TOC 9.5 g kg^{-1}; TKN 1.3 g kg^{-1}; Olsen-P 18 mg kg^{-1}; Exchangeable-K 170 mg kg^{-1}.

Total (TOC), extracted (TEC), humified (HA+FA) and non humified organic carbon (NH) were determined according to Ciavatta et al. (1997) method. DRIFT and TG-DTA analysis were performed on humic acids extracted from soil samples. DRIFT spectra were recorded with a Nicolet Impact 400 FT-IR Spectrophotometer (Madison, WI) equipped with an apparatus for diffuse reflectance (Spectra-Tech. Inc., Stamford, CT), according to Francioso et al. (2001) method. TG-DTA curves were carried out simultaneously using the TG-DTA92B (Setaram- France) device. Sperimental conditions: heating rate 10°C min^{-1} from 30 to 750 °C, in air atmosphere and calcinated kaolinite was used as reference material.

Results and discussion

TOC, TEC, HA+FA, NH, the degree of humification [DH% = TEC/(HA+FA) x 100] and the humification rate [HR% = TOC/(HA+FA) x 100] are shown in figures 1-2. The TOC has shown differences not statistically significant in the 0-20 cm horizon, whereas the difference in the row *vs.* inter-row 20-40 cm horizon was significant (Fig. 1). The phenomenon can be reasonably due to the irrigation that induces a higher microbial activity that increases the amount of TEC as well. On the contrary, a highest content of humic substances (HA+FA) was found in the 0-20 cm of the inter-raw with perennial grass *vs.* row tilled soil: the absence of tillage increases the accumulation of humified compounds. The values of humification parameters DH and HR were higher in the 0-20 cm horizon of the inter-row with perennial grass *vs.* the row (Fig. 2): similar differences were observed at 20-40 cm depth. The role of perennial grass, among the others agronomic properties, is to increase the TOC and the humification level, as well shown by the increase of the DH and HR in the top layer (0-20 cm). From a quantitative point of view, it can be calculated that a concentration of 1 g kg^{-1} of soil humic C corresponds to 2.5 tons ha^{-1}, assuming a soil depth of 20 cm and density of 1.25 kg dm^{-3}.

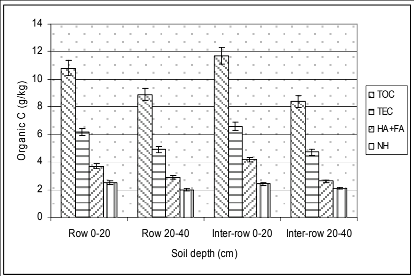

Figure 1: Total (TOC), extracted (TEC), humified (HA+FA) and non humified C (NH) of soil samples taken at 0-20 and 20-40 cm depth (row andin

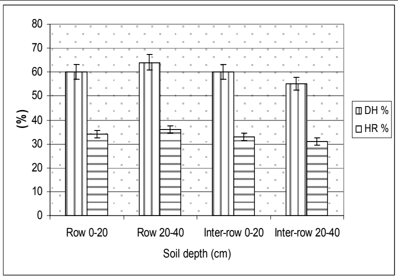

Figure 2: Degree (DH) and humification rate (HR) of soil samples taken at 0-20 and 20-40 cm depth (row and in the inter-row

inter-row space).	**space).**

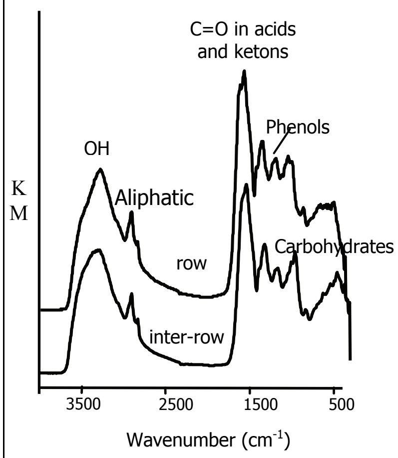

Figure 3: DRIFT spectra of the humic fraction of samples taken from the layer 20-40 cm along the row and in the inter-row space.

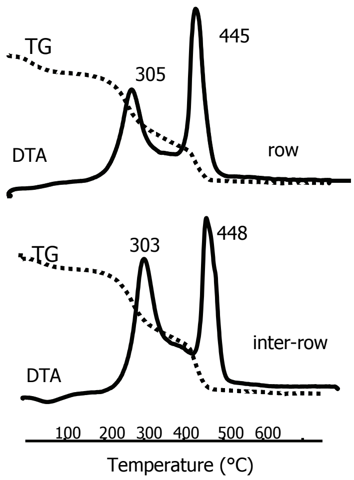

Figure 4: TG-DTA curves of the humic fraction of samples taken from the layer 20-40 cm along the row and in the inter-row space.

DRIFT spectra of humic fraction (HA) of soil taken from the top layer at depth 0-20 cm along the row and inter-row space did not show significant structural modifications due to treatment (data here not shown). Instead some small structural variation can be observed in the humic fraction from the samples taken from the layer at depth 20-40 cm (Fig. 3). The main modification might be assigned to different amount in carbohydrates content (Francioso et al., 2001). These results were supported by TG-DTA analysis (Fig. 4) as revealed by higher exothermic reaction at around 300 °C in inter-row sample (20-40 cm) than that found in row samples. This peak was mainly produced by the combustion of carboxylic groups and carbohydrates suggesting the formation of recent organic carbon (root exudates, microbial cells). The second peak at around 450 °C was typical of high resistant temperature components such as aromatic structures (Francioso et al., 2005b).

Conclusions

After 16 years of cultivation the distribution of TOC in a peach orchard tilled-irrigated on the row and perennial grassed on the inter-row space did not show statistically significant differences in the 0-20 cm horizon, whereas the difference in the row *vs.* inter-row 20-40 cm horizon was significant. The highest content of humic C was found in the 0-20 cm of the inter-row with perennial grass *vs.* row tilled soil suggesting that the absence of tillage increases the accumulation of humified carbon. Moreover the presence of slight structural modifications in the humic fraction from the layer 20-40 cm along the inter-row space may suggest the influence of the activity of the roots.

Acknowledgments

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The effect of green manure on root development and cotton yield under Mediterranean conditions

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Key words: green manure, cotton, vetch, faba bean, organic agriculture, roots

Abstract

Two experiments were conducted in Greece, during the years 2005 and 2006, in order to evaluate the effect of two legumes (vetch: Vicia sativa and faba bean: Vicia faba) on the root development and yield of the following cotton. Concerning the cotton cultivation the Organic Agriculture guidelines were followed. In both years the higher values of the root characteristics of the cotton were found in the plots where vetch had been incorporated. The seed cotton yield for vetch was 2850 and 3137 kg ha^{-1} in 2005 and 2006, respectively. Furthermore, in both years, a statistically important factor of correlation, between the nitrogen quantities of the soil and the seed cotton yield, had been appeared.

Introduction

The conventional agricultural methods created a lot of environmental problems. For solving these problems different approaches have been developed, such as organic farming (Scofield 1986), which consists of a rapidly developing agricultural sector.

The use of green manure is one of the basic cultivation techniques of Organic Agriculture (OA). The legumes can be used as green manure thanks to their ability to fix atmospheric nitrogen (Hardarson and Atkins 2003). Rochester et al. 2001 reported the positive effect of legumes used as green manure to the yield of various crops. Cotton (*Gossypium hirsutum*) is one of the most profitable irrigated summer plants in Greece, thus it has high economic value (Karamanos et al. 2004).

During this study the effect of two legumes used as green manure (vetch: *Vicia sativa* and faba bean: *Vicia faba*) on root development and yield of the following cotton, in an organic farming system, has been examined.

Materials and methods

The experiments were carried out in 2005 and 2006 at the organic research farm of the Agricultural University of Athens. The experimental design was based on a randomized complete blocks design consisted of three treatments and four replications. The three treatments were: fertilization (green manure) with vetch, faba bean and control (no fertilizer). Moreover the soil type was clay loam.

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The cotton seeds (*G. hirsutum cv*. Fantom) were hand sown in rows of 80 cm apart, at the recommended seed rate, vetch (*V. sativa cv*. Alexandros) and faba bean (*V. faba cv*. Grande Aquadulce) and had been incorporated into the soil as green manure for the cotton plants. The nitrogen quantities which were added to the soil, due to the legumes, are presented in Tab. 2. The total nitrogen was determined by using the Kjedahl method (Bremer 1960).

All plots were harvested manually at the recommended seed cotton moisture percentage in order to determine the seed cotton yield. Root samples were taken 104 and 94 days after the cotton sowing, during the years 2005 and 2006, from the 0-12.5 cm soil layer using a cylindrical auger. The roots were dried, weighted for their dry matter and put into a high resolution scanner to determine their root characteristics.

The data was subjected to the analysis of variance appropriate to the experiment design. Significant differences between the treatments means were separated by means of the least significant difference (LSD) at the 5% level of probability, using the "Statistica" program for windows.

Tab. 2: Total nitrogen (from shoots and roots) added to the soil by legumes for the culture of cotton during 2005 and 2006.

Treatment	Total nitrogen in $Kg.ha^{-1}$ (Shoots+Roots)	
	Year 2005	Year 2006
Vetch	211	230
Faba bean	205	217
$LSD_{(5\%)}$	5.87	12.7

Results and Discussion

During both years, in 0-12.5 cm soil surface depth, the highest values of root dry weight, surface area and density of cotton plants (tab. 3 and tab.4) were observed in the plots where vetch had been incorporated. On the other hand the lowest values were observed in the control plots. The results indicated significant differences between control and green manure, but no significant differences between vetch and faba bean. The interaction between the two years was not statistically significant.

Same tendencies were observed regarding the seed cotton yield. Specifically during 2005 and 2006 the highest values of seed cotton yield were observed in the plots where vetch had been incorporated (2850 and 3137 kg ha^{-1} for 2005 and 2006, respectively) followed by faba bean (2647 and 2958 kg ha^{-1} for 2005 and 2006, respectively) and control (2185 and 2337 kg ha^{-1} for 2005 and 2006, respectively) plots in decreasing order. Between green manure types there were no statistically significant differences observed in contrast to the green manure and control which indicated statistically significant differences (Table 4). The interaction between the two years was not statistically significant.

Tab. 3: The effect of green manure type on root dry weight (kg ha^{-1}), length density (cm cm^{-3}), diameter (mm) and surface area (cm^{-2} cm^{-3}) of cotton plants, in 0-12.5 cm soil depth, for 2005.

Characteristic (cotton)	Green manure type			
	Control	Faba bean	Vetch	LSD(5%)
Dry weight of roots	2819	3737	3986	695
Length density of roots	2.90	3.51	3.84	0.54
Diameter of roots	0.40	0.44	0.48	0.045
Surface area of roots	0.061	0.089	0.107	0.026

Tab. 4: The effect of green manure type on root dry weight (kg ha^{-1}), length density (cm cm^{-3}), diameter (mm) and surface area (cm^{-2} cm^{-3}) of cotton plants, in 0-12.5 cm soil depth, for 2006.

Characteristic (cotton)	Green manure type			
	Control	Faba bean	Vetch	LSD(5%)
Dry weight of roots	2777	3875	4170	831
Length density of roots	2.79	3.65	3.88	0.65
Diameter of roots	0.45	0.61	0.58	0.10
Surface area of roots	0.057	0.097	0.102	0.028

The seed cotton yield appears to be related to the nitrogen that was added in the soil by the green manure. Furthermore the nitrogen added to the soil by vetch was 211 and 230 kg ha^{-1} for 2005 and 2006, respectively (Tab. 2). Moreover, during 2005 and 2006, a statistically important factor of correlation (r=0.95 and r=0.96*, n=3), concerning the quantities between the nitrogen in the soil and seed cotton yield, was observed.

In most of the root characteristics the supremacy of cotton plants that have been cultivated after the incorporation of vetch, was explicit thanks to the larger quantity, and perhaps better availability, of nitrogen in the first stages of their growth (tab.3 and tab. 4).

* Significant at the 0.05 probability level

Tab. 5: The effect of green manure type on seed cotton yield (kg ha^{-1}) of cotton plants, for 2005 and 2006.

Cotton yield	Green manure type			
	Control	Faba bean	Vetch	$LSD_{(5\%)}$
2005	2185	2647	2850	387
2006	2337	2958	3137	475

The larger root surface area of the cotton plants after the vetch incorporation is related to the absorption of more water and through this of nutritious elements (Russell and Clarkson 1976). Karamanos et al. (2004) reported that the growth of the cotton crop root system was due to the positive effect of legumes used as green manure, as their incorporation improved the chemical and physical properties of the soil. Moreover the positive effect of the legumes on the subsequent crop yields was due to the soil enrichment with nitrogen after the incorporation of legume plant residues (Senaratne and Hardarson 1988).

Conclusions

In conclusion, the application of the green manure had a positive effect on the root growth and yield of the following cotton crop, for both years, but the differences between the cropping systems (vetch-cotton and faba bean–cotton) were not significant.

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Quality assessment of citrus-processing industry waste compost for organic and conventional farming

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Key words: Compost, Organic Farming, citrus-processing,

Abstract

The aim of the work was to verify the potential of citrus by-products for the production of a quality compost to be used in both conventional and organic farming. Two different composts were produced utilizing Pastazzo (mixture of citrus pulp and skins). One of them, to be used in conventional farming, was prepared adding sludges obtained from citrus industry waste water treatment to pastazzo. The other one, whose final destination was organic farming, was produced without the addition of sludge as starting raw material. Chemical parameters were used to evaluate the characteristics of the final product. Results obtained demonstrated that organic residues from citrus-processing industry could be considered as raw materials for the production of quality composts for both conventional and organic farming.

Introduction

In Italy, citrus-processing industry has increased its importance during the last ten years. The main product of the industrial process is the juice (35-45% of total weight of fresh product), while the main by-products are represented by pastazzo, a mixture of citrus pulp and skins (60% of fruit weight), and a significant amount of sludges obtained by industrial waste water treatment.

In order to solve the economic and environmental problem connected to the large amount of by-products obtained (600.000 t of pastazzo y-1) a sustainable approach to waste management should be identified. Compost processing is a potential technology to recycle organic matter component of these by-products.

The main aim of the work was to verify the potential of citrus by-products for the production of a quality compost. Moreover, since in organic farming sludges are not allowed, we wanted to verify the technical feasibility of compost production by the utilization of pastazzo and pruning materials.

Materials and methods

The composting trials were performed in the Experimental farm of CRA-ACM. Two different compost heaps were set up. The first one, to produce compost for conventional agriculture (C-conv), was prepared mixing pastazzo (40%) (w/w), sludge (20%) and pruning materials (40%). The other one, to be used in organic farming (C-

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org) was obtained mixing pastazzo (60%) and pruning materials (40%), without the addition of sludge.

Compost samples were taken from each pile at prefixed time. In details: just after the mixing of the raw materials, at starting of compost process(T0) and after 29 (T1), 67 (T2), 89 (T3), 130 (T4) e 165 days (T5). Samples were dried in oven at 50°C, ground and sieved at 1 mm and then stored for subsequent analysis.

Each sample was analyzed to determine total N, total organic carbon (TOC), total extractable carbon (TEC) and humic and fulvic like carbon (CHA+FA) In addition, the isoelectric focusing (IEF) in a polyacrylamide slab gel with a preformed pH gradient was performed in order to separate organic compounds, according to their isoelectric point and their electrophoretic mobility (Govi et al., 1994).

In order to determine the humic and fulvic like carbon (CHA+FA) and to perform the IEF profile, organic matter was extracted from samples in a solution of NaOH/Na4P2O7 0.1 N (2g in 100 mL) for 48 hours at 65°C. The humic acids were then precipitated by 0,5 N H2SO4 at pH 2. The fulvic acids were purified on a polyvynilpyrrolidone column and then joint to humic fraction (HA+FA) following the procedure proposed by Ciavatta et al. (1990). Degree of humification (DH%) and humification rate (HR%) were calculated according to Ciavatta et al. (1990) as follow:

DH% = (CHA+FA $\times$ 100)/TEC HR% = (CHA+FA $\times$ 100)/TOC

On T5 samples, obtained at the end of the composting process, the following parameters were determined: total P2O5 (%), total K2O (%), total Cd, Hg, Cu, Zn, Ni, Pb, Cr (VI) (mg kg-1) by atomic absorption.

Results

Table 1 reports the main physical-chemical characteristics of the two composts produced and, in order to allow an easy comparison of the values with the applicable legislative limits, the values imposed by Italian legislation (Lgs.D. 217/2006).

In table 2 quality and quantity parameters of compost organic matter, sampled during the composting process, are reported. The C/N ratio shows a decrease over time, while DH % and HR % presented an increasing trend. Figure 1 reports the IEF profiles of samples T0-T5 for C-conv and C-org. In C-conv the IEF profiles showed a sharp peak at pH 3.5 while in C-org its area decrease starting from T1 profile. For both the composts the IEF profiles, from T1 to T5, resulted better resolved in the pH range 4.2-4.7. Number and the area of the peaks focused at pH>4.7 increased over time.

Discussion

Both the composts produced complied with the limits imposed by Italian legislation concerning compost allowed in conventional and organic farming (table 1). The differences between C-conv and C-org regarding ashes and TOC could be explained considering that C-conv contained sludges, which are generally characterised by a high value of ashes and, consequently, a relatively low content of TOC. Similarly, can be explained the higher value in P_2O_5 of C-Conv. As far as heavy metals content is concerned, both composts presented low absolute values, complying with the national legislation. In addition, excluding Zn and Cd which are significantly higher in C-conv than in C-org, the two composts showed similar values.

Tab. 1: Chemical-physical characteristics of C-conv and C-org and limits of the Italian legislation.

Parameter	C-conv	C-org	IT Limits (Lgs.D. 217/06)
pH	8.4	8.5	6-8,5
Ashes (%)	37.5	24.6	-
TOC (%)	31.0	37.7	>25
Total N (%)	2.8	2.5	-
P_2O_5 (%)	2.3	0.7	-
K_2O (%)	0.8	0.7	-
C/N	12	14	<25
C_{HA+FA} (%)	14	18	>7
Total Cadmium (mg kg^{-1})	1.5	<0.5	<1,5
Total Mercury (mg kg^{-1})	<0.1	<0.1	<1,5
Total Copper (mg kg^{-1})	37	32	<150
Total Zinc (mg kg^{-1})	320	99	<500
Total Nickel (mg kg^{-1})	31	20	<100
Total Lead (mg kg^{-1})	10	13	<140
Hexavalent Chromium (Cr VI) (mg kg^{-1})	-	-	<0,5
Electric conductivity (dS m^{-1})	2.08	1.78	-

Tab. 2: Total organic carbon (TOC), humification rate (HR), humification degree (HD) and C/N ratio of the samples collected during the composting process.

	TOC (%)		HR %		DH %		C/N	
Sample	C-con	C-org	C-con	C-org	C-con	C-org	C-con	C-org
T0	45.0	49.8	22	23	57	64	31	37
T1	38.7	45.8	31	31	73	86	16	23
T2	37.2	43.5	34	36	78	88	14	17
T3	34.4	41.9	36	38	76	83	13	16
T4	35.2	38.5	40	42	72	85	12	14
T5	31.0	37.7	47	47	74	90	12	14

Results about C/N ratio and the different C fractions evolution during composting process (table 2) gives information about the appearance of more stabilised humic like substances. The C/N ratio decreased starting from T0, while DH% and HR % increase over time. In addition, DH% values were higher in C-org than in C-conv.

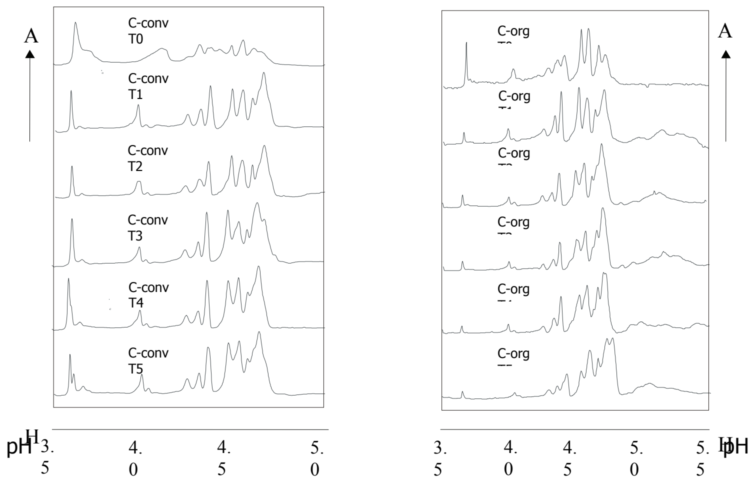

Figure 1: IEF profiles of investigated compost samples.

Isoelectrofocusing profiling technique, which allows evaluation of organic matter during the composting process from a qualitative point of view, showed an increase of complexity of organic fractions over time, as demonstrated by the larger size and number of peaks focused at pH higher than 4.7 (indicating more humified material) and by the decreasing of peaks focused at lower values of pH (Figure 1).

Conclusions

The low content of potential toxic elements and the positive properties of organic matter of the two composts produced allow affirms that the citrus-processing industry wastes can be utilized for a quality compost production (Tittarelli et al., 2007). Moreover compost obtained without sludges, depending on its qualitative-quantitative characteristics, can be utilized in organic farming.

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Controlling insect pests of stored organic chamomile by controlled atmospheres

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Key words: Carbon dioxide, chamomile, modified atmosphere, population dynamics.

Abstract

Different stages of Trupanea stellata *and* Lasioderma serricorne *were exposed to four different gas mixtures differing in their CO_2 content (20%, 40%, 60% and 80% CO_2). In general, increase in carbon dioxide combined with decrease in oxygen resulted in increasing mortality. The gas mixture containing 80% CO_2 was the most effective mixture to control the different stages of* T. stellata *(most tolerant than the different stages of* L. serricorne insects*). The use of this gas mixture to disinfest chamomile for 7day exposure in 30 m^3 fumigation chamber under temperature range between 28.7-30.9°C, resulted in complete control.*

Introduction

Chamomile (*Matricaria chamomilla L)* is produced in Egypt using the organic farming system. Most of this product is for export to the European and American markets, in which the major constraints for exportation are the detection of either insect infestation or pesticide residues, of any other chemical. Chamomile is exposed during flowering in the field to attack by the chrysanthemum fly *Trupanea stellata* (F.) and during drying, processing and storage to attack by the cigarette beetle *Lasioderma serricorne*

The classic way to control these insects has been and still by the use of fumigants such as methyl bromide (CH_3Br) and phosphine (PH_3), which are not allowed for treatment of organic products. Recent work in many countries has focused on the possibility of using the inert gases (CO_2 and/or N_2) as an alternative for chemical fumigants. This method of treatment is commonly termed modified atmosphere (MA) or controlled atmosphere (CA) (Reichmuth 1992).

This work reports on the population dynamics of *T. Stellata* under field conditions and tests of susceptibility of different stages of *L. serricorne* and *T. stellata* to different mixtures of CO_2, N_2 and O_2 under laboratory conditions and large scale conditions.

Materials and methods

The population dynamics of *T. Stellata* were carried out in Fayoum region in the winter season 2006/2007. Samples of 400 chamomile flowers were collected weekly, randomly for investigation. To examine the different stages found inside the flowers, each flower was examined under stereomicroscope after dissection. The number of larvae, pupae and infested flowers were recorded.

The Susceptibility of different stages of *L. serricorne* and *T. Stellata* to alterations of atmospheric gas concentration has been studied using the parental insects of *L.*

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serricorne, which were obtained from infested chamomile and reared on chamomile powder at 30^{o}C □ 2^{o}C and 70% □ 5% r.h. All stages except eggs were prepared for treatments. Trials were carried out on one week old adults, 3rd larval instars and 2-3 days old pupae of *L. serricorne*. The experimental unit for *L. serricorne* was 50 individual of each stage; and for *T. Stellata;* 50 dried chamomile flowers. Each unit of *L. serricorne* was prepared in a cylindrical cage (6 cm high and 1.5 cm diam.) made from 40 mesh stainless-steel wire gauze closed with rubber foam. Each 50 dried chamomile flowers was placed in small paper bag. Cages containing the different stages were introduced into a bottle of dressel flask (Hashem 2000).

The tested atmospheres were prepared from CO_2, O_2, and N_2. This component was monitored using a paramagnetic oxygen analyzer (SERVOMEX/ England). To improve distribution of the components, the cylinders with gas mixtures were kept at room temperature for two days before starting the experiment. The gas mixtures tested were: a. 20% CO_2, 64% N_2 and 16% O_2; b. 40% CO_2, 48% N_2 and 12% O_2; c. 60% CO_2, 32% N_2 and 8% O2; d. 80% CO_2, 16% N_2 and 4% O_2. Different stages in gastight connected dressel flasks were exposed to the gas mixtures from mixture cylinder through copper tubes and a humidifying unit containing saturated NaCl/H_2O solution in flasks, to create 70% R.H. At the outlet of the containers the O_2 content was determined continuously by an oxygen analyzer. After about 15 min. (time for about 10 replacements of total container volume by gas mixture) the outlet concentration became identical with the inlet concentration. After different exposure periods ranging from 1-4 days, each bottle was aerated and the insects transferred from the cages to Petri-dishes and held at 30^{o}C□2^{o}C and 70%□5% R.H. The adults were examined for mortality, and the pupae of *L. serricorne* were examined for adult emergence. Also the chamomile flowers were examined for adult emergence of *T. Stellata*. Each sample was accompanied by an untreated control. The experiments were designed to provide time-mortality regression lines for the different stages in various combinations of atmospheric gases and different exposure periods. Moralities of *L. serricorne* adults were corrected by Abbotts formula (Abbott, 1925), and Data was subjected to probit analysis (Finney, 1971) to calculate the slopes of regression lines and the values of LT_{50} and LT_{99},

The large scale application of the most efficient CO_2 -concentration carried out in 30 m^3 fumigation chamber (2.5 m high x 3 m width x 4 m long) which built at SEKEM Co. for biological products. The roof, walls and the interior side of the door were lined with aluminium sheets (150 □ thick) and the floor was covered with stainless-steel sheet (1mm thick). The door of the chamber has two openings; a lower opening for gas input and an upper opening for gas output. To ensure the air tightness of the chamber, all fill spouts, door margins and manholes, were sealed with duct tape. The pressure test to determine the efficacy of fumigation in the buildings, chambers and stores against stored product insect pests was applied before introducing CO_2 (Reichmuth, 1992).

A quantity of infested 1500 kg chamomile (in boxes) was put in the chamber. Twelve cages of different stages (50 individuals/ cage/stage) of *L. serricorne* were placed in wire cages to monitor insect mortality within the treated product. The same number of additional cages (prepared as described above) was pushed in untreated products to serve as controls. Small paper bags of 50 infested chamomile flowers with *T. stellata* each were placed also within the treated product to monitor the insect mortality after treatment. To measure the temperature and relative humidity throughout the test, a thermo-hygrograph was installed in the centre of chamber.

After exposure, each stage of the two insects was transferred from the cages to a Petri dishes and held at $30^{o}C \pm 2^{o}C$ and 70%±5% R.H. At 48 hours after exposure, the stages were examined for mortality. The criterion of dead larvae and pupae was its failure to develop to adults. At the same time, the infested chamomile flowers samples were examined to evaluate the survival stages of *T. stellata*.

Results and Discussion

Fig. (1) shows population dynamics of larvae, pupae/400 chamomile flowers as percentage of infestation. The obtained results show that the variations in the population density of larvae and pupae of *T. stellata* fluctuated from time to another.

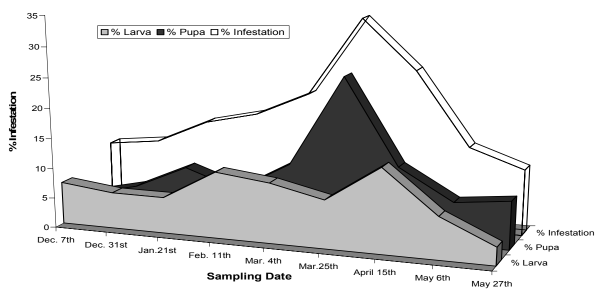

Figure 1: The percentage of infested chamomile flowers by larvae and pupae of Chrysanthemum fly *T. stellata*.

As indicated from Fig. (1), two peaks were obvious for the larval stage in Feb. and April, but in the case of pupal stage three peaks of abundance were obvious. The first peak of the pupal population was recorded on January 21st, after that of larvae with nearly of three weeks and almost equal to it. The second peak of pupae was recorded in the third week of March. This can be explained that the present larvae transferred to pupae representing the end of a generation with a decrease in oviposition during this time. The infestation rates were high during the season especially on March 25th (34%). Knowing that import countries reject any product if the rate of infestation reached up to 5%, explains the importance of this pest attacking this crop.

LT_{50} and LT_{99} levels indicate the susceptibility of different stages of *L. serricorne* to alterations of atmospheric gas concentration (Fig. 2). At all gas mixtures, the stages of *T. stellata*, were more tolerant than the stages of *L. serricorne*. The LT_{99} values for larval stage (more tolerant than other staged of *L. serricorne*) were 4.80; 4.30; 2.82 and 0.6 days at the different gas mixtures. The LT_{99} values of *T. stellata* were 6.40; 5.60; 4.70 and 4.00 days. The LT_{99} values for pupal stage of *L. serricorne* were 3.50; 3.00; 1.60 and 0.51 days, and those for adult stage were 2.81; 2.00; and 1.00 days, respectively. Mortalities of insects exposed to the mixture containing 80% CO_2, were higher than those of the insects exposed to mixtures containing 20%, 40% and 60% CO_2 at all exposure periods ranging from 1 to 4 days. When, using the mixture containing 80% CO_2, mortality reached 100% after 1 to 2 days for adults and after 5-7

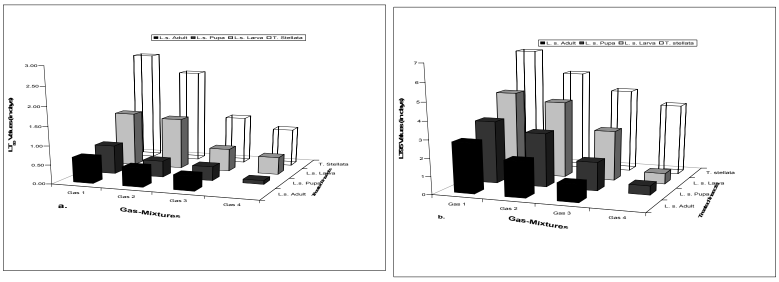

Figure 2: (a & b): LT50 and LT99 values (in days) of treated stages of *L. serricorne* and *T. stellata* exposed to 4 different gas mixtures.

days for the more tolerant stages of both insects. Hashem and Reichmuth (1994) have shown that decreasing the oxygen content in the mixture increases the mortality in shorter exposure period. The descending order of the treated stages according to the LT_{50} and LT_{99} values was as follows: Stages of *T. stellata* > Larva of *L. serricorne* > Pupa of *L. serricorne* > Adult of *L. serricorne* (Hashem, 2000).

The large scale application of the efficient CO_2-concentration for controlling stored chamomile insects was based on the results of the above mentioned tests (Fig. 2), the gas mixture containing 80% CO_2 against the different stages of *T. stellata* was applied. Free space conditions throughout the application were 28.7-30.9^{o}C and 65% R.H.

All treated stages of both insects were killed after 5 days exposure. Keever (1989) indicated that the pupae of the cigarette beetle are often more adversely affected during tests than the other stages.

Conclusions

The present findings indicate that the use of CO_2 in well sealed containers may be a method for disinfecting chamomile and other products as long as the exposure period is not less than 5 days and the temperature is not less than 28^{o}C.

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Soil fertility in Mediterranean organic farming systems II

N availability after long-term organic farming in irrigated and rain-fed Mediterranean semi-arid grassy crops

Romanyà, J.[1], & Rovira, P.[2]

Key words: soil fertility, farming practices, potentially mineralisable nitrogen

Abstract

The use of manures and rotation with legumes in organic farming systems does not always guarantee the adequate nutrient supply to crops. We studied post-harvest N availability in a series of Mediterranean semi-arid rain-fed and irrigated organic fields after 18 years of conversion and compared these with conventional fields nearby. In organic irrigated soils the use of legumes and the application of moderate amounts of manures resulted in higher amounts of soil organic C and potentially mineralisable N. In contrast, in organic rain-fed soils that did not incorporate legumes in their rotation and used low amounts of manures, soil organic C and potential mineralisable N were lower. In organic irrigated soils changes in organic matter quality resulted in a lower potential net N mineralisation per unit of SOC than in conventional irrigated soils.

Introduction

Organic farming systems have the potential to supply adequate amounts of nutrients to crops. However several studies suggest that in these systems soil fertility often limits crop productivity (Berry et al., 2002). Soil fertility management in organic farms is based on the enhancement of soil biological processes that are intimately associated to soil organic matter dynamics. In arable land the amount of fresh organic matter debris that is incorporated into the soil is associated with crop productivity, crop residue management and manuring programs.

Mediterranean arable soils often show levels of soil organic carbon of less than the 1% threshold proposed by Loveland and Webb (2003). Moreover, as a result of low cattle density occurring in dry areas, the availability of manures is normally low. These two factors may hinder the productivity of organic farming practices in the extensive agriculture of the Mediterranean area.

Organic farms rely heavily on soil biological activity to mineralise N and to enhance P availability. N availability in organic farms depends almost entirely on the ability of soil microorganisms to mineralise N that is mainly associated to soil organic matter turnover and quality.

In this paper we aim to study the changes in soil N availability occurring after 18 years of organic farming and to determine the factors that regulate soil N availability, paying special attention to the relationships between available N and organic C.

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Materials and methods

The study was carried out in a set of agricultural fields in the Ebro river depression (NE Iberian Peninsula; 41° 49' N, -0° 2' E). Some of the areas are irrigated by surface flooding while the rest of it is rain-fed. Mean annual temperature is 14.4°C and mean annual rainfall is 436.6 mm. Soil texture ranges between clay loam and sandy clay loam and pH ranges between 8.1 and 9.2. In the last 18 years, organic farming practices have been introduced in some rain-fed and irrigated fields scattered in the area of study. Organically managed soils received an application of 5 Mg ha^{-1} every two year of poultry manure for the rain-fed soils and 10 Mg ha^{-1} yr^{-1} for the irrigated soils. Conventional treatments did not use manures or legumes at all.

We selected 4 independent agricultural fields subject to organic farming practices in a rain-fed area and another similar set of 4 fields with conventional management within the same area following one factor randomized design. Similarly, we selected another set of 8 fields (4 with organic and 4 with conventional farming practices) in an irrigated area nearby. In each field three soil samples were taken and divided into two layers 0-10, and 10-20 cm. Soils were analysed for total organic C and N, mineral N (NO_3^- and NH_4^+) and for potentially mineralisable N by waterlogged incubation. The effects of the farming practices in each soil horizon were tested separately in rain-fed and in irrigated areas using a two level nested ANOVA. Differences between regression lines were tested using ANCOVA with C or C/N ratio as covariates.

Results and Discussion

Forms of available N

Post harvest soil mineral N content was mainly in nitrate form. In all studied organically managed soils nitrate content in the 10-20 cm layer was lower than in conventional soils thus reducing the possibility of leaching losses of N from organic fields. On the other hand, the amount of post harvest ammonia was higher in irrigated organically managed soils, in both studied layers, than in conventional soils receiving mineral fertilizer, suggesting that in this case the organic farming practices were likely to increase the supply of ammonia post harvest by enhancing the ammonification processes. Indeed these irrigated organically managed soils showed increased amounts of organic C (Table 1).

Potentially mineralisable N is a biological index that reflects the soil capacity to supply the N stored in labile organic forms. The effects of the farming practices on the potentially mineralisable N occurred mainly in the first 10 cm of soil. Irrigated organic fields that received large amounts of manures and rotated with legumes showed an increase in the mineralisation capacity of N. In contrast, rain-fed organically managed fields that received low amounts of manures and did not include legumes in their rotation showed the opposite trend as compared to soils receiving mineral fertilisers (Table 1). Moreover, this treatment showed a decrease in the mineral N forms that reached the 10-20 cm layer. It appears therefore that the management regime of the rain-fed organically managed soil did not improve the availability of N. Other authors have stated that low N contents in manures and its slow mineralisation rates can reduce N availability in organic farms (Berry et al., 2002) this does not seem to be the case in our irrigated farms but it may explain the low mineral and mineralisable N in rain-fed organically managed soils. A recent study on P availability carried out with the same soils also showed a large decrease in P availability in rain-fed organically managed soils (Romanyà and Rovira, 2007).

Tab. 1: Organic C, total N, C to N ratio and post harvest mineral N forms in the studied treatments. (n.s. refers to non significant (p>0.050)).

		Irrigated			Rain-fed		
Soil depth (cm)		Conv.	Organic	(p=)	Conv.	Organic	(p=)
0-10	C %	0.89	1.26	0.000	0.91	0.79	0.011
	N mg g^{-1}	1.02	1.30	0.004	1.05	0.85	0.05
	C/N	8.45	9.83	0.008	8.69	9.56	n.s.
	NO_3 mg kg^{-1}	14.70	16.67	n.s.	5.05	5.17	n.s.
	NH_4 mg kg^{-1}	2.56	4.40	0.005	2.09	1.75	n.s.
	NPM $mgkg^{-1}$	30.73	43.04	0.011	29.45	21.26	0.038
10-20	C %	0.69	0.86	0.000	0.85	0.72	n.s.
	N mg g^{-1}	0.88	0.95	n.s.	0.96	0.78	0.003
	C/N	7.93	9.38	n.s.	9.14	9.18	n.s.
	NO_3 mg kg^{-1}	9.57	6.91	n.s.	6.23	3.93	0.007
	NH_4 mg kg^{-1}	1.61	4.16	0.028	3.37	1.65	n.s.
	NPM $mgkg^{-1}$	18.04	18.66	n.s.	16.85	10.40	0.005

Soil organic matter and N availability

Soil organic C and total N contents after 18 years of organic farming were higher in both studied layers in irrigated organic soils. In rain-fed organic soils these measures were lower in the 0-10 cm layer (Table 1). Changes in potentially mineralisable N among treatments in the first studied layer showed a similar trend, suggesting that N mineralisation can be associated to the reserve of N and organic C. Indeed, the relationships between soil organic C and potentially mineralisable N were significant in all studied treatments (Figure 1) and the slope of the curves depended on the treatment. In rain-fed fields the organically managed soils potentially mineralisable showed higher sensitivity to soil organic C content than in conventionally managed soils, suggesting that the low N mineralisation observed in organically managed soils was intimately related to the soil organic matter content. Under these conditions increases in soil organic matter would likely result in increasing soil N supply.In irrigated fields organic management resulted in a decrease of net N mineralisation per unit of soil organic C, suggesting that in this case soil microbia can use part of the mineralised N and incorporate it into the soil organic fractions. In this treatment the organic matter quality index C to N ratio did not show any relationship with potentially mineralisable N. This fact contrasted with the close exponential relationship that we observed in conventionally managed irrigated fields. It is noteworthy that the range of C to N ratio in irrigated organically managed soils was much wider than in conventionally managed soils. It is likely that this was associated with the exogenous organic matter inputs applied to these soils during the last 18 years. In all studied rain-fed soils however, the range of C to N ratio was as narrow as in the irrigated conventional soils, and did not show in any case a relationship with soil mineralized N, suggesting that in these cases organic N was not the main limiting factor to N mineralisation.

Conclusions

N availability is sensitive to the organic farming practices carried out in the studied semi-arid area. Soils of rain-fed organic farms receiving low amounts of manures and not incorporating legumes in their rotation showed lower mineral N and potentially mineralisable N than conventional soils. In contrast, organic irrigated soils receiving moderate applications of manures and rotating with legumes showed higher N potential mineralisation than conventional soils and maintained the overall N availability. Furthermore, the organic management of the irrigated soils significantly changed SOM quality and quantity.

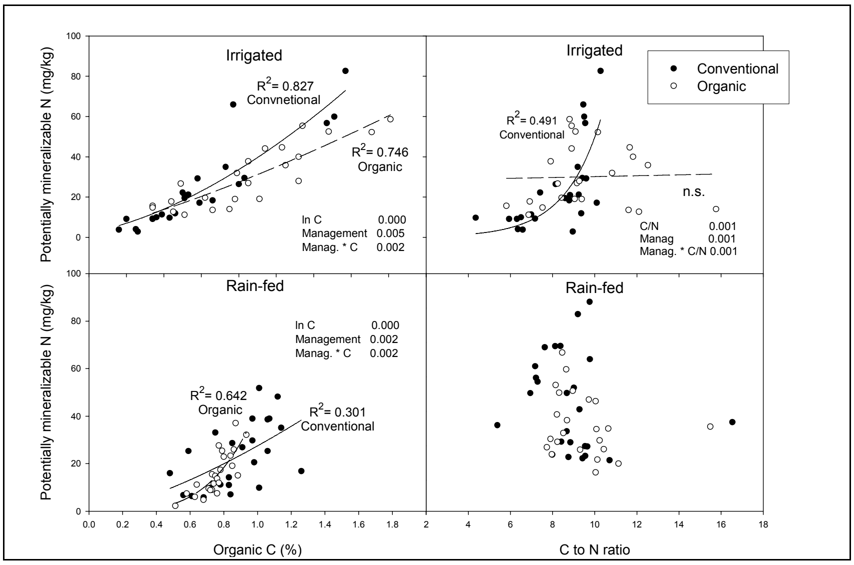

Figure 1: Relationships between organic C, C to N ratio and potentially mineralisable N in irrigated and rain-fed conventionally and organically managed soils. Solid regression lines refer to conventional while dashed lines refer to organic treatments.

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Organic vegetable production in Southern Italy: soil fertility management and fertilisation strategies.

Caturano, E.[1], Roccuzzo, G.[2], Canali, S.[2], Adamo, S.[1], Giuffrida, F.[1] & Leonardi, C.[1]

Key words: survey, fertilisation, vegetable, intensive cultivation, idrolised proteins.

Abstract

Despite the importance of the organic sector in Italy, there are still many difficulties in crop management amenable to weed control, plant protection and soil fertility keeping. Concerning this last aspect and focusing attention to the vegetables crops, the subject is even more complex for the intensive cultivations, the difficulty of rotations implementation, etc. To develop research programmes, we have in a preliminary phase carried out, in a representative area in the south of Italy, a survey aimed at better understanding the main characteristics of organic vegetable agrosystems in terms of plant nutrition and fertility maintenance.

Introduction

Italy, with more than 5% of agricultural land devoted to organic horticulture, is undoubtedly the first country in the European Union to operate in this area. Although the spreading and importance of the organic horticulture, the adoption of the European regulation still involves many problems due to weed control, crop protection and soil fertility management. Concerning this last aspect and with a particular attention to the vegetables crops, the subject is even more complex for the intensive cultivations (e.g.: protected cultivation), where there are difficulties for rotations implementation and for the high input of organic fertilizers (Leonardi and Noto, 2005); besides, climatic conditions and consequently dynamics of the fertilizers and their availability are peculiar. Considering those constraints and in order to obtain information useful to plan research activity aimed at the optimisation of plant nutrition under organic vegetable production, we have carried out a survey dealing with one of the most intensive vegetable production area in the country (i.e.: southern regions). The results concerning the plant nutrition and the fertility maintenance, as well as those concerning the characterisation of the most representative agrosystems are presented and discussed.

Materials and methods

The geographical area of interest has been identified in the south-eastern coast of Sicily and in particular in Ragusa province. The choice of this area was triggered by the high importance which it assumes for the vegetable intensive production at national and even more at the regional level. Fifty-three organic farms characterized by different extension were assessed during the 2006; attention was addressed to

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farms entirely on partially involved in intensive vegetable production. For all the farms, besides general information, data concerning pre-planting and post transplanting application of fertilisers was recorded, paying particular attention to timing, application typology, type of fertilizer, quantity used, etc. (Canali *et al.,* 2004); besides green manuring when carried out was recorded. The above information has been gained proposing to the growers structured questionnaire.

Results

Farm characteristics and produce destination

All the studied farms reached about 250 ha all together; 90 ha of these are devoted to grazing/grain/vegetables in open field, 109 ha in protected cultivation (74 ha in greenhouse and 35 ha under plastic net), 50 ha cultivated with tree crops (Table 1). Farm surface oscillates between 0.5 ha and more than 40 ha, with an average of about 5 ha. Among these, 30 farms have the cycle entirely under greenhouse, 7 farms adopt plastic nets only, 5 farms are involved in the production under protected cultivation (either greenhouse or plastic nets) and field as well, and 4 farms carry out their activities only in open fields.

Tab. 1: Distribution (% over 250 ha) of productive soil in the considered organic farms.

	(% /total)
Grazing/grain/vegetables crops in open	36
Tree crops	20
Greenhouse protected crops	30
Plastic net protected crops	14

Individual farmer provide their produce to some local collection centres (they are often members); then produce is transported in northern Italy platforms where the processing, packaging and the distribution will occur. The distribution is usually addressed to north European markets.

Agrosystems

According to crop requirement and production period, cultivation takes place under greenhouse (e.g.: tomato), under plastic net (e.g.: cabbages) or in open air (eg.: fennel). For some crops, according with the growing cycle and corresponding climatic conditions cultivation take place under greenhouse or in open air (e.g.: zucchini, pepper, eggplant). As far as crop rotation is concerned, under greenhouse sometimes monocropping is carried out (e.g.: tomato), on the contrary in open air crop rotations is usual among vegetables (e.g.: fennel and zucchini) or among different herbaceous crops (e.g.: wheat and

Tab. 2: Vegetable cultivar adopted in the considered farms.

Specie	Cultivar
Tomato	Shiren, Ovetto, Lacey, Zagor, San Marzano, Rubino top, Murano, Eldiez, Laetitia, Lady rosa, Portobello, Panarea, Alambra, Ambizioso, Italdor, Cuore di bue
Pepper	Estelle, Balico, Duke, Wakii, Pepita, Lucelt
Marrow	Tosca, Millennio, President, Thina
Melon	Magico, Dylan, Seven, Magenta

melon). Green manuring is seldom carried out either in greenhouse and in open air. In some cases intercropping under plastic net is achieved (e.g.: cabbages and table grape during winter). In open air, transplanting takes place according to crop requirement and market demand. For some crops in greenhouse cultivation (e.g.: tomato) starts in August-September and lasts (according to market demand and plant phytosanitary status) in May-June.

Biological profile

In our investigation 15 crops, mainly represented by *Solanaceae* (tomato, pepper, eggplant) and *Cucurbitaceae* (zucchini, melon, cucumber, watermelon) were recorded. Tomato holds the first position (cherry and truss as well) with about 50 ha invested, followed by zucchini (22 ha) and pepper (13 ha). As far as the cultivar is concerned, tomato with 16 cultivars shows the largest diversification, followed by pepper (6 cultivars) and by melon and zucchini (4 cultivars) (Table 2). Many of those cultivar are typical of conventional cultivation. Yields, as expected, vary according to species and cultivars adopted, the length of cultivation cycle and the cultivation techniques. For example, yields highlighted from the survey ranged between 80 and 120 t/ha for truss tomato, whereas for cherry tomato ranged between 50 and 80 t/ha. The production recorded for pepper varied between 40 and 60 t/ha and between 30 and 75 t/ha for zucchini. Of course, some of the variability derives from cultivation (either open or greenhouse).

Fertility management

Soil is solarised during the months of July-August; this period for some crops (e.g.: greenhouse ones) coincides with the period of rest. Soil fertility management is based on the use of off-farm fertilisers and soil conditioners. The fertilization before transplanting is almost the same in all the farms: manure, when available, is incorporated before solarization (if carried out), while sulphur, magnesium and potassium are distributed few days before the transplanting. In particular magnesium and potassium are spread in the form of sulphate with an average of 0.5 t/ha (Table 3).

Tab. 3: Before transplanting fertilisation (mean value)

	(t/ha)
Cow manure	5,5
Potassium sulphate	0,5
Magnesium sulphate	0,5
Sulphur	0,5

Concerning manure, the amount varies from 1 up to 9 t/ha; if good quality manure is used (N = 3%) amounts adopted is reduced. Only in small farms commercial seasoned and stabilized manure is used.

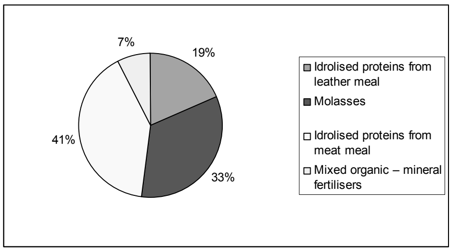

Figure 1: Percentage of fertilizer more adopted after transplanting.

After transplanting, fertilizers are distributed through fertigation once a week during spring-summer and once a fortnight during the winter. As a nitrogen source, molasses and idrolised proteins of animal origin obtained from leather meal of meat meal are used (Figure 1). From our investigation has been found that 15 farms use mixtures of molasses and idrolised proteins from leather meal, 8 farms mixtures molasses and idrolised proteins from meat meal, 8 farms only idrolised proteins from leather meal or other solid organic fertilizers, 3 farms mixtures of idrolised proteins from either leather and meat meal, 2 farms molasses, 2 farms idrolised proteins and a mix of other solid organic fertilizers. The amount of applied fertilizer is very variable in relation to different crops. Considering tomato, being the most representative crop, the total amount of fertilisers adopted pre and post transplanting is reported in table 4. The variability observed may be also due to the growing cycles and to different yields expected. However referring the data to the obtained yield and considering all the applied fertilizers (pre and post transplanting) the variability remains still very wide; besides, is some cases the inputs referred to the theoretical data of crop uptake per unit of produce harvested are very far.

Conclusions

The survey carried out has presented a picture expressing a great diversity of the vegetable organic agrosystems in Ragusa province. Those agrosystems are represented mainly by tomatoes (76% of the area) followed by zucchini and fennel. Information collected concerning soil fertility management indicate that seldom the basic principles of soil management in organic farming are fully respected and the following aspects can be highlighted:

- crop rotation is carried out mainly in open air being for some crops specialisation particularly enhanced;

- intensive crops cycle do not allow sometimes to have enough time for soil preparation (e.g.: solarization, manuring);

Tab. 4: Minimum, mean and maximum amount of nitrogen, phosphorus and potassium distributed in pre and post transplanting in tomato (CV = coefficient of variability).

kg/ha	N	P_2O_5	K_2O
Minimum	310.6	60.0	103.5
Mean	805.1	147.3	464.4
Maximum	1324.0	460.0	1626.0
CV	23.2	53.5	77.3
kg/t	N	P_2O_5	K_2O
Minimum	3.9	0.5	0.9
Mean	7.7	1.5	4.6
Maximum	11.3	5.1	18.1
CV	21.3	64.1	80.6

- soil fertility management is bases on the use of off-farm fertilisers and soil conditioners. Before transplanting manure, solid organic fertilisers, potassium and magnesium sulphates are utilised; whereas in post transplanting fluid fertilisers as idrolised proteins of animal origin and/or molasses are applied by fertigation;

- some of the growers choices (e.g. fertilisers typology and timing of spreading) are not related to clear criteria, but rather to market pressure;

- fertilization inputs not only differ widely between the different farms but also within the same crop; besides the inputs referred to the obtained yield sometimes differ considerably from the theoretical crop uptake.

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Leguminous cover crops: an important tool for improving resource use efficiency in organic arable cropping systems

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Key words: cover crops, nitrogen, mixtures, weeds

Abstract

*Cover crops are one of the most effective tools for organic farmers to improve the efficiency of their agro-ecosystems, while also reducing economic costs and environmental problems. The choice and usefulness of a cover crop species strictly depend on its adaptability to specific climate and soil conditions, but also on its relationships with other species (crops and weeds) and on the quality of farm management. Nine different pure species and three species mixtures were cultivated for two years as winter cover crops in a rainfed stockless arable organic cropping system as part of the MASCOT long-term experiment. Leguminous cover crops showed the highest level of biomass production in both years. Hairy vetch (*Vicia villosa*), either in pure stand or in mixture with grasses, was the most productive and stable species, and had the highest N uptake (ca. 200 kg ha^{-1}). Besides, leguminous species significantly increased the content of N (up to 100%) and P (up to 50%) in weeds and associated grass crops, probably as a result of increased nutrient availability in soil through root exudates.*

Introduction

Cover crops are one of the most effective tools for organic farmers to improve their agroecosystem efficiency without using expensive and environmentally risky external inputs, thereby enhancing the economic and environmental suitability of their farm management. Cover crops can play an important role in the improvement of soil organic matter content, in the supply of nutrients from biological fixation or surplus radical absorption to the following cash crops (Doran & Smith, 1991), and in weed control through competitive, physical, or allelopathic interference (Moonen & Bàrberi, 2006). Although several studies were carried out in the past 20 years on the characterisation of the most common cover crop species, there is still a lack of knowledge about their actual behaviour in the field, especially in Mediterranean environments. In fact, the benefits of cover crops strictly depend on their adaptability to specific soil and climate conditions and especially to their agronomic management.

Materials and methods

The so-called Green Manure Comparison Trial (GMCT) started in 2002 as a part of the MASCOT long-term experiment (Bàrberi & Mazzoncini, 2006), carried out at CIRAA E. Avanzi of the University of Pisa (lat. 43°41' N, long. 10°23' E). Climatic conditions are typical of Mediterranean areas, with a mean total rainfall ranging from

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550 to 1180 mm year^{-1}, mainly concentrated in autumn and spring. The soil is a silty-loam (Typic Xerofluvent) with low content of organic matter (OM), N and P. The aim of GMCT is to compare different species potentially usable as winter cover crops in a typical rainfed and stockless arable crop rotation (maize-durum wheat-sunflower-pigeon bean-common wheat). The main characteristics evaluated are the species adaptability to the specific soil and climate conditions, the amount and quality of biomass produced, the effect on soil nutrients and OM content, and weed suppression ability.

The GMCT was carried out in 2005/06 and 2006/07 on two organically managed MASCOT fields, with grain maize and sunflower as subsequent cash crops, according to a RCB design with four replicates. In the first year, a weedy control and eight different cover crops (*Avena sativa, Brassica juncea, Phacelia tanacetifolia, Secale cereale, Trifolium incarnatum, Trifolium squarrosum, Vicia faba* var. *minor* and *Vicia villosa)* were compared in pure stands. Two mixtures (*A. sativa* + *T. incarnatum* and *V. villosa* + *S. cereale*) were also included. In the second year, rye was replaced by barley (*Hordeum vulgare*), both in the pure stand and in mixture with hairy vetch. A mixture of *T. squarrosum* and *A. sativa* was also included. Cover crops were broadcast seeded in early autumn and ploughed under in early April by means of a disc harrow. Cover crops did not receive any fertilisation, crop protection or direct weeding measures. Dry matter biomass and N and P data were subjected to ANOVA (RCB design) and subsequent Duncan Multiple Range test at $P \leq 0.05$ for mean separation.

Results and discussion

Tab. 1: Cover crops, weeds and total dry biomass (t ha^{-1}) production at the date of cover crop ploughing under (7 April 2006 and 12 April 2007)

Species[1]	2005/06 season			2006/07 season		
	Cover crop biomass	Weed biomass	Total biomass	Cover crop biomass	Weed biomass	Total biomass
A. sativa	1.57 de	0.55 c	2.12 cd	1.30 d	1.04 cd	2.34 e
B. juncea	1.82 d	0.81 bc	2.63 bcd	2.74 cd	1.81 bc	4.55 cd
H. vulgare	-	-	-	1.54 d	0.97 cd	2.51 e
P. tanacetifolia	0.86 de	1.18 bc	2.04 cd	1.55 d	3.15 ab	4.70 cd
S. cereale	0.57 e	0.64 bc	1.21 d	-	-	-
T. incarnatum	4.06 abc	0.95 bc	5.01 a	5.42 b	1.18 cd	6.60 ab
T. squarrosum	3.11 c	1.10 bc	4.21 ab	6.80 ab	0.92 cd	7.72 a
V. faba minor	3.33 bc	2.39 b	5.72 a	3.49 c	1.74 bc	5.23 bcd
V. villosa	5.25 a	0.32 c	5.57 a	5.69 ab	0.56 cd	6.25 abc
Mix 1	-	-	-	7.45 a	0.19 d	7.64 a
Mix 2	3.71 bc	0.25 c	3.96 abc	5.97 ab	0.22 d	6.19 abc
Mix 3	4.38 ab	0.33 c	4.71 a	-	-	-
Mix 4	-	-	-	7.37 a	0.11 d	7.48 a
Control	-	4.37 a	4.37 ab	-	3.51 a	3.51 de
F test [2]	**	**	**	**	**	**

[1] Mix 1: *A. sativa + T. squarrosum;* Mix 2: *A. sativa + T. incarnatum*; Mix 3: *V. villosa + S. cereale*; Mix 4: *V. villosa + H. vulgare*; [2] ** Significant at P ≤ 0.01. In each column, values with the same letter are not significantly different at P ≤ 0.05 (Duncan Multiple Range Test).

As shown in Table 1, for each parameter there were significant differences between treatments in both years. Leguminous crops produced the highest biomass, thanks to their not being affected by low soil N content. Among them, hairy vetch (*V. villosa*), either in pure stand or mixture, showed the highest biomass production in both years. In the second year, the *A. sativa + T. squarrosum* mixture also gave a good result. *S. cereale, H. vulgare* and *P. tanacetifolia* had some difficulties during emergence and early growth because of the suboptimum soil conditions, which resulted in lower biomass yield. Cover crop mixtures containing hairy vetch were the most weed suppressive.

Tab. 2: Cover crops and weeds nitrogen content and total N uptake at the date of cover crop ploughing under (7 April 2006 and 12 April 2007)

Species[1]	2005/06 season			2006/07 season		
	Cover crop N (%)	Weeds N (%)	Total N uptake (kg ha^{-1})	Cover crop N (%)	Weeds N (%)	Total N uptake (kg ha^{-1})
A. sativa	1.09 e	1.23 de	23.70 ef	1.15 d	1.62 cdef	31.80 d
B. juncea	0.90 f	1.63 c	28.77 ef	0.84 e	1.34 fg	47.27 d
H. vulgare	-	-	-	1.06 de	1.49 def	30.78 d
P. tanacetifolia	0.96 ef	1.53 cd	23.86 ef	0.80 e	1.08 g	46.42 d
S. cereale	1.41 d	1.62 c	18.22 f	-	-	-
T. incarnatum	3.04 b	1.77 c	139.65 bc	2.61 bc	1.42 efg	158.22 c
T. squarrosum	3.04 b	1.86 c	106.27 cd	2.46 bc	1.66 cdef	182.55 bc
V. faba minor	3.03 b	1.80 c	143.65 bc	2.82 b	2.01 bc	133.39 c
V. villosa	3.66 a	2.65 b	195.95 a	3.63 a	2.68 a	221.56 ab
Mix 1	-	-	-	2.38 bc	1.81 cde	180.75 bc
Mix 2	2.49 c	1.64 c	97.38 d	2.32 c	1.90 cd	142.68 c
Mix 3	3.75 a	3.15 a	175.60 ab	-	-	-
Mix 4	-	-	-	3.40 a	2.54 ab	253.37 a
Control	-	1.20 e	53.31 e	-	1.35 fg	47.39 d
F test [2]	**	**	**	**	**	**

[1] Mix 1: *A. sativa + T. squarrosum*; Mix 2: *A. sativa + T. incarnatum*; Mix 3: *V. villosa + S. cereale*; Mix 4: *V. villosa + H. vulgare*; [2] ** Significant at P ≤ 0.01. In each column, values with the same letter are not significantly different at P ≤ 0.05 (Duncan Multiple Range Test).

Hairy vetch and its mixtures were also the most effective treatments in terms of N uptake (Table 2). Weeds had a higher % N content in hairy vetch than in the other plots (by an average of +82% in 2005/06 and +66% in 2006/07), suggesting a consistent release of N to the soil from degradation of fallen leaves and from root exudates of hairy vetch. P content (data not shown) gave similar results. Nutrient release from leguminous species was also evident when looking at N and P content of companion grass species in the mixtures (Table 3). In 2005/06, only the hairy vetch effect was significant (increases of +81% and +45% respectively in N and P content of rye), while in 2006/07 T. squarrosum (+50% of both N and P content of oats) and T. incarnatum (+33 and +22% in oats respectively) also gave good results.

Tab. 3: Effect of mixture on biomass production (t ha^{-1} d.m.) and N and P content of cover crops species

Species[1]	2005/06 season			2006/07 season		
	Biomass	N (%)	P (%)	Biomass	N (%)	P (%)
A. sativa	1.57	1.09	0.28	1.30	1.15 c	0.27 c
A. sativa (Mix 1)	-	-	-	0.54	1.76 a	0.40 a
A. sativa (Mix 2)	0.98	1.45	0.32	0.80	1.53 b	0.33 b
S. cereale	0.57 a	1.41 b	0.31 b	-	-	-
S. cereale (Mix 3)	0.11 b	2.55 a	0.45 a	-	-	-
H. vulgare	-	-	-	1.54	1.06 b	0.21 b
H. vulgare (Mix 4)	-	-	-	0.51	2.49 a	0.41 a

[1] Mix 1: *A. sativa + T. squarrosum*; Mix 2: *A. sativa + T. incarnatum*; Mix 3: *V. villosa + S. cereale*; Mix 4: *V. villosa + H. vulgare*. For each species and its mixtures, values with the same letter are not significantly different at P ≤ 0.05 (Duncan Multiple Range Test).

Conclusions

Leguminous cover crops gave the highest biomass yield in both years. Hairy vetch was consistently the best species in terms of biomass production and nutrient uptake, and also increased nutrient content in companion plants in mixtures. Cover crop mixtures exerted the highest weed control suppression.

Acknowledgements

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Compost enhances parasitization of *Brevicoryne brassicae* (L.) by *Diaeretiella rapae* (M'Intosh) in broccoli under different levels of crop diversification and plant competition

Ponti, L.[1], Altieri, M.A..[2] & Gutierrez, A.P.[3]

Key words: indirect effects of intercropping, crop biomass, buckwheat, mustard, organic fertilization.

Abstract

The effects of intercropping via competition on crop biomass, pest [cabbage aphid Brevicoryne brassicae *(L.)*] *abundance and natural enemy [the parasitoid* Diaeretiella rapae *(M'Intosh)*] *efficacy were studied in the* Brassica oleracea *L. var.* italica *system. From May to December 2004, insect populations and yield parameters were monitored in summer and fall in broccoli monoculture and polyculture systems with or without competition from* Brassica *spp. (mustard), or* Fagopyrum esculentum *Moench (buckwheat), and with addition of organic (compost) or synthetic fertilizer. Competition from buckwheat and mustard intercrops did not influence pest density on broccoli; rather, aphid pressure decreased and natural enemies of cabbage aphid were enhanced in intercropping treatments, but this varied with the intercropped plant and season (summer vs. fall). In compost-fertilized broccoli, increased seasonal parasitization rates of* B. brassicae *by* D. rapae *were observed along with the expected lower aphid pressure, when compared to synthetically-fertilized plants.*

Introduction

The role of crop diversification (e.g. intercropping) in reducing insect pest pressure has been extensively investigated in *Brassica oleracea* L. var. *italica* (broccoli) (Hooks and Johnson, 2003). However, the indirect role that inter-plant competition in intercropped systems plays in pest levels and dynamics is poorly understood (Ponti et al., 2007). Intercropping experiments have so far adopted additive designs (i.e., same density of target crop in monoculture and in polyculture) that implicitly introduce interspecific plant competition, which impacts crop growth and may also indirectly influence herbivore levels (Bukovinszky et al., 2004). In additive designs, plant competition is usually not an explicit experimental factor and thus its effects on pest levels cannot be separated from the effects of crop diversification alone (Hooks and Johnson, 2003). In addition, cultural methods such as crop fertilization can affect pest pressure, but the direct linkage to fertility is confounded by the increased abundance of natural enemies in organically-fertilized vs. conventional crops (Altieri et al., 2005).

Brassica crops including broccoli are cultivated year round in the moderate climatic zones of the central California coast, and are attacked by cabbage aphid (*Brevicoryne brassicae* (L.) (Homoptera: Aphididae), which is a specialist on the Brassicaceae. The aphid is an economic pest on broccoli as it infests the developing floral buds rendering

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the head they comprise unmarketable. Cabbage aphids are attacked by the polyphagous parasitoid *Diaeretiella rapae* M'Intosh (Hymenoptera: Braconidae).

In this study, an innovative additive intercropping model with broccoli as the target plant examines whether crop diversity per se influences aphid and natural enemies abundance with and without the effects of interspecific competition, and what effect organic (compost) vs. synthetic fertilizer has on aphid and natural enemies abundance.

Materials and methods

This study was carried out from May to December 2004 at the University of California Agricultural Research Station (Albany, California), where the same experiment was replicated twice: 1) May-August and 2) August-December (summer and fall experiments respectively). The experiment was a two-way factorial (5 × 2; i.e., cropping system □ fertilizer) in a completely randomized design, with treatments replicated three times and plot size 3 m × 3 m. Plots were separated by 1 m bare soil. The first factor consisted of five cropping systems: broccoli monoculture (Fig.1a); broccoli intercropped with mustard, *Brassica* spp., with or without competition; and broccoli intercropped with buckwheat, *Fagopyrum esculentum* Moench, with or without competition. Our additive design kept broccoli levels constant (50 × 50 cm row × plant grid; □ 54444 plants/ha) using two spatial arrangements that introduced intercropping and/or inter-specific competition (Fig. 1b and c). The second factor consisted of two types of fertilizer: synthetic fertilizer or compost applied at the rate of 100 kg N/ha. All plots and the 1 m inter-plot border were maintained weed-free by hand weeding.

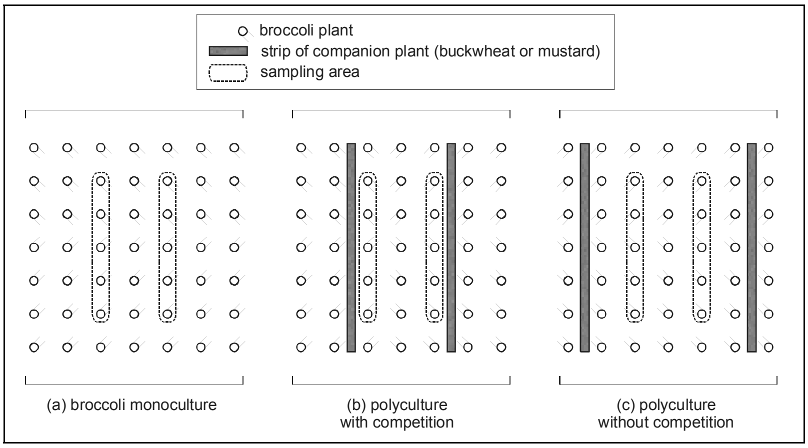

Figure 1: Schematic representation of the additive intercropping design used to separate effects of crop diversity from the effects of competition.

At the end of the season, the wet weight of experimental broccoli plants was estimated using an electronic balance (±1 g). In each of the 30 plots, aphids and natural enemies were counted directly on five broccoli plants at one-week intervals. Cumulative counts per plot on five dates were used as measure of season long aphid pressure and parasitization rates (%), allowing the analysis of untransformed data and making the analysis easier to understand. Multiple regression analysis was performed using dummy variables (values of 0 or 1 for absence or presence respectively) for compost (*O*), mustard (*M*), buckwheat (*B*), and competition (*C*) to assess their influence on dependent variable. Marginal analysis of the regression model was conducted to present a comprehensive synthesis of data, otherwise very difficult to accomplish within the required page limit. For further details on methods, see Ponti et al. (2007).

Results

Multiple regression analysis (*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$) shows that broccoli plant weight (*PW*) was reduced 292 g and 244 g by organic fertilization in the summer and in the fall experiments respectively (eqn. 1: $R^2 = 0.3617$, $F = 15.87$, *d.f.* = 1,28, $P < 0.001$; eqn. 2: $R^2 = 0.826$, $F = 41.15$, *d.f.* = 3,26, $P < 0.0001$).

$$PW_{\text{Summer}} = 795.8^{(***)} - 292.4\ O^{(***)} \tag{1}$$

$$PW_{\text{Fall}} = 1238.6^{(***)} - 244.3\ O^{(***)} - 289.0\ M^{(***)} - 281.7\ C^{(***)} \tag{2}$$

The fall experiment also showed a significant negative impact of mustard and competition on broccoli plant weight (eqn. 2).

Cumulative abundance of aphids (*Aphids*) in the summer was lowered by using compost as opposed to synthetic fertilizer, and when intercropped with either buckwheat or mustard (eqn. 3: $R^2 = 0.65$, $F = 9.07$, *d.f.* = 5,24, $P < 0.0001$). However, the interaction of intercropping plants with either buckwheat (*B*) or mustard (*M*) with composting (*O*) largely counteracted the effects of intercropping alone (eqn. 3).

$$\begin{aligned} Aphids_{Summer} = {} & 1579.7^{(***)} - 837.7\ O^{(***)} - 633.2\ B^{(***)} + \\ & -720.8\ M^{(***)} + 697.5\ OB^{(**)} + 568.3\ OM^{(*)} \end{aligned} \tag{3}$$

Partial derivatives with respect to single variables allow separating the effect of each significant experimental factor (i.e., marginal analysis). The presence of compost alone (eqn. 3a) decreased seasonal aphid pressure in the summer experiment, but this effect was reduced in buckwheat and mustard polycultures.

$$\frac{\partial Aphids_{Summer}}{\partial O} = -837.7 + 697.5\ B + 568.3\ M \tag{3a}$$

When broccoli was grown in polyculture with buckwheat (eqn. 3b), pest pressure was lower unless compost was present, in which case this positive effect was buffered:

$$\frac{\partial Aphids_{Summer}}{\partial B} = -633.2 + 697.5\ O \tag{3b}$$

As seen in equation (3a), broccoli/mustard polycultures (eqn. 3c) showed a similar situation, even though the buffering effect of compost was smaller:

$$\frac{\partial Aphids_{Summer}}{\partial M} = -720.8 + 568.3\ O \tag{3c}$$

In contrast, in the fall experiment no main effect resulted in a significant regression coefficient for predicting aphid cumulative counts. Composting significantly increased aphid parasitization rates (*Par*) (arcsine transformed) in both the summer (R^2 = 0.41, F = 9.69, *d.f.* = 2,27, P = 0.0006) and fall (R^2 = 0.17, F = 5.81, *d.f.* = 1,28, P = 0.022) experiments (equations 4 and 5 respectively). Competition significantly increased parasitization rates in the summer but not in the fall.

$$Par_{Summer} = 0.027\ (*) + 0.04\ O^{(**)} + 0.037\ C^{(**)} \quad (4)$$

$$Par_{Fall} = 0.005^{(**)} + 0.006\ O^{(*)} \quad (5)$$

Discussion and conclusions

No evidence was found that competition from intercropping influences pest abundance in broccoli. Although the observed yield reduction due to intercropping is not new, the effect of competition on aphid dynamics as mediated by reduced host-plant biomass had not been separated yet with a specific experimental design. Intercropping significantly reduced pest pressure only in the summer and we found that mustard is better than buckwheat at controlling aphids, probably due to mustard being able to serve as a trap crop. A positive effect of intercropping on natural enemies was evident in the summer experiment, when the proximity of flowers (i.e., polyculture with competition) significantly enhanced aphid parasitization rates on broccoli. Synthetically fertilized broccoli produced more biomass, but also recruited higher pest numbers. It is known that compost releases mineral nitrogen in the soil at a slower rate than synthetic fertilizer and this has been related to lower foliar nitrogen content leading to reduced pest incidence. Despite lower aphid densities, however, broccoli fertilized with compost consistently had higher parasitization rates than synthetically fertilized plants. In summary, intercropping and composting decreased pest abundance in broccoli regardless of interspecific competition from intercropped plants. In addition, depending on the intercropped plant and the growing season (summer vs. fall), intercropping enhanced natural enemies of cabbage aphid in broccoli. The seasonal effectiveness of natural enemies of *B. brassicae* was increased by composting despite lower aphid abundance in compost-fertilized broccoli.

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Inorganic nitrogen in soil green manured with biocidal crops

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Key words: green manure, biofumigation, soil texture, Brassicaceae

Abstract

The knowledge of the dynamics of inorganic N in soil may help to establish the most suitable timing for green manure (GM) incorporation, which leads to the improvement of crop N use efficiency in conventional as well as organic agriculture. The practice of green manuring with crop species belonging to the Brassicaceae family has recently expanded, in Italy and abroad, due to their demonstrated biocidal effect against soil-borne pathogens. In this plot-scale study we monitored the release of soil inorganic N in 3 soil types (1 clay and 2 loams), in the months following late-spring green manuring with plant material from Brassica juncea, Sinapis alba, and Raphanus sativus species. Soil inorganic N content increased and reached a maximum 2 months after GM incorporation (+14.4 mg N kg^{1} dry soil, on average, over the initial inorganic N content), and subsequently declined. The inorganic N accumulation was higher in soil amended with R. sativus. We did not observe any significant influence of the soil type on the variation of inorganic N content in the period after GM incorporation. The inorganic N released after late-spring green manuring with Brassicaceae species may become available in the early growth phase of subsequent summer-autumn crops.

Introduction

The practice of green manuring with biocidal crops, known also as biofumigation, has expanded in recent years as an alternative to methyl bromide for controlling soil-borne pathogens and pests, especially nematodes (Curto et al., 2005). These crops, besides having biocidal properties, when incorporated to soil supply it with nutrients, such as N, possibly competing as N sources with industrial fertilisers, in conventional as well as organic agriculture. To improve crop N use efficiency while containing the environmental impact of N losses it is important for the inorganic N release in soil, following green manure (GM) incorporation, to be synchronous with the N uptake by the subsequent crop.

The fertilising quality of GM has been studied mainly with reference to leguminous crop species (Cherr et al., 2006). Recent laboratory experiments on soils amended with plant material from Brassicaceae showed high values of potentially mineralizable N 3 months after GM incorporation, with differences depending on crop species and soil type (Marchetti et al., in this archive). We report here the results of an experiment

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we performed at plot scale with the goals of comparing crop yields and N removal for 3 crop species belonging to the Brassicaceae family, and of studying the dynamics of N release in soil, in the months following their late-spring incorporation into the soil as GM. In our Mediterranean environment this agricultural practice is even more frequently applied before the seeding or transplanting of horticultural crops characterized by a summer-autumn growth cycle (Lazzeri et al., 2004). During the sampling period the soil was kept without crops, to remove any interference of crop N uptake on soil inorganic N levels.

Materials and methods

The experiment was performed in 2005, at the I.S.A. experimental site of Modena (44 °39' N, 10°55' E), in lysimeters measuring 4 m^2 □ 1.3 m depth, containing 3 soil textural types (USDA classification): a clay (13.8 g organic C and 1.7 g Kjeldahl N kg^{1} dry soil), a loam with 38% sand (Loam I; 12.1 g C and 1.2 g N kg^{1}), and a loam with 48% sand (Loam II; 9.4 g C and 1.1 g N kg^{1}). The experimental design was a strip–split–plot with 2 replications (18 plots in total). The Brassicaceae species were: *B. juncea* (cv. 52), *R. sativus* (cv. Arena) and *S. alba* (cv. Concerta). Crops were seeded on March 23rd and harvested on June 1st, at full flowering. The aboveground biomass was incorporated on June 7th, after fragmentation of the plant material and hoeing of the top 20-cm soil layer. The inorganic N content in soil was measured, at 0–20 and 20–40 cm soil depth, before plant incorporation (June 6) and at days 31 (July 7), 65 (Aug 10), 127 (Oct 11), and 162 (Nov 15) after GM incorporation. Statistical analysis was performed using PROC MIXED for measurements repeated in time (SAS Institute, 1996). Inorganic N in soil was measured colorimetrically according to Keeney and Nelson (1982).

Results

N concentration in aboveground biomass and plant-N supply to soil. The total N concentration of the biomass of *B. juncea* at harvest was significantly higher than N concentration of *R. sativus* and *S. alba* (Tab. 1). However, the *B. juncea* yield having been lower, no significant differences were detected between crop species in the amount of N supplied to soil. Neither was there any significant effect of the soil type on the considered crop traits (data not shown).

Inorganic N dynamics in soil after plant incorporation. Significant differences of inorganic N content were observed between soils before GM incorporation (data not shown). In order to remove the effect of the soil type, instead of the absolute data values we analysed the differences between inorganic N content in soil samples collected 31, 65, 127 and 162 days after GM incorporation and inorganic N content in soil sampled the day before GM incorporation (net inorganic N content). Of the considered sources of variation, that is: block, soil (Soil), sampling depth, crop species (Crop), time (Time), only the following factor and factor-interaction effects were significant: Time ($P<0.001$), Crop ($P<0.05$) and Soil□Crop ($P<0.001$) (PROC MIXED results not shown). The increase of inorganic N was higher up until 65 days after GM incorporation, and declined in the following sampling dates (Tab. 2). The soil amended with *R. sativus* accumulated more inorganic N that the soil amended with *B. juncea*. In soil amended with *S. alba* there was a lower inorganic N increase, especially in the clay soil (significant soil□crop interaction).

Tab. 1: Plant dry matter (DM), nitrogen concentration in plant DM, plant biomass and N amounts incorporated with green manure.

Crop species	Plant DM (g m^2)	Plant Kjeldahl N (g kg^1 DM)	Incorporated plant DM (g m^2)	Incorporated plant N (g m^2)
R. sativus	330a	16.1b	299a	4.73a
B. juncea	200b	23.8a	161b	3.78a
S. alba	319a	15.9b	271a	4.38a
MSD[1]	105	5.6	103	1.85

[1] In each column, means followed by the same letters are not significantly different for P<0.05, according to the Tukey test for mean comparisons. MSD= Minimum Significant Difference.

Tab. 2: Net inorganic N content in the 40-cm top-soil from June until November for 3 soil types amended with different species of Brassicaceae.

Crop	Soil	Net inorganic N content (mg N kg^1 soil dry weight)				Means for Soil within Crop[1]	Means for Crop[1]
		Time from GM incorporation (days)					
		31	65	127	162		
B. juncea	Clay	8.0	14.7	3.6	1.7	7.0a	
	Loam I	4.4	17.4	˜3.4	0.2	4.6a	
	Loam II	9.7	12.6	1.3	2.8	6.6a	
							6.1XY
R. sativus	Clay	8.3	12.8	1.7	3.9	6.7a	
	Loam I	5.3	16.7	1.2	4.7	7.0a	
	Loam II	7.2	13.8	5.9	3.6	7.6a	
							7.1X
S. alba	Clay	2.2	8.2	˜3.8	˜1.9	1.2b	
	Loam I	6.1	13.9	0.9	3.5	6.1a	
	Loam II	11.3	19.1	1.8	3.9	9.0a	
							5.4Y
	Means for Time[1]	6.9B	14.4A	1.0C	2.5C		

1 With reference to the significant sources of variation (see text), upper-case letters were used for comparisons of the mean effects, lower-case letters for the comparison of first order interaction effects. For each source of variation, means followed by the

same letters are not significantly different for $P<0.05$, according to the Tukey test for mean comparisons.

Discussion

The increase of soil N availability following GM incorporation, which had been already observed in a previous laboratory experiment, was confirmed in this experiment at plot scale.

The decrease of net inorganic N content 127 and 162 d after GM incorporation could be attributed to weed uptake, to immobilisation in the soil microbial biomass, or to leaching, as the cumulated rainfall from mid-August until mid-November, when the soil was free from growing crops, amounted to 434 mm.

Aboveground biomass yields˜ and the relevant crop N removal˜ were lower than those which it is possible to obtain in the field in our environment, probably due to the confining of the crops in the lysimeters. In the hypothesis of a direct relationship between the amount of organic N incorporated with GM and the amount of inorganic N formed in soil, at field level higher amounts of N supplied with GM could give rise to higher amounts of inorganic N than those observed in our experiment.

Conclusions

The late-spring incorporation of Brassicaceae plant material, resulting in a moderate accumulation of inorganic N in soil during summer, may favour crop nutrition when summer-autumn crops follow in the crop sequence.

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Annual self-reseeding legumes effect on subsequent crops into a rotation program in Mediterranean organic farming systems

Al-Bitar, L.[1], Wehbé, E., Ayoub, M. & Jamea, M. Key words: annual self-reseeding legumes, *Trifolium* spp*., Medicago* spp*., biological* nitrogen fixation, Mediterranean region.

Abstract

Biological Nitrogen fixation (BNF) should be the most important means for N supply in organic agriculture. This study aimed at assessing the effect of fifteen legume cultivars on subsequent crops in three consecutive growing seasons to identify the most efficient and suitable ones as building crops in rotation programs under Mediterranean environment. T. subterraneum cv. York and T. glanduliferum cv. Prima, induced the best effects on wheat, particularly on total biomass, number of grains, dry matter production and increased yield by 670% and 567% respectively more than the control.

Introduction

The adoption of BNF, an important process that comes second after photosynthesis (Brady, 1990) might be a solution for poor farmers in less developed countries (Hungria and Vargas, 2000; Dobereiner, 1994). Large amounts of atmospheric nitrogen are fixed in the soil-building crops (legumes), a fundamental pillar of a crop rotation program (Gresshoff, 1990) and a constitutional element of sustainability (Caporali, 2004). Legumes can improve soil quality through their beneficial effects on soil biological, chemical and physical conditions (Biederbeck *et al.,* 1996). This study aims at assessing the fertilization effect of legumes on subsequent crops comparing the results over three years and evaluating the performance of subsequent crops.

Materials and methods

This paper presents a three-year investigation program carried out in the framework of a PhD study (Al Bitar, 2005) aiming at introducing as soil-building crops 15 Mediterranean native legume cultivars grown from November 2002 to March 2004 then green manured. Subsequent crops succeeded over three seasons: Lettuce (April - June 2004) - Corn (June - October 2004) and Wheat (December 2004 – June 2005).

Legume cultivars were the following: *Biserrula pelecinus* cvs. Casbah and Mauro, *Medicago sphaerocarpa* cv. Orion, *Ornithopus compressus L*. cvs. Avila and Santorini, *O. sativus* cv. Cadiz, *Trifolium glanduliferum Boiss*. cv. Prima, *T. hirtum All*. cv. Hykon, *T. incarnatum L*. cv. Caprera, *T. michelianum Savi*. cvs. Bolta and Paradana, *T. subterraneum* cvs. Dalkeith and York, *T. vesiculosum Savi*. cv. Cefalu and *T. spumosum* cv. WCT36.

The trial was carried out at the Mediterranean Agronomic Institute of Bari (IAMB) located in Apulia, south of Italy, characterized by a Mediterranean climate with humid mild winter (precipitations 400 to 500 mm) and hot dry summer. Soil is characterised by: organic mater (1.56%), pH (8.48), N (502 ppm), P (95 ppm), K (650 mel l-1).

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Legume cultivars and control, a green fallow, were arranged in a randomised complete block design with three replicates, each plot of 10 m2; upon flowering in their second growing cycle they were green manured and three subsequent crops (lettuce, corn and wheat) succeeded. Biomass production (fresh and dry) was determined on green manures by sampling plant parts including roots on an area of 0.25 m2 per plot. Samples were oven-dried at 70 °C for 48 h, crushed and digested by H2SO4 and HClO4 acid mixture. Total N was determined in the digested extracts by the standard semi micro-Kjeldahl procedure and Carbon content by Walkley and Black method (Jakson, 1967). Crop analyses were also made periodically to evaluate the subsequent crops performances by measuring several quantitative and qualitative parameters. Analysis of variance was done by the Statistical Analysis System (SAS, V8). The effects were tested using the General Linear Model, multiple comparison of means according to Duncan's multiple range test (Homogenous Groups, $\alpha = 0.05$). Combined data for the three subsequent crops were calculated in order to compare the cumulative effects of the cultivars on the subsequent crops by ANOVA.

Results and discussion

Most of tested cultivars seemed to perform well. However, WCT36 was the most performing since it produced the highest amount of biomass (17.6 t ha^{-1}) with highest N content (600 Kg ha^{-1}). Cultivars of the genus *Ornithopus* were the less performing and *T. michelianum* died before fruit setting overgrown by weeds (*Orobanche* spp.). Relative results on the 3 subsequent crops (table 1) were calculated by the following formula: Relative result = (Cultivar– Control) values/ Control value*100 = Relative value in %. Thus, it refers to the increasing effect of the cultivar in comparison with the control on the concerned parameter of each of the three subsequent crops.

Tab. 1: Cumulative effect of legumes cultivars on the yield and plant nitrogen uptake of the three subsequent crops.

Legume cultivar	Plant nitrogen uptake	Marketable yield (fresh matter)		
	Relative value (%)	Relative value (%)		
B. pelecinus Casbah	182,57 bc			275,48 abc
B. pelecinus Mauro	197,36 abc			276,43 abc
M. sphaerocarpa Orion	222,62 ab			254,63 bc
O. compressus Avila	170,77 c			237,31 bc
O. compressus Santorini	173,88 bc			250,27 bc
O. sativus Cadiz	165,9 c			220,43 bc
T. glanduliferum Prima	186,99 abc			324,85 ab
T. hirtum Hykon	202,1 abc			259,13 bc
T. incarnatum Caprera	173,59 bc			240,69 bc
T. michelianum Paradana	156,8 c			202,07 cd
T. michelianum Bolta	176,43 bc			254,56 bc
T. spumosum WCT36	194,11 abc			296,62 abc
T. subterraneum York	232,66 a			378,21 a
T. subterraneum Dalkeith	168,69 c			279,72 abc
T. vesiculosum Cefalu	173,86 bc			241,72 bc
Control	100 d	Lettuce	15.21 t ha^{-1}	100 cd
		Maize	6.61 t ha^{-1}	
		Wheat	0.23 t ha^{-1}	

The values that do not have the same letter are significantly different at $\alpha = 0.05$ (Duncan test).

All cultivars (except Paradana) showed to induce a significant increasing effect on yield at long term. The overall yield for the three crops was higher than the control ranging from 120% (Cadiz) up to 278% (York). Significant difference was found also among cultivars. York, Prima, WCT36, Dalkeith, Casbah and Mauro were the best performing over the three-year experiment. Moreover, cultivars induced also a significant increasing effect on both plant height and nitrogen uptake of the three crops ranging from 13% to 26% and 66% to 132%, respectively.

Residual effect of legume cultivars on the three subsequent crops are shown in fig 1. The effect of legumes on plant height decreased significantly from one season to another following a normal trend. Nitrogen uptake was higher than the control in the three seasons by at least 58% as found by Ten Holte & Van Keulen (1989) and Schroder *et al*. (1997). The highest value, significantly different from the first and the third seasons, was reached during the second growing season. The increase in terms of nitrogen uptake by the second subsequent crop could be explained by the late release of nitrogen from the nitrogen-fixing bacteria, whereas, the decrease observed in the third growing season may be normally due to the decrease in soil nitrogen content after its use by the first and the second subsequent crops.

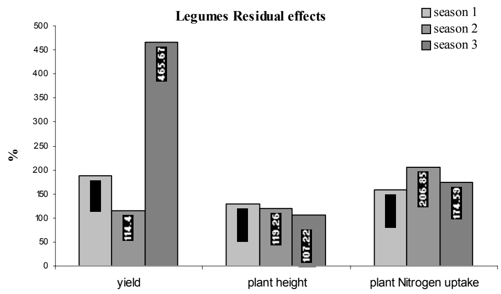

Figure 1: Beneficial residual effects during the three seasons. Values that do not have the same letter are significantly different at α = 0.05 (Duncan test).

The increase in crop yield following legumes was expected and it comfirmed previous results (Ten Holte & van Keulen, 1989; Schroder *et al*., 1997 and Breland, 1996). The positive effect of legumes decreased from the first to the second season, and then it increased drastically in the third. This may be explained by the fact that soil fertility in control plots decreased much faster than in the treated plots reaching very low levels in the third season; in other words, legumes have sustained soil fertility.

Different trends of plant nitrogen uptake and plant height might be due to plant behaviour and its physiology concerning the response to nitrogen; for instance, the difference in terms of soil fertility between treated and control plots, mainly soil nitrogen content, had clearer effect on wheat (third crop) yield than on plant height, due to the high nitrogen requirements for wheat grain formation in respect to its requirement for plant growth and development.

Conclusions

Most of tested cultivars showed to have a large potential to be used in sustainable Mediterranean agro-ecosystems in that they possess a large screen of characteristics making very wide their possible use (Talamucci, 1997).

Cultivars York and Prima were the best performing during the whole investigation program. WCT36 was the most performing in terms of biomass production and N fixation, making it highly recommended for green manuring.

The tested legumes showed also to induce a beneficial effect on the three subsequent crops in comparison to control by stimulating higher yields, higher plant height and better plant nitrogen content for the subsequent crops. The residual effect of legumes was still concrete even after three consecutive crops as was proved by Ten Holte & van Keulen, 1989; Schroder *et al*.,1997 and Breland, 1996. It could be concluded that the integration of annual self-reseeding legumes into Mediterranean organic cropping systems may contribute largely to sustain long-term soil fertility, to satisfy cash crops needs in N and to increase markedly production.

Although the results are very promising, they still very preliminary considering the short period of the experiment; in fact, further studies are being conducted to sustain the obtained results.

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Variety Recommended Lists of Organic Cereals in Emilia-Romagna

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Key words: variety trials, wheat, barley, corn.

Abstract

In order to meet the needs of Emilia-Romagna's technicians and farmers, specific trials on cereals (soft wheat, hard wheat, barley, corn) for organic production have been carried out since 1995. These trials helped draw up specific Variety Recommended Lists.

Introduction

Variety selection plays a main role in organic production and the best varieties in traditional production are not always the best solution for organic farming. Key features of organic production must be: high yield and rusticity, weeds competition and pest and disease resistance.

Specific trials on cereals for organic production have been carried out since 1995 in Emilia-Romagna. The investigation has started with soft wheat, later on corn (1999), barley (2000) and hard wheat (2004) have been involved, too.

Material and methods

Trials were carried out on a yearly basis in 1-2 organic certified farms in Emilia-Romagna (North Italy). The experimental layout consisted of randomised blocks with 3-4 replicates. The chosen varieties were among those achieving the best results in conventional farming trials and showing good resistance/tolerance to several pathogens. On the whole 111 varieties of soft wheat, 18 of hard wheat, 43 of barley and 132 of corn were compared. The following criteria were detected: yield, disease sensitivity and environmental stress, hectolitre weight, life cycle of the plant. Protein % and hardness on soft wheat and broken plants on corn were also detected.

The draft of the Variety Recommended Lists was made according to the following standards:

- this List is valid in Emilia-Romagna; data used derive from variety comparison trials in organic farming made in Emilia-Romagna and from additional information by technicians, farmers, millers and seed companies;

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[4] Azienda Agraria Sperimentale M. Marani, Via Romea Nord, 54 (RA), Italy

- proposed varieties and hybrids of each species are divided according to the following criteria:
  - soft wheat: Synthetic Quality Index - ISQ (Foca G. et al. 2007)
  - corn: FAO maturity classes; flint corn fits in a separate group
  - barley : ear type

- varieties and hybrids have to be tested for at least a two-year period;
- productivity must exceed at least 5% the field average yield and must not drop below the field average yield for more than one year;
- less productive varieties/hybrids can be put in the list if suitable varieties in a particular group are missing;
- varieties/hybrids must be pathogen tolerant

Results

Tab. 1: Yield index (field average yield =100) for Soft Wheat Varieties included in Recommended Lists for Organic Production in Emilia-Romagna - Year 2007. Quality categories ISQ: FB (w. for biscuits), FF (improver w.), FP (ordinary bread making w.) and FPS (superior red making quality w.).

Variety	Synthetic Quality Index (ISQ)	2002			2003		2004		2005	2006	Mean 2002-2006	Years 's trials no.
		Modena	Parma	Ravenna	Parma	Ravenna	Parma	Ravenna	Parma	Parma		
ARTICO	FB	104	111	117	100	95	110	100	105	106	106	5
CRAKLIN	FB	121	111	117	101	125	107	115	110	114	113	5
EUREKA	FB	110	108	119	111	102	110	113	112		111	10
RAVENNA	FF	99	95	107					100	95	97	4
TAYLOR	FF	88	96	74							86	3
AGADIR	FP						107	123	99	100	107	3
ALCIONE	FP	109	117	123	101	110	111	114	99		111	4
AUBUSSON	FP								102	111	107	2
GUARNI'	FP								108	112	110	2
ISENGRAIN	FP						115	128	104	102	112	3
TIBET	FP	105	110	110	105	115	109	98	100		106	7
BLASCO	FPS						95	102	103	101	100	3
GUADALUPE	FPS	103	103	104	108	92	104	98	105		102	7
NOMADE	FPS								100	101	101	2
PALLADIO	FPS								98	104	101	2
SOISSONS	FPS	98	105	88	100	105	110	113	101		103	9
Average production of field t/ha		7.0	6.9	6.6	7.2	6.9	6.6	7.6	6.7	7.8		

Tab. 2: Yield Index (field average yield = 100) for Barley Varieties included in Recommended Lists for Organic Production in Emilia-Romagna. Year 2007.

Variety		2002	2003	2004	2004	2005	2006	Mean 2002/2006	Years 's trials no.
		Parma	Parma	Parma	Ravenna	Parma	Parma		
BARAKA	Two row	110	98				98	102	4
KETOS	Six row			108	118	105	104	109	3
SIBERIA	Six row	122	127	98	106	99	104	109	5
MARADO	Six row			116	119	98	110	111	3
PASSPORT	Six row			114	126	111	110	115	3
AMILLIS	Two row	106	107			105		106	3
KELIBIA	Two row	108	106	98	110			106	4
NURE	Two row	99		107	116	102		106	4
ZACINTO	Naked	98	83	85	81			87	4
Average production of field t/ha		5.33	6.29	5.44	4.57	6.75	5.68		

Tab. 3: Yield Index (field average yield = 100) for Hard Wheat Varieties included in Recommended Lists for Organic Production in Emilia-Romagna. Year 2007

Variety	2004	2005	2006	Mean 2002/2006	Years 's trials no.
	Parma	Parma	Parma		
Claudio	117	106	104	109	3
Grazia	106	121	96	108	3
Iride	102	109	104	105	3
Simeto	102	104	115	107	3
Average production of field t/ha	4.66	5.82	6.10		

Tab. 4: Yield Index (field average yield = 100) for Corn Hybrids included in Recommended Lists for Organic Production in Emilia-Romagna. Year 2007.

Variety	Maturity classes FAO	2002	2002	2003	2004	2004	2005	2006	2006	Mean 2002/2006	Years 's trials no.
		Reggio Emilia	Ferrara	Reggio Emilia	Parma	Ferrara	Parma	Parma	Ravenna		
Anjou 450	300	89	118				83			98	4
DK 440	300			118	110	108	87			108	3
PR 36 B 08	300	112	82				95	106	106	99	3
DK C5353	400						119	119	94	110	2
Chalcao	500				107	115	88			107	3
DK C 5783	500				112	169	114	108	108	123	3
Helder	500	107	133	113	114	94				112	3
Karen	500				110	129	108	99	99	111	3
Keplero	500						108	119	98	113	2
Kult	500	121	139	118	103	91				114	3
Campodoro	600	123	120		89	100				108	3
Coventry	600						107	103	103	105	2
Larigal	600						104	117	117	111	2
Vertice	600	88	141		119	113				115	3
SIS Red	300			96	74	69		84	84	81	3
Roano	400			97	77	67	73			78	3
Average production of field t/ha		11.03	8.54	5.16	10.09	4.48	6.87	7.98	4.28		

Discussion and Conclusions

Soft Wheat: on the average, yield was more than satisfactory (Table 1) and in some years it was even higher than in traditional production (6.5-7.0 t/ha). Only in 2003 and 2004 crops were affected by Brown Rust and by Septoria spp., while Fusarium spp. and Powdery Mildew were quite absent. Protein level is 1% lower if compared to conventional fields (Corbellini M. et al. 2006), its average value varying between 12.7 and 13.5; some cultivars (Taylor, Ravenna, Blasco, Palladio) have maintained their protein values close to 14% in organic farming, too. Weight per hectolitre was good (slightly less than 80 kg/hl) in 2004 and 2006, but low in 2002

Barley: in addition to hulled barley types, naked varieties, being suitable substitute for coffee and soup preparation, were added in trials, too. In several cases cultivation after meadow-grass (alfalfa) has caused widespread lodging, lowering its yield (2004). Productive differences among varieties were not as evident as in wheat (Table 2).

Hard wheat: in the last few years an interest in this species has been increasing also in Emilia-Romagna. Yields were interesting, even if affected by Brown Rust and by Septoria attacks in 2004 (Table 3).

Corn: on the average, yields are lower than in conventional farming even though they can exceed 10 t/ha in optimal conditions (Table 4). From a productive point of view the most interesting FAO classes in organic cultivation are those reaching 400-500. While DK440, PR36B08, Karen, DKC5783, Larigal and Vertice are less sensitive to stem break.

Data obtained allow to identify, for every single species, a group of varieties to be grown in organic farming. At the beginning only soft wheat was in the recommended lists (C. Piazza et al. 2001), later on other species were included as well. According to the data obtained, the lists are updated every 1-2 years, the last update was carried out in 2007 (AAVV.,2007).

Acknowledgments

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Innovative crop and weed management strategies for organic spinach: crop yield and weed suppression

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Keywords: living mulch, cultural weed control, system approach, organic spinach

Abstract

*In organic agriculture, it is important to tackle crop and weed management from a system perspective to make it effective, especially in poorly competitive crops such as vegetables. For that reason, we developed two innovative integrated crop and weed management systems for a field vegetable crop sequence in a commercial organic farm that we have been comparing to a standard farm system from 2006 to 2008. The three systems are applied to a spinach-potato-cabbage-tomato two-year crop sequence and include different levels of technical innovation: Standard Crop Management System (SCMS); Intermediate Crop Management System (ICMS); and Advanced Crop Management System (ACMS). ICMS is based on a sequence of physical weed management treatments, whereas ACMS also includes a subterranean clover (*Trifolium subterraneum*) living mulch. In this paper we analyse the results obtained on spinach (*Spinacia oleracea*) in terms of crop yield and weed suppression. Both innovative systems increased total spinach fresh weight yield compared to SCMS, despite higher weed biomass. In ACMS, total weed biomass decreased linearly with increasing biomass of the subterranean clover living mulch.*

Introduction

In Italy, organic vegetable production has rapidly expanded in recent years. Organic spinach production has risen from 93 ha in 2005 to 347 ha in 2006 (www.sinab.it), but it still is much lower than the area of conventional spinach (ca. 7,000 ha in 2005). Vegetables, including spinach, are generally very sensitive to competition from weeds, so that the weed management component of any organic vegetable cropping system must be given high priority. However, management of short-cycle vegetable crops must necessarily be tackled from a whole system perspective because of the numerous interactions among agroecosystem components that take place under organic production (Bàrberi, 2002). It then is necessary to develop improved crop management systems that take into account two basic features of any successful organic vegetable cropping system: 1) timeliness of interventions, especially with regard to direct physical weed control measures (Peruzzi, 2006); and 2) inclusion of multifunctional elements, such as cover crops, that can suit the needs of soil, crop and weed management,. As to this latter point, use of legumes such as subterranean clover (*Trifolium subterraneum*) has proven to be beneficial in Mediterranean environments and elsewhere (Ilnicki and Enache, 1992; Bath et al., 2006).This study is part of a research project aiming to develop improved crop management systems

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for organic vegetables based on integrated and optimised use of crop rotations, cover crops/green manure, compost, and weed management strategies. Three crop management systems were then developed and compared on a commercial vegetable organic farm with the active involvement of the farm manager. The three systems correspond to increasing levels of innovation: standard (i.e. the usual crop management system practised on farm); innovative; and advanced. All three systems were applied to the same crop sequence (spinach-potato-cabbage-tomato) in the period 2006-08. This paper reports on crop yield and weed suppression results obtained on spinach, the first crop in the sequence.

Materials and Methods

An experiment was carried out in the 2006-07 season at the Colombini vegetable organic farm, located in Crespina (Pisa), central Italy (43°35' N; 10°34' E), on three different fields. The soil is a sandy loam with an organic matter content of 1% and a pH of 6.8. Three different crop management systems were tested: Standard Crop Management System (SCMS); Intermediate Crop Management System (ICMS); and Advanced Crop Management System (ACMS), allocated to the fields according to a randomised complete block (RCB) design with three replicates (each field corresponding to one block). Each plot was 160 x 3 m. Prior to spinach, the fields were disc harrowed at 25 cm depth, chisel ploughed at 70 cm, rotary hoed at 15 cm, and ripped at 50 cm. Subsequently, 1.4 m-wide ridges were created. The SCMS consisted of manual transplanting on biodegradable maize starch mulch (MaterBi®) of 40-60 plants per m^2 in plant units containing 2-3 plants per unit. No direct weed control measures were applied. In the ICMS, false seed bed technique was performed with a rolling harrow (Peruzzi et al., 2007). Spinach was sown on 5 October 2006 by means of a pneumatic drill (5 rows, 55 seeds/m^2). After seeding, a flame weeder and a precision hoe (two passes) were used. (For more information about ICMS strategies and machines see the article by Fontanelli et al. in the Proceedings of this Congress.)

This sequence of physical weed management operations was also used in the ACMS, where in addition a subterranean clover living mulch (cv. Clare) was broadcast interseeded in spinach on 20 November 2006, at a seeding rate of 30 kg ha^{-1}. In each plot, two 1.4 x 2 m control areas received no physical weed control. Spinach yield and weed biomass were sampled twice in four subplots of 1.4 x 2 m, on 28 November and 15 December 2006. Subterranean clover biomass was sampled on 5 March 2007. All data were subjected to ANOVA according to a RCB design with three replicates. Linear regression analysis was used to relate total weed biomass to subterranean clover biomass. Means were compared by LSD tests at $P \leq 0.05$.

Results and Discussion

Table 1 shows the effect of the three management systems on spinach yield. Total yield of spinach was significantly affected by management system: in particular, both ICMS and ACMS increased spinach yield compared to SCMS in terms of both total leaf fresh weight (+34%) and average fresh weight per plant (+46%). Compared to ICMS, inclusion of subterranean clover in ACMS did not result in statistically significant additional yield gain. No difference among systems was observed in the percentage of discarded leaves (on average ca. 20%). The better results of ICMS and ACMS over SCMS are related to higher yields at the second harvest date, when ICMS and ACMS achieved 44% and 43% of total spinach yield respectively vs. 36% for SCMS. This suggests that the innovative systems are likely to cause a more gradual yield accumulation, which should be seen favourably from a farmer's perspective. Yield gains in ICMS and ACMS were likely due to the concomitant effect of lower intra-specific competition in spinach sown with a regular crop spatial arrangement (single-row precision sowing instead of the 2-3 plants per unit transplanting of the SCMS), and to the overall positive effect of weed management strategies.

Tab. 1: Fresh weight yield (g m^{-2}) and unit f.w. (g per plant) of spinach at the first and second harvest dates and in total.

	28 November 2006			15 December 2006		Total harvest		
System[1]	Fresh weight yield		Unit f.w.	Fresh weight yield	Unit f.w.	Fresh weight yield		Unit f.w.
	g m^{-2}	sqrt				g m^{-2}	sqrt	
SCMS	333.22	18.26 ±4.74	20.97 ±6.61	189.11 ±44.41	10.24 ±2.66	522.33	22.97 ±4.09	15.61
ICMS	369.27	19.22 ±4.68	25.95 ±4.57	290.57 ±70.83	18.97 ±5.62	659.84	26.21 ±4.24	22.46
ACMS	421.86	20.54 ±2.42	26.85 ±3.81	318.37 ±42.67	19.30 ±3.84	740.23	27.20 ±2.46	23.08
F (P)	0.75 (.482)		3.07 (.065)	12.04 (.000)	9.66 (.001)	3.53 (.045)		5.91 (.008)
LSD 5%	4.00		5.72	61.55	5.13	3.61		5.33

[1]SCMS = Standard Crop Management System, ICMS = Intermediate Crop Management System, ACMS = Advanced Crop Management System. See text for details.

The SCMS had the lowest weed biomass (2.4 and 1.2 g m^{-2} at the first and second harvest dates respectively), thanks to the suppressive effect of biodegradable mulch. Total weed biomass did not differ between ICMS and ACMS, being on average 11.6 and 14.5 g m^{-2} at the first and second dates respectively. Therefore, higher spinach yield in the innovative systems cannot be explained by the weed biomass data. In the case of ACMS, this can partly be due to the lack of appreciable growth of the living mulch at spinach harvest dates because of delayed interseeding. However, in early March 2007 we observed a significant linear negative relationship between subterranean clover biomass and total weed biomass (Figure 1), which might be relevant from a cropping system perspective (e.g. for the subsequent potato crop).

Conclusions

The results show that there were differences among systems in crop yield and weed suppression, and that the two variables were unrelated. In fact, the SCMS showed the lowest weed biomass but also the lowest spinach yield, an effect likely due to the suboptimum crop spatial arrangement on biodegradable plastic mulch, which possibly increased intra-specific competition. No evidence was found that the living mulch-based system, applied as described in this paper, would give better weed control with respect to the system relying only on physical weed management. However, the negative linear relationship between biomass of weeds and of subterranean clover suggests that the latter has a weed suppression potential that was still unexpressed during the spinach growing cycle.

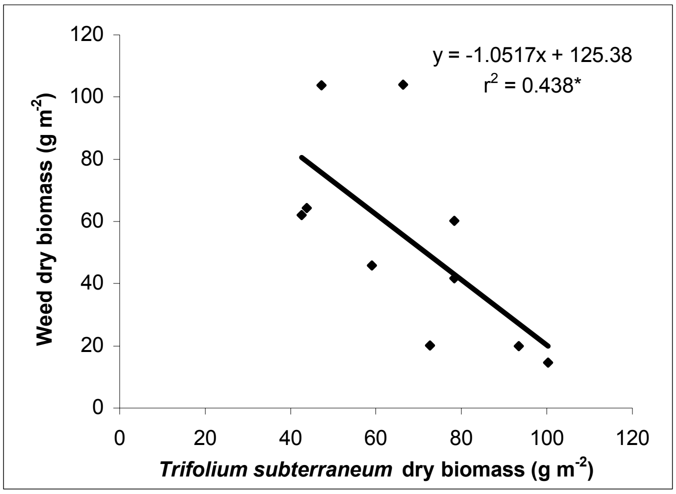

Figure 1: Simple linear regression of weed dry biomass on subterranean clover dry biomass (* significant at P ≤ 0.05)

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Innovative crop and weed management strategies in organic spinach: machine performances and cultivation costs

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Key words: physical weed control, operative machines, vegetable crop rotation, fresh market spinach, biodegradable plastic mulch

Abstract

*Weed competition is one of the most serious problems in vegetable crops. Physical and cultural methods represent the only adoptable solutions in organic farming systems. A two-year (2006-08) on-farm research is being carried out to test innovative operative machines for physical weed control on a typical vegetable crop sequence in the Arno Valley (Pisa, Italy). In this work we present the first results, obtained on organic fresh market spinach (*Spinacia oleracea*). The new strategy is compared with the standard crop and weed management system, characterised by the use of biodegradable maize starch mulch, and with a system in which the use of improved physical methods is coupled with the use of a subterranean clover (*Trifolium subterraneum*) living mulch. Performances of the operative machines, labour time requirement and cultivation costs of the three crop and weed management systems are reported. The two innovative strategies showed interesting results, determining effective weed control and a significant reduction of costs for working and hand labour (-70%).*

Introduction

Weed management is one of the most serious problems in organic farming systems (Bàrberi, 2002). Crop development and yield can be significantly affected by weed competition, especially in vegetable crops (Fogelberg, 2007), that are often characterized by slow emergence (e.g. carrot), low competitive ability, and limited capacity to cover the soil (Peruzzi et al., 2004 and 2007).

Standard physical weed control machines (e.g. standard duckfoot share equipped hoe) can not successfully carry out effective intra-row crop weed control unlike herbicides. This implies that a high amount of labour time is required for intra-row hand weeding (Fogelberg, 2007). For this reason, the study of innovative strategies and tools for intra-row selective weed control is an important and relevant research area for European agricultural scientists (Dedousis et al., 2007).

Achieving a significant reduction in labour time in organic farming is a target that can effectively be reached by the use of purposely made operative machines and by the choice of a correct, integrated (holistic) weed strategy in which preventive, cultural and direct methods are concurrently used (Bàrberi, 2002).

Different low- and high-tech solutions for physical weed control are presently available on the market or are being studied as prototypes. Precision hand-guided hoes

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equipped with torsion weeders, vibrating tines or finger weeders belong to the first group (Peruzzi et al., 2004 and 2007), while more technologically-advanced hoes equipped with electronic devices for row detection belong to the second group (Dedousis et al., 2007). In this work we report the first results (on fresh market spinach) of a two-year on-farm research project aimed to develop improved crop and weed management systems for organic vegetable crops mainly based on optimised use of innovative operative machines for physical weed control.

Materials and methods

An ongoing field experiment started in October 2006 on a commercial organic farm located in Crespina (43°34' lat. N, 10°33' long. E), near Pisa (central Italy). Innovative machines for physical weed control are being tested on a two-year crop sequence composed of spinach (*Spinacia oleracea* L.), potato (*Solanum tuberosum* L.), cauliflower (*Brassica oleracea* L. var *botrytis* L.) and tomato (*Lycopersicon esculentum* Mill.). In this paper we report the data gathered on spinach, the first crop in the sequence.

Three crop and weed management systems are being compared, characterised by increasing levels of technological innovation: the standard crop management system practices on farm (SCMS), an intermediate crop management system (ICMS) and an advanced crop management system (ACMS). The SCMS is characterised by the use of a black biodegradable maize starch plastic mulch (Mater-Bi®), on which spinach was manually transplanted on 1 m-wide ridges. The ICMS is based on the use of innovative machines for physical weed control and by direct sowing (performed on 5 October 2006) on 1.4 m-wide ridges with a pneumatic 5-row drill. The ACMS has the same features of ICMS plus the inclusion of a subterranean clover (*Trifolium subterraneum* L.) living mulch, interseeded on 20 November 2006 during the last pass of machines for physical weed control (for more informations about agronomical data of the trial look the article Barberi *et al.* in the Proceedings of this Congress).

In ICMS and ACMS we made use of three innovative mounted operative machines: a rolling harrow, a flaming machine and a precision hoe. The rolling harrow is a new patent of the University of Pisa, equipped with spike discs placed in the front and cage rolls in the back (Figure 1). This machine can efficiently be used both for performing the false or stale-seedbed technique (exploiting its whole working width), and for precision hoeing (removing and adjusting the working tools to the inter-row distance). In this trial the rolling harrow was used just for pre-sowing interventions. The flaming machine performs weed control by means of an open flame (Figure 1). The flamer was equipped with three 50 cm-wide rod-burners and three commercial 15 kg LPG tanks. This machine can be used for pre-sowing, pre-emergence or post-emergence treatments (the latter only on tolerant crops), but in this trial it was used just before crop emergence. The precision hoe was equipped with a seat, steering handles and directional wheels. It is characterized by six working units, each one holding one rigid element with a 9 cm wide blade (for inter-row weed control) and two couples of elastic elements for selective intra-row weed control (torsion weeders and vibrating tines) (Figure 1). For spinach, the ICMS and ACMS included one pre-sowing pass with the rolling harrow (5 October 2006), one pre-emergence pass with the flamer (11 October 2006) and one post-emergence pass with the precision hoe (30 October 2006).

Performances of the operative machines, labour time requirement and cultivation costs of the three crop management systems were assessed. Data were not processed to statistical analysis because referred just to the operative aspects of the research.

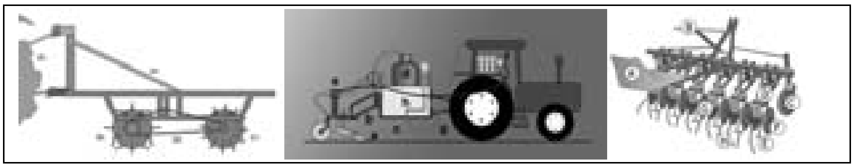

Figure 1: Innovative operative machines used for physical weed control: rolling harrow (left), flaming machine (middle) and precision hoe (right).

Results and discussion

The performances of the innovative operative machines utilised in ICMS and ACMS are shown in Table 1. The working width was the same for all the machines tested and was set at 1.4 m, corresponding to the ridge width. The highest working speed and work capacity was reached by pre-sowing treatments with the rolling harrow (ca. 8 km h^{-1}). Flaming was performed at 5 km h^{-1} while precision hoeing was the most expensive operation., since it was characterised by low speed (2 km h^{-1}) and the need of a back seated operator. All the operative machines require a low engine power (37 kW are almost exceeding); for flaming, LPG consumption was ca. 30 kg ha^{-1}.

Tab. 1: Performances of operative machines adopted for mechanical and physical weed control on spinach

Parameter	Unit of measure	Rolling harrow	Flamer	Precision hoe
Working width	m	1.4	1.4	1.4
Working depth	cm	3.1	-	2.5
Driving speed	km h^{-1}	7.9	5.0	2.0
Work capacity	ha h^{-1}	1.0	0.6	0.3
Working time	h ha^{-1}	1.0	1.7	3.3
Number of workers	-	1.0	1.0	2.0
Tractor power	kW	37.0	37.0	37.0
Engine load	-	0.2	0.2	0.2
Fuel consumption	kg ha^{-1}	2.0	3.4	6.6
LPG pressure	MPa	-	0.3	-
LPG consumption	kg ha^{-1}	-	33.3	

Total labour time requirement and total cultivation costs were considerably higher for the SCMS with respect to the two innovative systems (+225% for both parameters), mainly due to spinach planting operations (Table 2). Costs of the crop nursery phase plus manual transplanting were 11-fold that of mechanical precision planting. Sensible differences in the cost of weed management were also registered: the cost of SCMS (mainly due to biodegradable plastic mulch) was nearly double that of ACMS and triple that of ICMS (Table 2).

Tab. 2: Labour time and cost estimations (including cost of the technical means used but excluding cost of machines) of the three crop and weed management systems tested on spinach

System[1]	Soil tillage		Manual harvest		Planting		Weed management		Total	
	$h\ ha^{-1}$	$€\ ha^{-1}$	$h\ ha^{-1}$	$€\ ha^{-1}$	$h\ ha^{-1}$	$€\ ha^{-1}$	$h\ ha^{-1}$	$€\ ha^{-1}$	$h\ ha^{-1}$	$€\ ha^{-1}$
SCMS	8	450	340	3,000	815	11,487	8	1,004	1,171	15,951
ICMS	8	450	340	3,000	5	1,042	6	317	359	4,809
ACMS	8	450	340	3,000	5	1,042	8	524	361	5,017

[1]SCMS = Standard Crop Management System, ICMS = Intermediate Crop Management System, ACMS = Advanced Crop Management System. See text for details.

Consequently, the estimated total cost per unit yield was appreciably higher for SCMS ($3.24\ €\ kg^{-1}$) than for the innovative systems (on average $0.72\ €\ kg^{-1}$).

Conclusions

The comparison between the standard and the innovative systems gave very interesting and encouraging results. ICMS and ACMS showed considerable lower costs and hand labour requirements (on average -70%) with respect to the standard system practised on farm. The operative machines used in the innovative systems are cheap, versatile and well adapted to the farm context. Furthermore, soil incorporation of interseeded subterranean clover seeds did not interfere with physical weed control interventions. No appreciable cost differences were observed between the two innovative systems. Further experiments are ongoing to evaluate the feasibility of use of the innovative systems on other organic vegetable crops typical of the Arno Valley.

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Physical Weed Control in Organic Carrot in Sicily (Italy)

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Key words: carrot, weed control, rolling harrow, flame weeding, precision hoe.

Abstract

Weeds are the major biotic factor that negatively affects organic carrot yield. As a matter of fact, weeds can reduce carrot growth from early stages to harvest because of the low competitive attitude of this vegetable. Innovative and conventional crop and weed managements were compared in an experiment carried out on farm in the Catania Plain (Sicily, Italy) in 2005-2006. Innovative planting pattern, operative machines (rolling harrow, flaming machine, precision hoe) and crop management increased carrot yield up to 8%, and also increased first category carrot yield and density, thus increasing production quality. Precision hoeing resulted in intra-row weed biomass decrease ranging between 55 to 97%, and in a total working time reduction up to 74%. Furthermore, the innovative crop and weed management systems reduced the costs for hand weeding and increased gross income.

Introduction

In Italy mean annual carrot (*Daucus carota* L.) harvested area is c.a. 13,400 ha, and total production is 620,000 t (Istat, 2006). Carrot is cultivated in many agricultural areas of Italy, and Sicily region accounts 24% of national production, with mean yield of 38 t ha^{-1}. Weeds are known to be one of the major biotic factors that negatively affect organic carrot yield. Carrot seeds have extremely slow emergence and the taproot is preferred as the photosynthate sink during the growth cycle at the expense of the above ground plant part. As a result, carrot canopy can only achieve a very scanty ground cover compared to most weeds (Li and Watkinson, 2000; Peruzzi et al., 2005). One of the main technical constraints to organic carrot growing is the limited range of effective direct weed control means capable of replacing chemical herbicides. Many researches have focused attention on preventive, cultural and direct post-emergence physical control strategies in order to provide the carrot crop with a competitive advantage during the entire cycle (Bàrberi, 2002; Hatcher and Melander, 2003). At present, the main limitation of direct mechanical means is the intra-row weed control. An effective post-emergence intra-row weed control could in fact reduce considerably the number of man-hours required for hand weeding, a practice that is indispensable in carrot production.

This research was planned to study the effects of an innovative organic carrot crop system in comparison with the conventional system of the Ramacca area, in order to increase organic carrot yield and quality as a consequence of the adoption of a new agronomic technique, based on the utilization of innovative operative machines.

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Materials and methods

The experimental trials were carried out in the 2005-2006 growing season at the organic farm “Terre del Sud” in Ramacca (Catania, Sicily) (37°23’ N, 14°42’ E). Soil tillage consisted in three passes with a cultivator at 18-20 cm depth during summer and autumn. In November fields were arranged in ridges 1.6 m wide and 25 cm high, then sowing was carried out. The conventional crop system for organic carrot was compared to an innovative crop system, differing in planting and weed control techniques. In the conventional crop system each ridge was divided before sowing in two strips 50 cm wide. Carrots were planted in two bands per strip 7 cm wide and spaced 30 cm. For early pre-emergence weed control a flaming machine was used. Afterwards intra-row weed control consisted in five manual interventions carried out during the entire crop cycle.

In the innovative crop system a false seedbed was carried out by means of a rolling harrow once the ridges were arranged. As described by Peruzzi et al. (2005), the action of this operative machine is characterized by the passage of spike discs that till the top 3-4 cm of soil, followed by the passage of gage rolls that work at a higher peripheral speed. This machine acts as a direct weeder, because it crumbles the soil superficially and detaches the weed seedlings, but also it stimulates weed emergence, in order to reduce as much as possible the potential weed flora with the subsequent physical treatments.

Then carrots were planted in 5 rows spaced 20 cm apart using a pneumatic precision planter. Before crop emergence, flaming was carried out over the ridges. The flamer was equipped with three 50 cm wide rod burners, set at 10 cm from the soil and at 45° slope, based on previous experimental evidence (Peruzzi et al., 1997). Pre-emergence flame weeding was operated at a mean working speed of 7 km h^{-1} and LPG pressure of 0.3 MPa.

Precision hoeing and manual weeding were carried out for post-emergence physical weed control. Precision hoeing operations in the innovative crop system differed in the number of treatments, while manual weeding was carried out twice (in April and May) in all plots. Two or three hoeing passes were performed with a six elements precision hoe realized in order to work on the ridge and equipped with manual driving system.

Carrots were harvested mechanically with a self-propelled equipment operating on a single row.

The determinations carried out during the filed tests were carrot yield and quality, carrot density, weed biomass and density, and work chains characteristics. A complete randomized block design was used, and data were treated by ANOVA. Means were compared by protected LSD test at $P \leq 0,05$.

Results

Carrot yield statistically differed between the two physical weed management, and innovative crop system resulted in higher vegetable production and quality (Tab. 1).

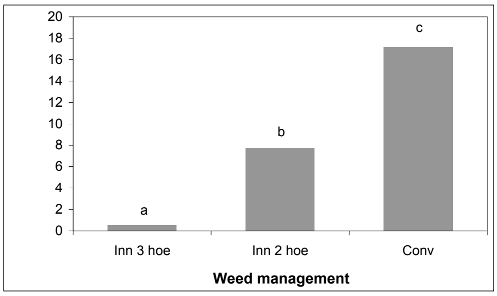
Tab. 1: Yield (t ha^{-1}) of the organic carrot with different crop system menagements.

Crop system	Total	1st cat.	2nd cat.	Ungraded
Inn 2 hoe	32.1 b	3.9 a	18.0 b	10.2 a
Inn 3 hoe	35.7 a	2.7 b	22.7 a	10.3 a
Conv	33.0 b	0.4 c	21.4 a	11.2 a

In the same column, values labelled with different letters are significantly different at $P \leq 0.05$.

Innovative crop system with three precision hoeing operations increased total carrot yield of about 8% with respect to conventional management. Innovative crop system also increased carrot quality with both two and three precision hoeing treatments. Although both innovative and conventional systems resulted in most carrots being included in second marketable class, innovative crop systems with two and three hoeing operations increased about ten and seven fold the first category carrot yield. The same trend was observed for carrot density at harvest. Differences in total carrot density at the end of the crop cycle were not significant, but first category carrot density was markedly increased by innovative systems.

As a consequence of preventive weed control (rolling harrowing and flaming), weed density of innovative management was reduced of about 65% in comparison to the conventional management at early stages, and the following precision hoeing treatments allowed a further weed reduction up to 76%. If compared to the conventional system, the innovative managements allowed a more constant and effective weed control, as evidenced by the weed dry weight at harvest (Figure 1).



Inn 3 hoe: innovative weed management with three hoeing treatments;
Inn 2 hoe: innovative weed management with two hoeing treatments;
Conv: conventional weed management.
Columns labelled with different letters are significantly different at $P \leq 0.05$.

Figure 1: Weed dry weight at harvest as influenced by different weed managements.

Innovative weed management with three hoeing interventions was the most effective among weed control treatments and allowed almost the total elimination of weeds at the end of crop cycle, while innovative management with two hoeing operations reduced weed biomass by 55%.

Total working time for innovative managements with two and three precision hoeing passes was respectively 60% and 74% lower than that relative to the conventional management, as a result of a lower manpower used for hand weeding.

Discussion

The present research showed that an appropriate physical weed management can effectively reduce weed density and working time needed for hand weeding, but it can also guarantee good yield and quality, and also high gross margin.

The false seedbed technique adopted in this experiment allowed a good weed control during the early stages, and provided the crop with a competitive advantage during the entire cycle. However, preventive strategies alone are not sufficient for an effective weed management, thus the utilization of specific machines like the precision hoe is crucial in order to perform a relevant intra-row post-emergence weed control. The single row crop arrangement was adopted in order to perform precision hoeing operations, that considerably reduced the amount of manpower required for post-emergence hand weeding and slightly increased total yield and yield quality. The higher root commercial quality obtained with the innovative system can be explained taking into account that the single rows, associated with precision planting, lead to a more rational arrangement of the space available for the crop plants.

Conclusions

As a conclusion, the results showed that the use of effective strategies and operative machines can increase yield and quality of organic carrot. Although further investigations concerning physical weed control are clearly needed, yet today organic vegetable producers can use innovative, simple, flexible, and not expensive technologies that allow to reach a good degree of weed control, high yield, quality, and gross margin in organic carrot production.

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Innovative Mechanization of Garlic in Vessalico (North Italy)

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Key words: garlic, physical weed control, organic farm, rolling harrow, flame weeding.

Abstract

Vessalico is a small village close to Imperia (Liguria region), where garlic is a typical crop. The garlic of Vessalico is a product that is very appreciated being one of the most traditional and top quality food in Italy. The division of Agricultural Machinery and Farm Mechanization of the Department of Agronomy and Agroecosystem Management and the CIRAA "E. Avanzi" of the University of Pisa, in collaboration with the Agriculture and Civil Defence department of the Liguria Region and the cooperative of farmers "A Resta", carried out a trial aimed to study the possibility of introducing a mechanization chain in order to solve the main agronomic problems of the garlic cultivation in this area, such as sowing, weed control and harvesting, thus improving garlic yield and quality. Ordinary organic garlic crop management was compared with an innovative system in which physical weed control was carried out using a rolling harrow, two flame weeding machines and a precision hoe. The innovative treatments increased whole plant and bulbs dry weight of about 38 and 78% respectively, and reduced weed biomass at harvest up to 77%.

Introduction

Vessalico is a village (Latitude 44°3 N, Longitude 7°58' E) in the district of Imperia, Region Liguria, NW Italy. The farms in this area are very small, and crops are grown in small terraced plots. As a result, operating machines must be handy and not cumbersome. Garlic is the main crop in this area, and it is sold as dried or processed high quality product, that is famous worldwide. Furthermore all the garlic cultivation of the area is organic, and it gives an added value to the crop. The division of Agriculture Engineering and Farm Mechanization Departement of Agronomy and Agro-Ecosystem Management and the CIRAA "E. Avanzi" of the University of Pisa, in collaboration with the Agriculture and Civil Defence department of Liguria and the Cooperative of farmers "A Resta", carried out an experimental test, aimed to study the possibility of introducing a mechanization chain to solve the main agronomic problems of the garlic cultivation in this area, such as sowing, weed control and harvesting, thus improving garlic yield and quality (Peruzzi et al. 2007).

Materials and methods

The research was carried out in 2006-2007 in Vessalico (Imperia, Italy). The ordinary organic garlic cultivation was compared with an innovative system. The farmers of Vessalico usually plant the bulbs using a "one row" potato planter, modified for garlic. This equipment allows a reduction in working time compared to hand sowing, but it

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places the bulbs too deep in the soil, making the emergence of the plants difficult. The inter-row space is 50 cm. Weed control is carried out with a self propelled cultivator between the rows and by hand in-row. This technique is very expensive and can damage the garlic root system if the weeds are too much developed.
Concerning the innovative system, three different equipments for physical weed control were used: a rolling harrow, two flame weeding equipments and a precision hoe, all having a working width of 1.4 m. (figure 1).
The rolling harrow is equipped with specific tools. The tools are spike discs placed at the front and gage rolls mounted at the rear. The front and rear tools are connected by an overdrive with a ratio equal to 2. The disc and the rolls can be placed differently on the axles: in close arrangement, in order to create a very shallow tillage (3-4 cm) of the whole treated area (for seedbed preparation and non-selective weed control after false seed bed) and in spaced arrangement, in order to create efficient selective post emergence weed control (for precision inter-row weeding) (Peruzzi, 2005 and 2006).
The flamer is an open flame machine equipped with five 25 cm wide rod burners. In the experimental field trials the operative machine was used at crop emergence treatment with a driving speed of about 3 km h^{-1} and different LPG pressures. During the trials a hand flamer, equipped with a one 15 cm wide rod burner and LPG pressure of 0.2 MPa, was also used.
The precision hoe is equipped with a seat and steering handles and directional wheels. The machine is equipped with six working units connected to the frame by means of articulated parallelograms. Each working unit is provided with a 9 cm wide horizontal blade and two couples of specific tools (elastic teeth suitable as vibrating tines and torsion weeder) in order to perform both inter and intra row weed control.

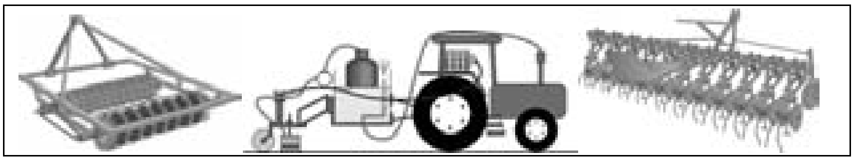

Figure 1: The equipments used for physical weed control: rolling harrow (left), flame weeding machine (middle), precision hoe (right).

The innovative weed control strategy consisted in a false seedbed technique performed with the rolling harrow, followed by flame weeding after crop emergence, as garlic can tolerate an exposure to thermal radiation for a few digits of second. Further interventions of weed control were performed by means of flame weeding or precision hoeing. Harvest was completely manual for both systems, because the garlic plants are dried with whole leaves, in order to twist them in the traditional strings (typical product manufacturing of the area).
During the experimental trials, physical weed control treatments were differentiated. Firstly, a false seed bed was performed with the rolling harrow on each experimental plot. Subsequently, garlic was manually sown in three rows spaced 20 cm apart. At early post emergence, an intervention of flame weeding was carried out at different working pressures (0.2; 0.3; 0.4; 0.5 MPa) using a 3 km h^{-1} driving speed. At the fourth leaf stage, three different secondary treatments for each working pressures were performed: precision hoeing with vibrating tines + torsion weeder, precision hoeing + torsion weeder and manual flame weeding (with a knapsack equipment and a working pressure of 0.2 Mpa). On some experimental plots, no secondary treatment was performed. Weed inter-row and intra-row density was determined on a basis of 25×30

cm^2 sampling area. At harvest crop production and weed biomass were determined. The experimental design was a strip plot with three replicates. Data collected were analysed by ANOVA. Treatment means were separated by Fisher's least square difference at P≤ 0.05 (Gomez e Gomez 1984).

Results

Data collected 29 day after the first flame weeding treatments showed that the most efficient working pressure in controlling inter-row weeds was 0.3 MPa. Weed density recorded 35 day after the secondary treatment revealed significant differences between the treated and untreated plots, but no significant differences were observed between the systems. The weed flora percentage reduction ranged from 24 to 57%.

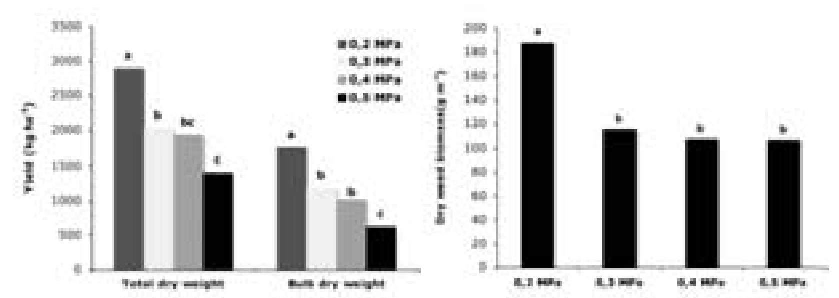

Figure 2: Effects of the different flame weeding working pressures on crop production (left) on weed biomass at harvest (right). Different letters indicate significant difference (LSD P≤0.05).

Significantly higher total dry weight and bulb dry weight were observed when using a working pressure of 0.2 MPa. No significant differences were observed between the secondary treatments. As with weed dry biomass, significant differences between the different working pressures used in the first flame weeding intervention were noticed, with higher values for 0.2 MPa (Figure 2).
Comparing the data collected on innovative experimental plots treated with a working pressure of 0.2 MPa with the ones obtained on field managed in a traditional way, a significantly higher production in terms of total and bulbs dry weight, and a significant lower value of weed biomass at harvest were observed.

Discussion

Weed control is the main agronomic problem of garlic crops in this area. Flame weeding seems to ensure good weed control. The working pressure of 0.3 MPa ensured the best weed control results both in terms of density and biomass at harvest. The working pressure of 0.2 MPa allowed to obtain the highest yield and to control the weed flora in a acceptable way, in comparison with the traditional weed management. In order to explain these results, it should be considered that, during flame weeding intervention (with constant driving speed), the higher LPG pressure resulted in higher transmitted energy.

Conclusions

The introduction of a mechanization chain in organic garlic in Vessalico seems to be feasible, using suitable operative machines available on the market, with opportune setting up and possible modifications. Regarding weed control, the experimental trials carried out by means of the equipments realized at the University of Pisa showed interesting results, that aim to identify a more precise definition of effective weed management and its practical applications.

Acknowledgments

The authors would like to thank Mrs Roberta Del Sarto, Mr Alessandro Pannocchia, Mr Paolo Gronchi, and Mr Calogero Plaia of the M.A.M.A.-D.A.G.A. and C.I.R.A.A. of the University of Pisa, and also all the members of the "A Resta" farmer cooperative for their precious collaboration and participation in the experimental work.

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Innovative strategies for physical weed control on processing tomato in the Serchio Valley (Central Italy)

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Key words: physical weed control, operative machines for weed control, processing tomato, stale seed-bed technique.

Abstract

An "on-farm" open field research on processing tomato weed control was carried out during 2006 in a conventional farm in the Serchio Valley (Pisa, Central Italy). The aim of the experiment was to test innovative strategies and operative machines for non-chemical (physical) weed control.The innovative strategy was compared with the farm traditional technique. The innovative strategy consisted in the application of the stale-seedbed technique (by means of a rolling harrow and a flaming machine in the pre-transplanting phase) and precision hoeing interventions in post-transplanting phase (with an innovative machine equipped with rigid elements, for inter-row weed control, and elastic tines for selective intra-row weed control). Traditional technique consisted in two chemical pre-transplanting interventions and two post-transplanting rotary hoe treatments.Innovative operative machines performances, weed density during the crop cycle, dry weed biomass at harvest and crop fresh yield were recorded.The innovative strategy allowed to reach significantly higher yield values (+18%), a good weed control and a relevant increase of gross marketable production with respect to traditional strategy (+4500 € ha-1 as net value of weed management costs).The experiment is still on-going and it will finish in 2008.

Introduction

Processing tomato is the most important Italian vegetable crop (ISTAT, 2007), although a significant reduction of tomato harvested area was observed in Italy in the last two years (-20%, from 113000 to 91000 ha). This trend is mostly due to political (uncertainty of CMO reform) and economical (high cultural fixed costs) reasons (ISTAT, 2007; Bazzana, 2007).

The production valorisation (for example by organic cultivation) could be a good strategy in order to follow the new policy trends and to guarantee accurate profits to the farmers. This aim could be easily reached by means of cultural practices that respect environmental and consumers health safety.

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The development of new strategies and operative machines for physical weed control (one of the most serious problems in organic summer crops), could represent a good way to reach the aims previously mentioned.

Actually physical weed control research field is mostly studied in Northern Europe, while processing tomato is a typical Mediterranean crop. Thus, with the exception of some recent Spanish field trials (Cirujeda et al., 2007), no scientific papers are at the moment available on this crop.

In this work, the preliminary results of a three year long (2006-2008) “on-farm” open field research are reported. It is still on-going and it is being carried out by the University of Pisa with the aim to develop and improve innovative strategies and innovative operative machines for an effective physical weed control in processing tomato.

Materials and methods

The experiment was carried out during 2006 on processing tomato in a conventional farm placed near Pisa. The tomato variety was called “Leader”. The crop was mechanically transplanted on paired rows at the density of 33000 plants ha-1 (1.60 m of inter-pair space; 0.4 m of inter-row space; 0.25-0.30 m of intra-row space). Crop was irrigated by drip hoses placed in the middle of the inter-row space.

During this first year of experiment the traditional farm weed management system (FS) was compared to an innovative physical weed control system (PWCS). FS was carried out by means of two different chemical pre-transplanting treatments (1 kg ha-1 of “Stomp” – a.i. Pendimetalin – and 1 kg ha-1 of “Ronstar” – a.i. Oxadiazon) and two post-transplanting rotary hoe interventions (not able to till the soil in the intra-row space). PWCS was carried out by means of the stale seedbed technique (realized by one rolling harrow pass followed by one flaming treatment) and two post-transplanting precision hoeing interventions. “Superalba” organic-mineral fertilizer (9-12-21) was applied before crop-planting in both cropping systems at a rate of 1 t ha-1. Fertirrigation was carried out in post-emergence, using a 12-61-0 and a 13-0-40 fertilizers at the beginning and the end of the crop cycle respectively. The soil type was sandy-loamy and a four year rotation was adopted (tomato, wheat, maize and wheat).

The experimental design was a randomized block with four replicates. Data were analyzed by ANOVA. Innovative operative machines performances, weed density during the crop cycle, dry weed biomass at harvest and crop fresh yield were recorded. Three different innovative operative machines were used for physical weed management: a rolling harrow, a flaming machine and a precision hoe.

The rolling harrow was projected, built, tested and patented by Pisa University. It was set up both for pre-sowing (or pre-transplanting) and post-emergence hoeing (for inter-row and intra-row selective weed control) interventions. Working tools are spike disks (placed in the front) and cage rolls (placed at the rear), respectively mounted on two different parallel axles. The axles are connected by an overdrive with a ratio equal to 2. Spike discs till the soil very shallowly while cage rolls (rotating with a double peripheral speed) allow to separate weed seedling roots from soil (Peruzzi et al., 2007a and 2007b). In this case the treatment was carried out just before crop transplanting with a working speed of 7 km h-1 and a working depth of about 4 cm.

The flaming machine controls weeds by the use of an open flame. In this experiment it was equipped with three 50 cm wide rod burners, for a total working depth equal to 1,5 m. The treatment was performed just in the pre-transplanting phase, but if necessary, tomato may tolerate post-emergence selective flaming interventions (with the flame directed to the crop collar) (Peruzzi et al., 2007a and 2007b). Working speed was about 3 km h-1 and LPG consumption was about 35 kg ha^{-1}.

The precision hoe is characterized by a 3 m wide frame. It is equipped by rigid elements for inter-row cultivation (goose sweeps and side "L" shaped sweeps) and elastic elements for intra-row selective weed control (torsion weeders and vibrating tines). The operative machine is also equipped with a seat, steering handles and directional wheels (Peruzzi et al., 2007a and 2007b). By means of these tools, it was possible to till soil and control weeds even inside the crop pairs, without removing the drip irrigation hoses. Furthermore, the precision hoe was equipped by on purpose made "V" shaped elements, that allow to "open" crop vegetation during late hoeing interventions (Fig. 1). Average working speed was about 2 km h-1 and working depth was about 4 cm.

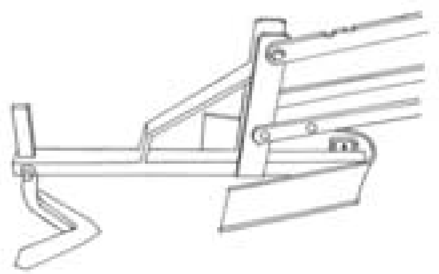

Figure 1: Scheme of a goose sweep and a "V" shaped tool used for late hoeing.

Results and discussion

The innovative physical control strategy allowed a good weed management and a fresh marketable yield increase of about 18%.

Tab. 1: Yield, weed biomass at harvest, total labour time requirement and gross marketable production weed management costs net value (GMP w.n.v.) registered during 2006 on processing tomato.

Weed management system	Yields ($t\ ha^{-1}$)	Weed dry biomass at harvest ($g\ m^{-2}$)	Total labour time ($h\ ha^{-1}$)	GMP w.n.v.* (€ ha^{-1})
Farming system	59.4 b	102.9 ns	15.0 b	22790
Innovative system	72.1 a	126.1 ns	54.1 a	27298

Different letters on the same column mean significant differences for P<0.005 (LSD test), *Gross marketable production weed management costs net value. Data were not analysed by ANOVA

This result was probably due to the good “agronomical” effects of precision hoeing on crop development (Tab. 1). Conventional rotary hoeing, on the contrary, didn’t till the soil into crop pairs, with worse consequences on crop roots development and soil water contents.

Concerning with weed control, no significant difference was observed on weed biomass at harvest between the two different systems (Tab. 1).

Otherwise conventional weed management system allowed a significant reduction of manual labour time for weed control with respect to innovative weed control system (-72%) (Tab. 1). This fact could be explained taking into account the good chemical treatments on weed control. However gross marketable production weed management costs net value (GMP w.n.v.) was higher for PWCS than FS. The estimated differences between the two systems was equal to 4500 € ha^{-1} (Tab. 1).

Conclusions

The innovative physical weed control strategy allowed to reach higher yields and gross marketable production values.

Furthermore, innovative operative machines for physical weed control appeared very versatile, suitable and adaptable to the processing tomato crop. Moreover, these machines can be easily utilized for weed control in organic agriculture, where herbicides use is not permitted. The results of this first year of experiment showed that the alternative cultural strategy could be convenient for environment and consumers health and also for farmers gross income.

However, further experimental work is obviously required in order to verify and improve the effectiveness of innovative strategies and machines for physical weed control on processing tomato.

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Cropping systems

Influence of alleycropping microclimate on the performance of groundnut (*Arachis hypogaea* L.) and sesame (*Sesamum indicum* L.) in the semi-desert region of northern Sudan

Haider E. Shapo[1] & Hussein S. Adam

Key words: Irradiance, Semi –Arid, *Acacia stenophylla*, Evapotranspiration, Water use

Abstract

An alley cropping system was established at Hudieba Research Station (17.57'N and 33.8' E) on a loamy sand soil of the semi-desert region of northern Sudan. The objective of this study was to investigate the influence of modified microclimate in 6-m wide alleys formed by Acacia ampliceps and Acacia stenophylla on growth and yield of groundnut. and sesame. Above-ground interactions were determined by measuring air temperature, relative humidity, wind speed, solar energy and shade length and behaviour. Groundnut and sesame were evaluated for growth and yield by laying out sample plots at southern, central and northern part of the alleys and at control plots. Due to microclimatic modifications in the alleys, the yield of both crops in the alleys significantly (p=0.01) exceeded that of the sole crop. Yield reduction at the northern alley was fully compensated by high yield increase at southern and central alleys. The yield of groundnut increased by 37.7 and 19.6 % in the A.stenophylla and A.ampliceps alleys, respectively. On the other hand, the yield of sesame increased with the stenophylla-alley (+40.3%), while it decreased with ampliceps-alley (-51.5%). The results indicated that the competition for light was the major factor contributing to the increase or reduction of growth and yield of groundnut and sesame.

Introduction

The northern region of Sudan is viable for production of a number of food crops, however, desertification is a threat to the development of agricultural activities. Growing trees is a high priority for productive and sustainable agriculture. However, high cost of irrigation and lack of short-term incentives from the trees restrict plantation of pure tree stands. Trees for protective and productive role could be established on the base of alley cropping technology, which has been defined as " a production system in which trees and shrubs are established in hedgerows" on arable crop land, with food crops cultivated in the alley between the hedgerows (Kang and Wilson, 1987)" .

Alley cropping or tree-crop association has been advocated by several workers as a means to improve productivity, maintain soil fertility, control soil erosion, reduce environmental degradation, and offer better utilization of natural resources (Kang and Wilson, 1987; Kang et al., 1990). In the semi-desert of the northern Sudan, the soil is marked by the virtual absence of soil organic matter and extremely low nitrogen content. In addition, the area seriously suffers from desertification. Thus, alley cropping, using N-fixing trees, is sought of as a potential production practice that can

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provide several conservational and production benefits in the study area. Despite, the economic and nutritional importance of groundnut and sesame, both crops have received little attention in alley cropping research. The objectives of these trials were to examine the effect of alley cropping on microclimate and consequently on growth, yields and yield components of these two crops.

Materials and methods

An alley-cropping experiment was established on loamy sand soil during the period 1998 -2000 at Hudieba Research Station (HRS)., The study area lies within arid to semi-arid zones with mean annual rainfall ranging from 0 to 100 mm. The seedlings of Acacia stenophylla and Acacia ampliceps were planted in hedgerows, 3m within row spacing and 6.3 m between rows. Each hedgerow was 180 m long and arranged in an east-west direction. The groundnut and sesame were grown in the alleys formed by the two acacias assigned randomly in a spilt plot design replicated three times. The plot size was 3X6 m. The alley was divided into three zones: northern, central and southern alley. The central alley had the largest width (4 m), while the northern and the southern alleys were each 1.0 m wide. According to the orientation, and position of the sun at different times of the day and season, radiation varies in each zone. Groundnut (Arachis hypogaea, sub ssp hypogaea, var hypogae) and sesame (Sesamum indicum L.) seeds were sown between rows according to recommendations released by Agricultural Research Corporation in the Sudan. Plant samples were taken at harvest from an area of one square meter in the center of the northern, central and southern alleys and control plots to determine plant characters, yield and yield components.

The Stevenson screens (Meteorological Instrument, 19961) were positioned at a height of 2 m above ground level at each of the three zones of the alley and control plot. The readings of all thermometers were taken simultaneously between 8.00 – 9.00 LT every day and continuous measurements were made from June to October. Cup anemometers were used for measuring wind speed. Tube solarimeters were placed at ground level across the three zones of the alley to measure solar irradiance.

Statistical analysis was carried out using the computer program MSTAT package by SAS Corporation.

Results and Discussions

Table 2 shows that the average reduction in maximum temperatures and solar irradiance was 1.8 ˚C and 54% of the control, respectively. Relative humidity gave average increase of 12%. The southern alley had the highest reduction in maximum temperatures and the highest increase in relative humidity. Its transmitted radiation was higher than in northern alley. On the other hand, the northern alley gave higher reduction in maximum temperatures and higher increase in relative humidity than the central alley. Table 1 demonstrates that there was significant (P=0.01) differences in yields and yields components between the alley cropping and the control plots. Stenophylla–alley, gave higher significant (P=0.01) yields of groundnut and sesame than ampliceps–alley. Regarding the zones of the alley, the southern zone gave the highest yield and yield components.

In agroforestry systems, the tree canopy reduces and modifies the light availability to plants in the understory, with possible beneficial consequences for photosynthesis, water relations and morphogenesis (Bergez et al, 1997). In this study the stenophylla-alley with its relatively higher average radiation (62% of the control) remarkably increased the economic yield of both groundnut and sesame by 37.7 and 40.3%, respectively, compared to the control. On the other hand, ampliceps-alley, with its low radiation (46% of the control), increased the yield of groundnut by 19.6 %, while it decreased that of sesame by 51.5%. The southern zone of the alleys had intermediary radiation, and gave the highest yield. This indicates that the groundnut and sesame yields did not increase as light supply had increased as other environmental factors, seemed to be influential (e.g. temperatures, humidity and wind speed). The highest radiation in the central alley coincided with the least improvement in temperature and humidity, while the lowest radiation in northern alley was concurrent with the complicity of the co-existence of tree-crop roots competition.

Tab. 1: Yield and yield components of groundnut and sesame in the alley and control plots (1999-2000)

Treatments	Groundnut			Sesame		
	Plant height (cm)	weight of kernels kg\ha	Yield as % O f control	plant height (cm)	Wt. seed Kg/ha	Yield as % Of control
Control	17	437	-	136	747	-
Northern-stenophylla	20.6	546	+ 24.9	160	853	+ 14.2
Southern-stenophylla	26.2	676	+54.6	163	1426	+ 90.8
Central-stenophylla	26.8	584	+ 33.6	171	850	+13.8
A.stenophylla-alley	24.5	602	+ 37.7	165	1043	40.3
Northern-*ampliceps*	23.1	320	- 26.7	150	333	- 55.0
southern-*ampliceps*	26.9	681	+ 55.8	136	420	- 43.7
Central-ampliceps	24.7	570	+ 30.4	144	326	- 56.3
A.ampliceps-alley	24.9	523	19.6	143	359.7	-51.8
Sig. L	*	*	-	* *	*	-
S.E+\-	1.2	13.4	-	4.9	6.8	-
C.V %	9.4	10.4	-	2.0	115	-

*significant for P<0.01   * * significant for P<0.001

On the other hand, the yields of groundnut in the southern and central zones of the ampliceps increased by 55.8 and 30.4%, respectively, while it decreased by 26.7% in northern alley. In addition, the sesame yield in the southern, central and northern zones of the ampliceps decreased by 43.7, 56 and 55 %, respectively. The increase in groundnut yield and decrease in sesame yield in ampliceps-alley may not only be due to low radiation (42 – 50% of the control), but may also be due to competition for water. The severe reduction of yield in the northern and central alley of A.ampliceps may be due to complexity of the co-existence of the root of the tree – crop mixture. The competitive roots of the ampliceps extended laterally up to the central alley and compete with sesame for water. Sesame requires adequate moisture for early growth and before flowering, which have the greatest impact on yield (Weiss 1971). Therefore, water-use might be another factor in reducing sesame yield within ampliceps-alley.

Tab. 2: Differences in temperatures (˚C), relative humidity (%) and % of irradiance in various zones of the alley as percentage of control (kw /m^2)

	A.ampliceps-ally				A.stenophylla-ally				ā	Control
	S	N	Ce	x	S	N	Ce	x		
Max. temperatur	-2.7	-1.9	-1.3	-1.9	-1.8	-1.7	- 1.5	-1.7	**-1.8**	41.5
Relative humidity	+18	+13	+10	+14	+12	+10	+8	+10	**+12**	42.0
Solar energy	46	42	50	46	58	54	75	62	**54**	0.354

*S= Southern alley *N=Northern alley *Ce=Central alley *Co= Control

* x = average * Am = Acacia ampliceps * St = Acacia stenophylla

* (-) Reduction in maximum temperature * (+) increase in relative humidity

* ms-1 = wind meter per second

Conclusions

Thus, the current conditions in the Northern Region of Sudan are favourable for adopting agroforestry technology in order to arrest environmental deterioration and to secure productivity and sustainability of agricultural crops. The study revealed that trees influenced the plant-environment-relationship in a way that conditions become more conducive for crop growth. Although, the micro-environmental variables were responsible for yield increase or decrease, but in reality, it seemed difficult to separate the complex interacting climatic factors involved in the system. Nevertheless, the obtained results indicated that the competition for light was the major contributing factors responsible for yield reduction or increase in the different alley' zones. Groundnut had proved to be shade tolerant and it gave the highest yield with *A.ampliceps* with low radiation (46% of control).

In high terrace soils of northern Sudan, groundnut is recommended to be alleycropped with *A.stenophylla* and *A.ampliceps* trees, while sesame is recommended to be alleycropped with Acacia stenophylla.

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The significance of mycorrhizal fungi for crop productivity and ecosystem sustainability in organic farming systems

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Key words: organic agriculture, plant-soil interactions, crop productivity, mycorrhizal symbiosis

Abstract

Mycorrhizal fungi are widespread in agricultural systems and are especially relevant for organic agriculture because they can act as natural fertilisers, enhancing plant yield. Here we explore the various roles that mycorrhizal fungi play in sustainable farming systems with special emphasis on their contribution to crop productivity and ecosystem functioning. We review the literature and provide a number of mechanisms and processes by which mycorrhizal fungi can contribute to crop productivity and ecosystem sustainability. We then present novel results, showing that mycorrhizal fungi can be used to suppress several problematic agricultural weeds. Our results highlight the significance of mycorrhizal fungi for sustainable farming systems and point to the need to develop farming systems in which the positive effect of these beneficial soil fungi is optimally being utilized.

Introduction

The 400 million year old symbiosis between the majority of land plants and arbuscular mycorrhizal (AM) fungi is one of the most ancient and abundant mutualisms on Earth. AM fungi form extensive hyphal networks in soil and provide plants with nutrients in return for assimilates (Smith & Read 1997). AM fungi can act as support systems for seedling establishment, provide resistance against drought and some pathogens, and AM fungi can enhance biological diversity in grassland (van der Heijden et al. 1998). Several studies have shown that AM fungi contribute to up to 90% of plant P demand (Jakobsen et al. 1992; van der Heijden et al. 2006).

AM fungi are especially important for sustainable farming systems because AM fungi are efficient when nutrient availability is low and when nutrients are bound to organic matter and soil particles. Many important agricultural crops can benefit from AM fungi, including maize, potato, sunflower, wheat, onion, leek and soybean, especially under conditions where nutrient availability is limiting plant growth. Moreover, AM fungi not only can promote via directs effects, but there are also a number of indirect effects such as a stimulation of soil quality and the suppression of organisms that reduce crop productivity (see Table 1 for an overview).

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Table 1: Direct and indirect effects of mycorrhizal fungi on crop productivity in organic farming systems

Direct effects on crops
Stimulation of plant productivity of various crops
Nutrient acquisition (P, N, Cu, Fe, Zn)
Enhanced seedling establishment
Drought resistance
Heavy metal resistance
Indirect effects
Weed suppression
Stimulation of nitrogen fixation by legumes (green manure)
Stimulation of soil aggregation and soil structure
Suppression of some soil pathogens
Stimulation of soil biological activity
Increased soil carbon storage
Reduction of nutrient leaching

Until now, most studies have investigated the effects of AM fungi on plant growth using pot experiments with single plants. However, in the field crops co-occur with weeds and some crops are grown together with other crops in mixtures. Hence, it is necessary to use a "system" approach in order to assess the significance of AM fungi for the functioning of agricultural ecosystems. Using such a system approach we explore in this paper whether AM fungi can suppress growth of several highly problematic agricultural weeds that coexist with crops.

Methods

42 microcosms simulating a sunflower cropping system were established in the greenhouse under controlled conditions. Sunflower and six weed species were grown together in microcosms (sunflower-weed mixtures) or weeds and sunflower were grown alone (weed and sunflower monocultures respectively). Half of the microcosms of each treatment were inoculated with a mixture of three AM fungal species and the other half of the microcosms received sterilized inoculum as a control. The microcosms were harvested after 14 weeks. Dry weights of sunflower and weeds were determined in each treatment and used to calculate the competitive balance index according to Wilson (1988). It was tested whether AM fungi reduce weed growth and alter competitive interactions between weeds and sunflower.

Results & Discussion

It is well known that AM fungi enhance plant growth. However, AM fungi are not only beneficial and interactions between plants and AM fungi can range from mutualistic to parasitic (van der Heijden 2002; Klironomos 2003). Studies performed with plants from natural communities show that AM fungi have a negative impact on several ruderal plants (Francis & Read 1995). Many important weeds have a ruderal lifestyle, suggesting that AM fungi have the potential to suppress weed growth. To test this we established microcosms in which sunflower was grown together with weeds (see methods). We observed a reduction in weed biomass when AM fungi were present in the microcosms supporting our expectations. Moreover, the presence of AM fungi significantly enhanced the competitive ability of sunflower relative to the weeds (Figure 1). Thus, our results show that AM fungi alter the interaction between weeds and sunflower, promoting sunflower and suppressing weeds.

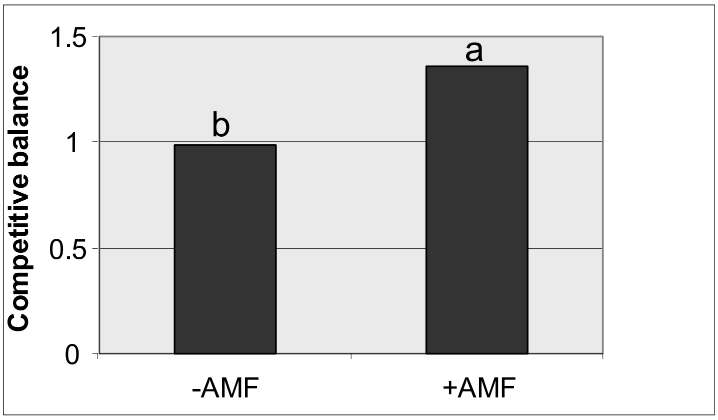

Figure 1: Competitive balance between sunflower and weeds in microcosms with AM fungi (+AMF) or without AM fungi (-AMF). A higher competitive balance indicates a higher competitive ability of sunflower. A competitive balance of > 0 indicates that sunflower is more competitive than weeds.

Conclusions

Our results show that mycorrhizal fungi can contribute to weed control because they suppress the competitive ability of weeds relative to sunflower. Moreover, mycorrhizal fungi can directly and indirectly contribute to plant productivity in organic farming systems. Mycorrhizal effects include enhanced nutrient uptake, enhanced seedling establishment and stimulation of soil structure. Additional research is needed to develop farming systems that optimize the use of natural resources such as mycorrhizal fungi for sustainable agricultural production.

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National-scale modelling of N leaching in organic and conventional horticultural crop rotations - policy implications

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Key words: Nitrogen leaching, modelling, crop rotations, vegetables, water framework directive

Abstract

A method is presented to model N leaching in crop rotations on a national scale. Representative crop rotations for different regions and soil types are used in the cross-disciplinary, plant, soil, environment & economics model EU-Rotate_N. By comparing contrasting farming systems (organic and conventional) in the UK, their strengths and weaknesses in delivering environmental and economic sustainability can be assessed. Modelling results show that the annual leaching in different horticultural rotations and UK regions, using median weather, is within the range of 13 - 88 kg N/ha/year for organic and 54 - 130 kg N /ha/year for conventional. The weighted annual average figures are 39 kg N/ha/year for organic and 81 kg N/ha/year for conventional, respectively. It is concluded that organic horticultural rotations, with a current share of 6.1% already contribute to lower overall N losses from agriculture. However, on a UK national scale, only a large share of organic land use (e.g. > 50%) has a large effect on reducing N losses. Similar reductions are also predicted by substantial cuts in conventional N inputs, giving a policy choice if pollution from agriculture steps up further on the political agenda.

Introduction

Many arable and vegetable crops across Europe are produced in intensive rotations, with large nitrogen (N) fertiliser inputs. Arable crops and especially field-scale vegetable crops use nitrogen often inefficiently and leave N residues in the soil after harvest. This can cause pollution to soil, water and aerial environments, economic losses and unnecessary recourse use. For policy planning, it is necessary to quantify these effects not only on a crop or farm rotation level but also on a national or county level with all its variations in soil type, climate, rotational design, management practise and marketing specifications. With the given constrains in computer power and data availability it is obviously currently not possible to model all rotations of a country and its differing farming systems. Therefore, the two main contrasting farming systems, conventional and organic production, in the United Kingdom were used. To simplify model inputs, statistic data were used to source representative rotations for each farming type.

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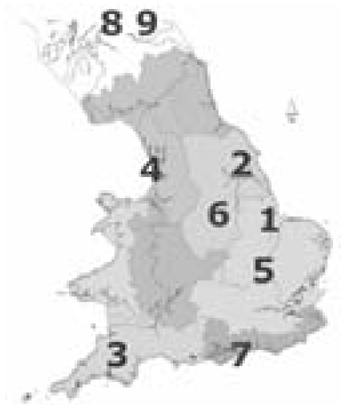
Materials and methods

The data were modelled using EU-Rotate_N a computer model developed over the last five years by a consortium of European researchers. It is a decision support system for soil-plant interactions based on N use in crop rotations. Up to 30 years of cropping can be simulated on a daily step in organic or conventional rotations. The model is written in Fortran and allows the experienced researcher great flexibility since all inputs can be modified to suit local conditions. The model includes routines for water use, water stress, mineralisation, snow and frost (Riley and Bonesmo 2005), root growth and distribution (Kristensen & Thorup-Kristensen 2006), N release from fertility building crops (Rayns et al. 2006) and economics including market channels, marketable yields, crop spacing and variable costs (Schmutz and Firth 2005). The model is available at www.warwick.ac.uk/go/eurotaten (Because of space constrains no further basic details about the model can be given here and reference may be consulted). The data and methods used to source representative 3 - 8 year crop rotations on a national scale are described elsewhere (Schmutz et al. 2006).

Based on these data, the following model runs have been selected (UK regions representing less then 5% of the national vegetable production e.g. Wales, North East England, Northern Ireland were excluded). The first five areas were also run with organic rotations. They represent main UK production areas for conventional and organic and are also scattered in the main river basins according to the water framework directive (WFD) as shown the England and Wales map Table 1.

Tab. 1: Represenative areas, regions, soil types and main crops used in the model runs. The first five areas are also done for organic rotations (run 1o-5o).

Run Nr	Area	Region	Soil Type	Main crops
1	South Lincolnshire	East Midlands	Heavy Silt	Brassicas
2	North Lincolnshire	East Midlands	Sandy Loam	Brassicas
3	Cornwall	South West	Sandy Loam	Brassicas
4	Lancashire	North West	Silt Loam	Brassicas
5	Bedfordshire	Eastern England	Light	Mixed vegetables
6	Nottinghamshire	East Midlands	Light sand	Onion, Carrot, Potatoes
7	Sussex	South East	Sandy Loam	Lettuces
8	Fife	Scotland	Sand	Root Crops
9	Fife	Scotland	Sandy Loam	Brassicas



Organic rotations were run with management data (not shown) representing current organic practices as defined by the Compendium of UK Organic Standards (Defra, 2006). Conventional rotations were run with management data (not shown) representing good agricultural practice (GAP) and N fertiliser inputs as defined by the Defra publication RB209. An example for current practice organic rotation is 2-year grass/clover, potatoes, broccoli, leeks, while the conventional has spring wheat, potatoes, broccoli leeks. In order to compare the land use patterns of organic and conventional rotations in a UK scenario they were statistically weighted according to their importance within UK vegetable regions (e.g. the current high representation of organic production in the high rainfall area of the South West (27.8% weight organic versus 5.8% weight conventional) is taken in account. The current dataset and method represents 86% of the UK conventional and 68% of the UK organic vegetable production. Because of limitations in statistically available data, potatoes and leguminous vegetable crops were excluded (Schmutz et al. 2006). The effects on N leaching, rotational gross margins and other parameters are shown for the current UK organic vegetable land use share of 6.1% and for scenarios with 0%, 2%, 20%, 50% and 100% organic management of the UK vegetable area.

Results

Given space constrains, the inputs and results of individual rotations and model runs are not discussed. Results are only presented on an aggregated level showing the weighted national UK average including all regions, rotations soil types and weather conditions. Data show (Table 2) that current good practice (GAP) horticultural land use has predicted looses of 39 kg N/ha/year under organic and 81 kg N/ha/year under conventional management, respectively.

Tab. 2: Average %-cropping in rotation, modelled N-fluxes and rotational gross margins of weighted organic and conventional horticultural rotations. Data are shown per ha and year, and for the UK horticultural sector assuming different land use percentages of horticultural crops.

Data per ha and year	Organic	Conventional	org%conv
% vegetables	56%	65%	
% cereals	4%	32%	
% fertility crops	40%	3%	
Modelled rotational N fluxes			
N input Mineral Fert (kg/ha/yr)	0	158	
N input Organic Fert (kg/ha/yr)	18	0	
N leach below 90cm (kg/ha/yr)	42	85	
N uptake below 90cm (kg/ha/yr)	3	3	
N system loss water (kg/ha/yr)	**39.2**	**81.4**	**48%**
N gaseous loss (kg/ha/yr)	54	28	191%
N fixed (kg/ha/yr)	30	0	
N system loss air (kg/ha/yr)	**24**	**28**	**86%**
N total loss (kg/ha/yr)	64	110	58%
Rotational gross margin (€/ha/yr)	**€ 3,466**	**€ 2,515**	**138%**
Data for UK horticultural sector			Combined
UK vegetable area (ha)	4720	72866	77586
N system loss water (kg/ha/yr)	39.2	81.4	78.8
Total UK kg N leached (t/year)	185	5929	6114
% organic land use	6.1%	93.9%	100%
Scenario with different % organic	% org	N (kg/ha/yr)	N (t/year)
	0%	81.4	6313
	2%	80.5	6247
current % organic land use	**6.1%**	**78.8**	**6114**
	20%	72.9	5658
	50%	60.3	4676

Gaseous losses of organic production are predicted to be higher than for conventional farming (54 kg versus 28 kg N/ha/year), however when N fixing by legumes is included, the system loss to air is slightly lower (24 kg versus 28 kg N/ha/year). With the current organic land use of 6.1%, the overall system loss for the horticultural sector of field scale vegetables (excluding potatoes and leguminous vegetables) is 79 kg N/kg/ha. Without organic land use (0%-scenario), the losses are predicted to be 81 kg N ha/yr or 6114 tonnes N per year for this sector. With 20% organic land use, the next realistic milestone in organic expansion of UK horticultural land use, the sector's losses are predicted to be 5658 tonnes N per year.

Conclusions and Discussion

For the organic rotations, it can be concluded that the annual leaching predicted for different UK regions and rotations, using median weather, is within the range of 13 - 88 kg N/ha/year. The weighted annual average figure for the UK with median weather is 39 kg N/ha/yr. The 25- and 75- rainfall percentiles give a range of the weighted average of 24 - 45 kg N/ha/year. Overall leaching losses in organic are predicted 48% of conventional. If individual rotations, not weighted, are compared a Student's t-test is possible showing significantly lower (5% error level) leaching losses in organic. For the conventional rotations it can be concluded that the annual leaching is within the range of 54 - 130 kg N /ha/year, with a weighted annual average of 81 kg N/ha/year. The 25- and 75- rainfall percentiles give a range of 50 - 93 kg N/ha/year. On a policy level, it can be concluded that organic production can play an important roll in reducing N losses from horticultural land use. However, on a UK national scale, only a large share of organic land use (e.g. > 50%) has a large effect on reducing N losses by 36% to 60 kg/ha/year. Similar reductions are also predicted by substantial cuts in conventional N inputs. Model runs where the current conventional average N input (based on GAP recommendations) was reduced from 158 kg/N/year to 111 kg/N/year resulted in leaching losses of 50 kg/ha/year on a national scale. However, these are only projections from today’s land use and management practices, it is difficult if not impossible to predict the complex interactions of scale effects when organic production increases its critical mass, moves into more favourable low-rainfall areas and simultaneously conventional production becomes “greener”. The conclusion is certainly different on a catchment scale, where 100% organic land use can be achieved or enforced by restricting management practices and reductions more specifically modelled.

Aknowledgments

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Beneficial System Outcomes in Organic Fields at the Long-Term Agroecological Research (LTAR) Site, Greenfield, Iowa, USA

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Key words: Crop rotations, soil quality, corn, soybean, economics

Abstract

In 1997, Iowa State University established the first U.S. Land Grant University permanent faculty position in organic agriculture to assist farmers in the rapid expansion of organic production in that state. Research agendas, developed in consultation with organic farmers and processors, led to the establishment of the Neely-Kinyon Long-Term Agroecological Research (LTAR) site in Greenfield, Iowa, in 1998 to study the long-term effects of organic production in terms of yield and economic performance, in addition to other system effects. Over nine years of comparison, there was no significant difference in corn or soybean yields in the organic and conventional systems. Organic corn yields in the longest rotation (C-S-O/A-A) over a 9–yr period were 9914 kg/ha compared to 10113 kg/ha in the conventional system and organic soybeans in the same rotation yielded 3043 kg/ha while conventional yields averaged 2906 kg/ha. Soil quality remains high in the organic system, with soil organic carbon and mineralizable nitrogen greater in the organic rotations relative to conventional, demonstrating greater C sequestration potential and N-use efficiency in the organic system. Over nine years, revenues generated from organic corn crops increased average revenues by a factor of 1.67 over conventional corn, while organic soybean revenues were 2.32 times greater than conventional soybean revenues.

Introduction

Because the state of Iowa advanced quite rapidly in organic production from 1992 to 1996 (USDA-ERS, 2007), Iowa State University (ISU) established the first U.S. Land Grant University permanent faculty position in organic agriculture in 1997. Research agendas were developed in consultation with organic farmers and processors in order to address the needs of the organic community. The Iowa State University Neely-Kinyon Long-Term Agroecological Research (LTAR) site was established in 1998 to study the long-term effects of organic production in Iowa, U.S. In the LTAR, we have involved organic farmers in the design and analysis, and in complementary on–farm trials examining soil processes in the organic transition and beyond certification. The State of Iowa Department of Agriculture organic division, which is accredited by the USDA–National Organic Program, certifies the LTAR organic plots on an annual basis.

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Materials and methods

Treatments at the LTAR site, replicated four times in a completely randomized design, include the following rotations: conventional Corn-Soybean (C-S), organic Corn-Soybean-Oats/Alfalfa (C-S-O/A), organic Corn-Soybean-Oats/Alfalfa-Alfalfa (C-S-O/A-A), and Soybean-Wheat with a frost-seeding of red clover (S-W/RC). For purposes of this paper, we will discuss the first three rotations. A 9.1–m buffer separates the certified organic and conventional plots within the forty-four plots, measuring 42 by 21 m each, that constitutes the experiment. Crop variety selections vary annually, according to recommendations from the farmer association affiliated with the LTAR site. Sowing dates and seeding rates follow local organic practices (Table 1). Following harvest of the organic corn plots in all years, winter rye is no-till drilled at a rate of 78 kg/ha into plots going to soybean to provide allelopathic control of future weed populations. Compost, made from a mixture of manure and corn stover that is removed from deep-bedded swine 'hoop-house' structures, is composted for one year and averages 7.8, 9.6, and 13.7 g/kg N, P, and K, respectively. The compost is applied to organic plots at rates intended to apply 134 kg N/ha during the corn phase of the rotation. Organic oat plots receive compost at a rate to apply 78 kg N/ha. Conventionally managed corn is fertilized at planting with 28% urea ammonium nitrate at a rate of 134 kg N/ha. Herbicides and insecticides are applied in conventional plots according to ISU recommended rates; no pesticides were applied in organic plots over the nine years of the experiment. Weed management in the organic plots included an average of four mechanical cultivations (two rotary-hoeings and two row cultivations) per season in the corn and soybean plots; no weed management was needed in the oat, wheat and alfalfa plots. Crops were mechanically harvested with combines and hay rakes/balers per local organic farm practices in the nine years of the experiment.

Tab. 1: Sowing and harvesting data for all crops in the rotations at the LTAR, 1998–2006.

Crop	Sowing Dates	Seeding Rate	Harvest Dates
Corn	17–27 May	79,040 seeds/ha	9 October–1 November
Soybean	15–28 May	407,550 seeds/ha	9–27 October
Oats	29 March–18 April	108 kg/ha	14 July–3 August
Alfalfa	29 March–18 April (seeded with oats)	18 kg/ha	26 May–25 August (green manure)
Wheat	15–24 October	101 kg/ha	8–25 July
Red Clover	1–9 March	28 kg/ha	Retained for green manure

Soils were sampled in the fall of each year from five randomly located 3.3-cm diameter soil cores collected to a depth of 15 cm from each plot, one from each of four quadrants and one core from the plot center. The five cores were combined into one composite sample, stored in plastic zip-lock bags, and kept cool during transport to the laboratory. A 10-g sub-sample of field moist 8-mm-sieved soil was extracted with 50-mL of 2M KCl, and inorganic N (NO_2 + NO_3) in the filtrate was quantified using flow injection technology (Lachat Instruments, Milwaukee, WI). Five grams of the sub-sample was ground pass a 250-□m diameter sieve and used to determine total organic C and total N (TN). Total organic C (after removal of carbonates with 1 M H_2SO_4) and TN were quantified by dry combustion using a Carlo-Erba NA 1500 NCS elemental analyzer (Haake Buchler Instruments, Paterson, NJ). Potentially mineralizable N was measured using an aerobic 28-day incubation method described by Drinkwater et al. (1996). All analyses were conducted at the USDA-ARS National Soil Tilth Laboratory, and the Iowa State University Agronomy Soil Analysis Laboratory, Ames, Iowa. Because farmers converting to organic production were particularly interested in the revenue generated from organic crops, we maintained records on all crops sold into commercial organic and conventional markets over the course of the experiment. Revenue was determined by multiplying the price received in the market by the yields from each crop in each rotation (Delate et al., 2006).

Results and Discussion

In each of the nine years of production (1998 to 2006), organic corn and soybean yields in the LTAR have equaled or exceeded conventional crop yields, with no statistical difference between conventional and organic crops over the combined 9-year period (Table 2).

Tab. 2: Average 9-yr yields in organic and conventional rotations at the LTAR, 1998–2006.

Rotation	9-Yr Corn Yield (kg/ha)	9-Yr Soybean Yield (kg/ha)	9-Yr Oat Yield (kg/ha)	9-Yr Alfalfa Yield (t/ha)
Conventional C-S[1]	10113a	2906a	N/A	N/A
Org. C-S-O/A-A	9914a	3043a	3260a	8.6
Organic C-S-O/A	8387a	2959a	3309a	N/A (green manure)
Significance (0.05 level)	NS[2]	NS	NS	—

[1] C = corn, S = soybean, O = oat, A = alfalfa, [2] not significant (LSD test $p \leq 0.05$)

Despite the lower external N input in the organic system, the organic crop rotations appeared to maintain adequate N levels throughout the season, as demonstrated by high organic corn yields, especially following two years of alfalfa. Soybean, not relying on external N, produced yields in both systems that were equivalent throughout the experiment. Organic corn yields in the longest rotation (C-S-O/A-A) over a 9–yr period were 9914 kg/ha compared to 10113 kg/ha in the conventional system; organic soybeans yielded 3043 kg/ha while conventional yielded 2906 kg/ha. Oat yields did not vary between the three- and four-year rotations. Soil data, when combined across all crops in each system, indicated that organic soils have the potential to cycle and store plant nutrients more efficiently and sequester more C than conventional soils (Table 3). After nine years of organic management, the organic soils had more total soil organic carbon and higher mineralizable N than the conventional soils. This result was particularly important in light of the four tillage operations in each of the corn and soybean years. The inclusion of the small grain crop and alfalfa in the rotation, in addition to the compost applications in the corn and oat years, led to significantly greater carbon and nitrogen pools in the organic system.

Tab. 3: Soil quality at the LTAR site after the first and ninth year of the experiment.

System	1998		2006	
	SOC[1] (Mg C/ha)	Mineralizable N (kg N/ha)	SOC (Mg C/ha)	Mineralizable N (kg N/ha)
Conventional	40.9a[2]	72a	44.4b[2]	95b
Organic	40.9a	65a	45.4a	114a
Signif. (0.05)	NS	NS	*	*

[1] Soil organic carbon, sampling depth 15 cm, [2] ,significant (LSD test $p \leq 0.05$).

Economic returns were a critical metric for farmers following the results of this experiment. The revenue received for the organic crops (during the two transition years and the seven certified years) was highest in the organic corn and soybean crops, followed by the alfalfa and oat crops (not shown). While income generated from the small grain crop produced the least revenue, the inclusion of the small grain/legume intercrop in the rotation is essential for soil building and pest management.

Conclusions

Over nine years of comparison, there was no significant difference in corn or soybean yields in the organic and conventional systems (Table 1). In a related study, costs of production were found to be lower in the organic system (Delate et al., 2006) while prices received for the organic crops increased significantly over conventional prices after certification in the third year. Organic corn increased average revenues by a factor of 1.67 over conventional corn, while organic soybean revenues were 2.32 times greater than conventional soybean revenues. Soil quality remained high in the organic system, with soil organic carbon and mineralizable nitrogen greater in the organic rotations. The critical issue of communicating results from this research is enabled through field days, workshops, internet broadcasts, and lectures in Iowa and across the U.S. (Delate et al., 2006).

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Experiences with intercropping design – a survey about pulse cereal-combinations in Europe

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Key words: Intercropping, cereal grain legume combinations, survey, European countries, EU project

Abstract

A survey was carried out within five European countries with regard to the practice of cereal grain legume intercropping. The mostly given combination was spring barley-spring pea beside 27 other combinations between pulses and cereals. 72 % of all examples consisted of spring varieties, the rest of winter varieties, mainly a special case of the French South West with mild winter climate. Intercrops were mainly used for feeding purposes. Best experiences were named as better yield stability, effective weed suppression, and good quality of feed. Of the negative experiences complicated mechanical weed regulation, unequal maturation and additional costs for separation were mostly named. The interviewed farmers showed predominantly positive prospects for the development of intercropping on their farms, problems with sowing techniques were only of minor importance.

Introduction

Intercropping per se corresponds to a very high extent to the concept of increased biodiversity within organic crop husbandry. It is mostly realised in multi-species mixtures of perennial pastures, partly in green manuring or undersowing approaches, much less in cultivation of main crops (Gliessman 2000). The latter aspects was focus of one workpackage of a European project <*Intercropping of cereals and grain legumes for increased production, weed control, improved product quality and prevention of N-losses in European organic farming systems (QLK5-CT-2002-02352)*> in order to record the daily practice, the experiences and the prospects of that cropping design within the farming community of organic farmers in Denmark, France, Italy, United Kingdom, and Germany.

Materials and methods

The survey was carried out in each country of the project partners by personal farm visits. A common questionnaire consisted mainly of questions concerning

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intercropping, farm structure and personal estimations, experiences and demands. All data of 65 interviews were collected through an online php-based input mask, stored in a mysql database and finally statistically evaluated by SPSS.

Results

The use of intercropping design in the organic farms was mainly initiated from 1981 on (table 1), approximately 90 % of all counts could be referred to that period. Between 1981 and 1990 it was mainly implemented on German farms, followed by French and Danish farms. Ten years later most of the Danish (and French) farmers integrated intercropping into crop husbandry. After 2000 another 11 % followed into the same direction (DK > FR > UK). That also reflects the different periods of conversion. Among the German group there was a longer experience of organic farming practice compared to the colleagues of the other countries.

Tab. 1: Since when intercropping was used? (*% of all counts*)

Year	(N)	(%)	DE	UK	FR	IT	DK
– 1970	2	3.1	*3.1*				
1971 – 1980	5	7.7	*3.1*		*3.1*		*1.5*
1981 – 1990	19	29.2	*15.4*		*9.2*		*4.6*
1991 – 2000	32	49.2	*7.7*	*1.5*	*13.8*	*7.7*	*18.5*
> 2000	7	10.8		*1.5*	*3.1*		*6.2*
Counts [N]	65		19	2	19	5	20

As reasons for intercropping six criteriae were named out of which intercrops for the production of feed was most prominent, especially in DE, DK and FR (table 2). Production for the market was the second criterium although the marketing due to necessary separation can only be realized with additional efforts and costs (table 5). Soil conservation was specified as third reason for working with intercropping, but on a distinctly lower level. The other criteria can be assessed as negligible with regard to number and relevance for the daily practice.

Tab. 2: Reasons for the use of intercrops (*% of all counts*)

Year	(N)	(%)	DE	UK	FR	IT	DK
Feed	39	60.0	*23.1*	*1.5*	*16.9*		*18.5*
Market	18	27.7			*12.3*	*4.6*	*10.8*
Soil conservation	5	7.7	*4.6*			*3.1*	
Demonstration	1	1.5					*1.5*
Research	1	1.5		*1.5*			
Seed production	1	1.5	*1.5*				
Counts [N]	65		19	2	19	5	20

Although intercropping in most cases and countries relied on 2 component mixtures (table 3), 3- and more component mixtures were also appointed, mainly in DE, DK and FR. Most of the specified examples for intercrops were build up with spring pea (22 %), spring barley (22 %), oats (13 %), winter pea (9 %) and winter triticale (9 %).

Tab. 3: Number of components per mixture (% per country)

No components	DE	UK	FR	IT	DK
2	52	100	72	100	80
3	39		10		15
4	6		14		5
5	3		3		
Counts [N]	31	1	29	5	41

Tab. 4: Frequency of spring and winter types (% per country)

Variety	DE	UK	FR	IT	DK
Spring	96	100	24	60	95
Winter	4		76	40	5
Counts [N]	27	1	29	5	40

Of 28 different combinations for used intercrops three examples covered >50 % of all combinations: (A) spring barley-spring pea (24 %), (B) spring barley-spring oats-spring pea (15 %) and (C) winter pea-winter triticale (15 %). The latter example is a special situation of the mild winter climate in the South West of France. Example (A) was grown on 513 ha, example (C) on 200 ha. (table 4). There was a clear distinction between the mixtures of Danish farmers on the one hand (prevalence of pulses), and French and German farmers on the other hand (prevalence of cereals). Farmers were asked about positve and negative experiences and estimations of intercrops (table 5). Of the 13 arguments emphasizing the benefit of mixed cropping systems yield stability, effective weed suppression, good quality of feed, easier harvest, good precrop effect, and less pests and diseases covered > 60 % of all answers. The opposite perspective was seen with regard to more complicated mechanical weed control (15 %), unequal maturation (11 %), problems due to lodging and additional costs for separation (7 %).

Tab. 5: Advantages and disadvantages of intercropping?

Positive	(%)	Negative	(%)
Yield stability	15	Mechanical weeding more complicated	15
Effective weed suppression	12	Unequal maturation	11
Good feed	11	Problems due to lodging	7
Easier harvest	9	Additional costs for separation	7
Good precrop effect	9	IC mixture at harvest unpredictable	6
Less pests & diseases	7	Marketing of mixed seeds	4
Less lodging risk for peas	4	Problems to preserve	4
Less labour	2	Grain losses at harvest	4
Better use of resources	2	Undersowing difficult in IC	2
More flexibility in rotational management	2		
Higher yield	2		
Higher diversity	2		
Compensation	2		

Among the group of interviewed farmers at least 40 % of the answers indicated maintenance and expansion of the area of intercropping in the next future of crop husbandry (not shown). Changes of the composition of mixtures were named as other aspects of wanted improvements of the intercrops. Aspects i.e. change of sowing technique or reduction of growing area were appointed less common.

Discussion

The results of the survey reflect the findings of Rauber & Hof (2003) to a high extent. The positive experiences about better weed suppression are in accordance with findings of Hauggard et al. (2006), Jensen (2006) and Trenbath (1993). Technical problems such as adequate mechanical tools for sowing and weeding were not so much emphasized by the farmers as done by interviewed advisors within the study of Rauber & Hof (2003), but belonged to the mentioned obstacles towards the use of intercropping. There is a distinct tendency for simple combinations, most of the appointed examples consisted of 2 or 3 components. Thus the claim for increased biodiversity by cultivation of intercropped pulses and cereals is of limited value and should be supported by further genom intercrops i.e. mixtures of cultivars within the species (Finckh 2001). The longest experiences were found on organic farms in Denmark, France and Germany, whereas very limited numbers of farmers with intercrop experiences could be found in United Kingdom and Italy. Therefore most of the conclusions are related to the Danish, French and German data.

Conclusions

Intercropping provides distinct benefits for organic farming systems. That is also true for the combination of pulses and cereals. It is desirable that scientific work is more concerned with related questions in order to convince advisors of these systems and to encourage practitioners to implement more of such cropping designs into their cultivation plans.

Acknowledgments

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Growing rapeseed in mixed cropping with cereals

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Key words: seed density, rapeseed, barley, rye wheat, LER

Abstract

Yields of mixed cropping systems of winter rapeseed (Brassica napus) with winter rye, winter wheat and winter barley in organic farming are reported by the example of a one year field trial in Trenthorst, North Germany. The trial was established as perpetuation of trials in the years before with different seed densities and row distances due to very low yields of both components to increase the overall yield of the mixtures. Winter rapeseed was heavily suppressed by the cereals when grown in mixture with rye. The winter rapeseed yields were more adequate in relation to the chosen seed reduction in combination with wheat. In systems with delayed drilling of the cereals between rows of rapeseed, wheat and barley had problems in field establishment and rapeseed yields were over-proportional in relation to the chosen seed reduction. Land equivalent ratios (LER) were around 1 in all systems. The use of those mixtures as practicable yield buffer in organic farms needs further evaluation.

Introduction

Rapeseed in organic farms is prone to pest and insect infestations. Additionally it has a high nitrogen demand. Its use as component of organic crop rotations therefore is very risky. Mixed cropping systems of rapeseed with cereals could be a possible tool to compensate for unstable rapeseed yields in organic farming and to keep a small scale rapeseed production upright. Effects on weed suppression and yields of those systems in Canada have been reported by Szumigalski and van Acker 2005 and 2006. The first experiences with rapeseed-cereal mixtures in organic farming are reported by Paulsen and Schochow (2007). These trials showed a very high variability in rapeseed yields due to difficult post winter establishment of the rapeseed and to heavy yield losses by *melingethes aeneus.* When cereals established well rapeseed biomass and seed yield at harvest were strictly reduced by the cereal partners and cereal yields were small. To increase overall yields of the mixtures row distances, row distribution and seeding dates were varied. The results of this trial are reported below.

Materials and methods

The actual field results given here are from field trials in 2005/2006 in Trenthorst in the South-East of Schleswig-Holstein in Germany at a loamy site with good water conditions and sufficient soil nutrient supply (available nutrient contents in spring [mg 100 g^{1}]: P_{CAL} 7.7, K_{CAL} 14.3, Mg_{CaCl2} 12.5, pH 6.4, C_{org} 1.1%, N_{min} 60 kg ha^{-1}). Preceding crop in the crop rotation was clover grass. The rapeseed cereal mixtures were established with different seeding times (table 1) and row densities. The following varieties were used: Rapeseed: Express, Barley: Lomerit, Wheat: Capo, Rye: Boresto. Sole cropped rapeseed and cereals were grown with 25 cm and 12.5 cm row distance, respectively. At end of August in mixtures alternating rows with 12.5

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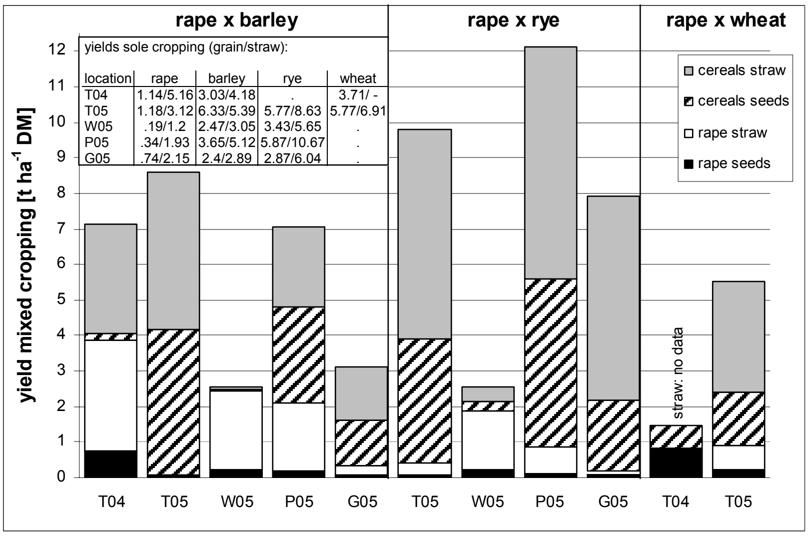
cm row distance were drilled simultaneously. Wheat and rye between the rapeseed rows were drilled in September in the rough soil after hoeing. For these treatments cereals were sown in double rows, 12.5 cm spaced, between two rapeseed rows with 37.5 cm row distance. Seed densities for the reduced row number, comparable to the seed densities in the rows of the sole cropped cereals were chosen. In the treatments with simultaneous drilling of the components in August the seed densities in the rows were kept constant or reduced to 50 % due to the untimely seeding date (table 1). Rapeseed densities were reduced so far that an overall seed density of 100 % compared to the sole cropped cultures was reached. Plot size at harvest was 27.5 m^{-2}. Four repetitions were used. Only the sole cropped plots were mechanically weeded with hoe or harrow. In the preceding trials in the years 2004 and 2005 in Trenthorst and additionally at tree other sites in 2005 single alternating rows of the crop components with 12.5-14 cm row distance, same plant varieties and clover grass as pre-crop were chosen.

Results

Seed and straw yields of mixtures of rapeseed with barley, rye (Paulsen and Schochow 2007) or wheat from the years 2004 and 2005 are shown in Figure 1.



T=Trenthorst, W=Wilmersdorf, P=Pfaffenhofen, G=Guelzow , shifted seeding only in T04

Figure 1: Seed and straw yields of mixed cropping of winter rapeseed with winter cereals (bars) and their components in sole cropping (table) (2004, 2005)

In 2005 barley was dominated by rapeseed in Wilmersdorf, whereas in Trenthorst, Pfaffenhofen and Guelzow grain and straw yields of barley reached more than 50 % in the mixtures compared to the sole cropping. Shifted seeding led to heavily decreased grain yield of barley in Trenthorst 2004. Except for Wilmersdorf the rye in mixture with rapeseed established very well and reached more than 50 % of straw and grain yield compared to the sole cropping variants. Wheat reached seed yield values between 17 and 25 % in mixture with rapeseed compared to its sole cropping. LER values higher than 1 where only reached in rape x barley in Wilmersdorf where the rapeseed yield in the mixtures were higher than sole cropped rape and in Pfaffenhofen at a low yield level of both components in sole and mixed cropping. In the trial of 2006 in Trenthorst reported in the following, insect pressure was moderate and rapeseed yields of 1.4 t ha-1 were possible. High barley yields (6.2 t ha-1) and medium rye (4.9 t ha-1) and wheat yields (4.4 t ha) were gained in sole cropping (table 1). The early drilling of wheat at end of August with halved seed density led to yield losses in seeds of 22 % compared to the normal seeding time.

Tab. 1: Seed and straw yields of mixed cropping of winter rapeseed with different winter cereals [t ha-1 dry matter], Trenthorst 2006

Variants	Seed density	Seeding date	Seeds Rape	Seeds Cereals	Straw total	Seeds total	Seeds + straw total
Barley 1/1	300	27 Sept		6.14	5.4	6.14	11.5
Wheat 1/1	350	27 Sept		4.46	7.6	4.46	12.1
Wheat 1/2	175	23 Aug		3.49	6.8	3.49	10.3
Rye 1/2	110	23 Aug		4.90	6.5	4.90	11.4
Rape 1/1	100	23 Aug	1.39a		4.7bc	1.39e	6.1d
Rape 2/3 Barley 2/3	65/225	23 Aug 27 Sep	1.20ab	0.73c	3.9d	1.93d	5.9d
Rape 2/3 Wheat 2/3	65/260	23 Aug 27 Sep	1.28a	0.69c	4.1d	1.96d	6.1d
Rape 1/2 Rye 1/2	50/110	23 Aug 23 Aug	0.31d	4.05a	5.6a	4.36a	9.9a
Rape 3/4 Rye 1/4	75/55	23 Aug 23 Aug	0.44d	3.23b	5.2ab	3.66b	8.8b
Rape 1/2 Wheat1/2	50/175	23 Aug 23 Aug	0.65cd	2.47b	4.7bc	3.11c	7.8c
Rape 3/4 Wheat 1/4	75/88	23 Aug 23 Aug	0.94bc	1.35c	4.6bc	2.28d	6.8cd

Comparison of rape and rape-cereal mixtures: Tukey-HSD, p=5%, after significant ANOVA

Later drilling of cereals between rapeseed rows led to high yield decreases for barley (-90 %) and wheat (-85 %) compared to their sole cropped treatments. Simultaneous drilling of rapeseed and cereals together showed a more proportional yield development. When seed numbers in the rows of rye or wheat were reduced to 50 % compared to the treatments with sole cropping (indicated in the table by 1/4), -34 % and -62 % lower cereal seed yields were found respectively. In the mixed variants 50 % of the seed rows of the sole cropped cereals were replaced by rapeseed. So for rye the yield loss was lower than anticipated by the row replacement. Compared to the early sown cereals in sole cropping non reduced seed numbers (indicated in the table by 1/2) led to over-proportional yield reduction of wheat (-61 %), even when rape density was also reduced. Rapeseed yields were reduced significantly when sown together with cereals in August due to the lush pre winter development of the cereals. The bad cereal establishment in the cereals with delayed seeding led only to small but insignificant yield decreases in rape. Looking for the total seed yield of the systems rapeseed in combination with rye had the highest yield but with lower rapeseed production than in combination with wheat.

Discussion

Obviously rapeseed and cereal yields in mixed cropping systems can be influenced by seed density management. But establishment problems of both cultures and their inhomogeneous year and site specific development are making reliable conclusions and even a suitable pooled statistical interpretation of all data dissatisfying. The LER (land equivalent ratio) values (Mead and Willey 1980) of the seed yields in the examined mixed cropping systems of 2006 are close to one and show no real yield advantages (table 2). That is congruent to the findings of the years before where other seed densities and row distances were chosen. Another open point of the cropping system is the probable risk of fungal pre-winter infections in the early sown cereals.

Tab. 2: Relative yields and LER values of different mixed cropping systems with rapeseed an winter cereals

	Relative yield compared to sole cropping		LER
	Rapeseed	Cereals	
Rape 2/3 Barley 2/3	0.86	0.12	0.98
Rape 2/3 Wheat 2/3	0.92	0.15	1.07
Rape 1/2 Rye 1/2	0.22	0.83*	1.05*
Rape 3/4 Rye 1/4	0.31	0.66*	0.97*
Rape 1/2 Wheat1/2	0.46	0.71/0.55**	1.17/1.01**
Rape 3/4 Wheat 1/4	0.67	0.39/0.30**	1.06/0.97**

*relative to rye 1/2, **first value is relative to wheat 1/2 Aug, second to wheat 1/1 Sept

Conclusions

With different seeding times cereals in rapeseed-cereal mixtures were difficult to establish due to inadequate possibilities for seed bed preparation between the rapeseed rows. Simultaneous drilling at end of August with non reduced seed distances led to luxurious growth of the cereals and suppression of the rapeseed. Rye showed the highest yield potential in the mixtures, independent of row distances and seed densities. Ongoing trials will give more experiences on yields and practicability of the systems.

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Evaluation of Crop Rotation on Organic Farms in Northern Serbia

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Key words: crop rotation, organic agriculture, crop management

Abstract

The objective of this paper was to analyze six organic farms in northern Serbia in order to evaluate crop rotation composition and identify its role in cropping technology of the organic production. The major agronomic indicators of organic crop rotation were analyzed: number of crops and their ratio, number of different crop schemes and fields in rotation, land coverage with crops, crops structure, etc. Information was acquired by visiting and surveying farmers during the 2005/06 as well as reading their documentation required for certification. The obtained results showed that the farmers carried out production on a 3-4-year rotation basis. The cropping plan was strongly driven by market demands. Deficiencies in structure of the rotation were compensated with crop management or organic fertilizers. The potential for the development of good farming management based on efficient crop rotation has not been fully achieved.

Introduction

Increasing demands for safe food in Serbia had resulted in conversion from conventional to organic farming which contributes significantly to the sustainability of the agricultural production. The fully converted organic area in Serbia now covers 591 ha of the total agricultural area (Willer and Yussefi, 2007), with potential for permanent growth. Crop rotation plays a central role in the basic design of an organic farm (Wijnands, 1999), maintenance and improvement of soil quality (Lampkin, 1994). In the organic production systems designing and planning of crop sequence is necessary for establishing the appropriate ratio between crop groups (i.e. legumes, cereals or row crops). In addition to that, the preferred order of crops and arrangement of plots can develop the desired agro-ecological layout of the farm and strongly contribute to the sustainability of the agro-ecosystem. For designing and evaluating multifunctional crop rotations there are several methods and approaches (Vereijken, 1997; Dogliotti *et al.,* 2003). The inappropriate selection of crops and design of rotation can create many problems with weeds (Barbieri, 2002), pests and diseases, which may lead to lower yields (Porter *et al.,* 2003). Possible weaknesses of designed crop rotation, especially at the beginning of the organic farming, could be the number of plots and their area, the number of species grown, and decrease of soil fertility (Seremesic and Milosev, 2006; Cuvardic *et al.,* 2006). In addition to that there is a relatively long period before rotations can be assessed in terms of their true effects on crop production and nutrient cycling on farm (Watson *et al.,* 1996).The aim of this study was to evaluate crop rotation composition at six organic farms in order to improve utilization of farm resources and management practice.

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Materials and methods

The following farms were analyzed: Kelebija, Tavankut, Ljutovo, Bajmok, Kisac and Orom. Selected farms were recommended for study after discussion with certification organisation in Serbia and therefore we consider them eligible according to national organic standard. Among them there were no common treatments. The information about cropping practice was obtained from questionnaires, farm documents (prepared for the certification), and by interviewing the farmers in investigation conducted 2005/06. Numerical data were presented as average values for two production year after statistical analyses, whereas indicators of crop rotation were expressed by proper mark. Soil chemical analyses indicated that the certified organic sites were either as fertile as the adjacent conventional fields or marginally less fertile but not significantly so (Cuvardic et al., 2006). Soil fertility was maintained, primarily, with different amounts of an organic fertilizer (i.e. manure, compost) applied at four-year intervals on each field and microbiological fertilizers (i.e. Bactofil A and B, Humisin, Bioactive etc.). Selected farmers utilized on-farms resources for additional nutrient input such as N-fixing crops (i.e. soybean, pea) and green manures (*Trifolium* sp., *Medicago sativa*, *Phacelia tanacetifolia* etc.). Primary tillage was conducted with shallow mouldboard ploughing or disc harrowing in autumn, and seedbed preparation was carried out with harrow, disk harrow and field cultivators.

Results

Organic farming at the observed sites was combined crop-livestock production fitted to specific agro-ecological condition. However, animal husbandry is not as important as arable production. We found that each farm is an independent production unit, strongly subjected to the dominant constraint of the production area. The number of the species grown at the organic farms was significantly different (Tab. 1, Tab. 2). As good preceding crops, cereals shared 21.4-25.8% of the total arable area of examined farms (except for Tavankut). The high proportion of cereals and legumes, necessary for the composition of a balanced crop rotation, was found on Ljutovo and Orom. Different from this, organic producers at Kelebija and Bajmok grew > 50% row crops and may have difficulties in achieving optimal rotation design. The Kisac farm was vegetable-oriented with more than 30 different varieties of vegetables and >60% of arable land covered with vegetables indicating that this production is orientated to fresh markets with labour intensive management and high production costs.

Tab. 1: Crop structure on the examined organic farms

	ORGANIC FARMS											
	KELEBIJA		TAVANKUT		LJUTOVO		BAJMOK		KISAC		OROM	
Total Arable area (ha)	**11.7**		**5**		**15,5**		**11.9**		**14**		**6.5**	
CROP STRUCTURE	*Crops (%)*	*Area (ha)*	*Crops (%)*	*Area (ha)*	*Crops (%)*	*Area (ha)*	*Crops (%)*	*Area (ha)*	*Crops (%)*	*Area (ha)*	*Crops (%)*	*Area (ha)*
Legumes (annual/perennial)	11.1	1.3	40	2	37.4	5.8	13.4	1.6	7.1	1	53.8	3.5
Cereals (winter/spring)	24.8	2.9	-	-	25.8	4	25.2	3	21.4	3	23.1	1.5
Roots and tuber plant	1.7	0.2	-	-	1.9	0.3	-	-	14.2	2	-	-
Vegetable	11.1	1.3	-	-	15.5	2,4	-	-	64.3	9	-	-
Row crops	51.3	6.0	60	3	19.4	3	61.4	7.3	-	-	23.1	1.5

On the Tavankut farm, there were only two fields in the certified production (alfalfa (third year) and oil pumpkin), established at the beginning of the certified production after soybean and wheat as preceding crops.

Tab. 2: Crop structure on the examined organic farms

CROP GROUPS	ORGANIC FARMS					
	Kelebija	Tavankut	Ljutovo	Bajmok	Kisac	Orom
Legumes	2	1	3	2	1	1
Cereals (winter/spring)	2	-	4	2	1	1
Roots and tuber plant	1	-	2	-	1	-
Vegetable	5	-	1	-	11	-
Row crops	3	1	3	2	-	1
Total number of crops	13	2	13	6	14	3

Discussion

After conversion from conventional agriculture organic producers continue growing same crops. Arable organic systems at the organic farms showed a tendency toward development in two directions, one being the improvement of soil quality with more N_2-fixing crops and lower economic value and the other more N demanding cash crops. As for the number of grown crops (except for Tavankut) and field allocation (Tab. 1) there were many possibilities for different rotations, especially mixed ones with row crops, cereals, vegetables and forage crops. Organic production on the examined farms was based generally on a 3-4 crops in rotation with a tendency for proper alternation of different crop groups (legumes/cereals/row crops/vegetables). However selection of appropriate crop (among desired crop group) was limited only to one year ahead, compatible with rotation design, proportion of crop groups, and agro-ecosystem resources (Tab. 2). Consequently, this approach generally resulted in "loose" rotation, where specific, apparently important crops for farmers can be overrepresented in the rotation and grown too intensively (Wijnands, 1999). The desired level for soil cover index (SCI) is to have crops covering the soil for more than 80% of the year (Helander and Delin, 2004). In our study soil cover index varies (55-90%). We found that SCI for the observed period averages at 70% (8 ½ months), which should be improved. Only two out of six farmers regularly included winter cover crops and planted second crop into a main crop to improve efficiency of the system.

Tab. 3: Agronomic evaluation of crop rotations

INDICATORS	ORGANIC FARMS					
	Kelebija	Tavankut	Ljutovo	Bajmok	Kisac	Orom
Type of rotation[1]	V/FCV	L	FCV	FCV	V	FCV
Intercropping	Yes	No	Yes	No	No	No
Winter cover crops	No	No	Yes	No	Yes	No
Number of crops in	4-5	3	3-4	4	4	3-4
SCI[2] (%)	70%	75%	65%	65%	90%	55%
Rotation planning[3]	1	1	2	1	1	1

[1]Types of crops that were the subject of planned rotation (other crops were grown in other fields on the farm); **V**- vegetable crops, **FC**- field crops, **L**-legumes; [2]**S**oil **C**over **I**ndex-period of year during which the soil is covered with plants (% of 12 month) - estimated by farmers; [3]Number of years of planned crop rotation in the future.

Based on the observed crop rotation indicators and farm resources crop rotations should be more efficient in resources utilization and less dependant on market conditions. With clear goals of the organic production farmer will consider diversification of crop rotation which will provide an economical buffer against price fluctuations for crops and production inputs as well as unpredictable changes of pest infection and weather conditions.

Conclusions

The investigated farms in Northern Serbia were different in organic management and cropping technology. At the observed farms crop rotation was strongly driven by market demand. The obtained results show that the cropping strategy was based on a 3-4 year rotation, with the potential for the proper alternation of different crops. Design of the rotations can be improved with: introduction of winter cover crops; inclusion of N_2 fixing legumes; stubble crops and application of higher doses of organic fertilizers.

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Effect of two Oat–legumes intercrop systems on weed flora under Mediterranean conditions

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Key words: intercropping, maize- legumes, LAI, weeds, PAR

Abstract

The experiments were conducted in Greece in 2002 and 2003. The objective of this research was to investigate i) the effect of intercrop system on weeds and ii) if each intercrop system (oat-pea or cereal legume) is going to affect the weed control differently. The light penetration within the canopy measured during the first experiment (2002), was decreased up to 90%, due to the increase of the companion crops' leaf area. In both years the decrease of the available light to the weeds, has led to the reduction of the weed dry matter, in comparison to the pure stands. Finally the oat-bean intercrop system gave better results than oat-peas system. As a result we can say that the intercrop system constitutes a new approach to weed control for low input agriculture under Mediterranean conditions.

Introduction

Intercropping, through more effective use of water, nutrients and solar energy, can significantly enhance crop productivity compared to the growth of pure stands (Bilalis 2005). The light plays a critical role in weed-plant growth and development; quantity and quality, as well as direction of the light, are perceived by photosensory systems which collectively regulate plant development, presumably to maintain photosynthetic efficiency (Hangarter, 1997). The amount of light intercepted by the component crops in an intercrop system depends on the crops geometry and foliage architecture. Intercrop systems are reported to use resources more efficiently and be able to remove more resources than monocrop systems, thus decreasing the amount available for weed production. Liebman and Dyck (1993) noted a decrease in weed biomass in intercrop as compared with monocrop systems in 47 studies, a higher level of weed biomass in four studies and variable results in three other cases. Our two year experiment was designed to investigate the effects of intercropping winter oat *(Aneva sativa)* with pea (*Pisum sativum*) and broad beans (*Vicia faba*) on the weed control. The question of this research is "what are the effects of different intercrop systems on weed growth?"

Materials and methods

This two years experiment was conducted at the organic field at Mavrica area (Lat: 38°36´, Long: 21°21´, alt: 24m) located at West Greece (2003). The soil type was Clay Loam (24.9% clay, 61.2% silt and 13.9% sand) with pH (1:1 $H_2 0$) 7.56, 3.21% organic matter, 13% $CaCO_3$, 0.152% total nitrogen and a sufficient supply of both phosphorus

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(P-Olsen 92ppm) and potassium (632ppm). Annual temperature and precipitation were 17.2^{o}C and 955mm. The site was managed according to the Organic Agriculture (OA) guidelines (EN 2092/91) and no fertilization was applied. The experiment had a randomized plot design with eight replications. The main-plot treatments were solo cropped and intercropped spring crops (oat, broad bean and pea). The crops were seeded in rows with a distance of 30cm between the rows. Each plot was 50m^2 and each replication 250m^2 with a total coverage area of 2000m^2. Intercrops seeding were 1:1 ratio oat/bean and 1:1 oat/pea. Legumes and cereal seeds were sown manually on 1 and 3 December of 2002 and 2003 respectively. Furthermore the components of mixtures were mixed within each row.

Plants were destructively sampled and the leaf area was measured using an automatic leaf area meter (Delta–T Devices Ltd, Burwell, Cambridge, UK). The sampling dates, for all parameters in the first year, were 40, 80 and 140 days after sowing (d.a.s.) and in the second were 40, 80 and 120 d.a.s. respectively. The difference of the third sampling day, between the two years (140 d.a.s. for the first and 120 d.a.s. for the second), was due to the climate conditions, which slowed down the Relative Grow Rate (RGR) of the plants. The results, on a plant basis, were converted into Leaf Area Index (LAI) by multiplying the average crop density of each plot. At each sampling date, weeds were sampled from five 0.25m^2 quadrates per plot, dried at 70^{o}C during 72 hours and dry matter (WDM) was weighted. All weeds were collected from the measured area then dried at 70^{o}C during 72h and finally weighted, measuring their dry matter (WDM). The fraction of Photosynthetic Activate Radiation (PAR) intercepted was calculated by taking ten readings in rapid succession above the canopy and ten readings below the canopy at the soil surface using a 60cm light sensor (Sunfleck Ceptometer by Decagon devices, Pullman, Washington State, USA). The fraction of the incident PAR intercepted by the canopy (F_{int} PAR) was calculated with the following equation:

$$\%\ F_{int}\ PAR = \left(1 - \frac{PAR\_belowcanopy}{PAR\_abovecanopy}\right) \times 100$$

Results

The values of the LAI are presented in Table 1. At 40 days after soil (d.a.s.) in both years, the two systems (inter and solo crop) did not appear to have any statistically significant differentiation. At intercrop system plots the LAI was significant lower than the correlative solo crop plots at 120d.a.s. The highest values were observed at 140d.a.s. at the oat- broad beans intercropping plots.

The fraction of the incident PAR intercepted by the canopy (Fint PAR) is presented in Table 2. These results were similar to the aforementioned LAI results. The highest values were observed for the oat-broad beans (90% for both years at 140d.a.s.) and then at the oat-pea system. The observed differences between the two treatments of the intercrop were not statistically significant. The highest fraction of PAR intercepted for pure stands were observed at broad beans (78% in 2002 and 67% in 2003 at 140d.a.s.) and the lowest values at the solo oat crop (52% and 48% respectively).

The dry matter of weeds is presented in Table 3. From, 80d.a.s. up to 140d.a.s. in both years the least weed dry matter was observed at the intercropping systems, while the most weed dry matter observed at the pure stands. In all cases, between the crop systems (inter and solo) there were statistically essential differences observed.

Furthermore, between the two intercrop types, for the significance level of 5%, there were no statistically important differences observed.

Tab. 6: Leaf area index for solo and inter-crops

	cultivation period 2002			cultivation period 2003		
	40 d.a.s.	80 d.a.s.	140 d.a.s.	40 d.a.s.	80 d.a.s.	120 d.a.s.
Oat+pea*	0.22	1.89	3.22	0.30	3.98	5.05
Oat+broad bean*	0.24	2.24	3.78	0.39	3.21	4.66
Oat	0.21	1.22	2.11	0.21	1.52	2.71
Pea	0.19	1.41	2.42	0.29	1.93	3.45
Broad bean	0.22	1.67	2.66	0.25	1.77	3.32
$LSD_{5\%}$	0.07	0.14	0.25	0.08	0.16	0.29

*Summary of LAI_{cerial} and LAI_{legume}

As presented in Table 3 a 140 d.a.s. the weed dry matter at intercrop was less than the half in relation to that of the solo. Comparing the two intercrops types with pure stands, we come to the conclusion that there was less weed dry matter observed at oats-broad beans type, but the differences, between them, were not regarded as statistically essential for the level of 5%. Similar results have been also mentioned by Baumann et al. (2001).

Tab. 7: The percentage fraction of PAR intercept (Fint %) as affected by solo and inter-crops

	cultivation period 2002			cultivation period 2003		
	40 d.a.s.	80 d.a.s.	140 d.a.s.	40 d.a.s.	80 d.a.s.	120 d.a.s.
Oat+pea*	10	40	82	14	55	76
Oat+broad bean*	12	55	91	19	65	89
Oat	8	29	52	11	34	48
Pea	9	32	66	12	39	61
Broad bean	10	37	78	13	48	67
$LSD_{5\%}$	3	17	19	4	13	16

*Summary of LAI_{cerial} and LAI_{legume}

Tab. 8: Weed dry matter ($g.m^{-2}$) by solo and inter-crops

	cultivation period 2002			cultivation period 2003		
	40 d.a.s.	80 d.a.s.	140 d.a.s.	40 d.a.s.	80 d.a.s.	120 d.a.s.
Oat+pea*	1.32	6.31	16.71	3.24	7.12	14.56
Oat+broad bean*	1.23	4.78	12.32	2.11	4.32	12.21
Oat	4.42	15.11	28.45	8.12	16.76	27.45
Pea	3.20	12.22	24.17	6.21	13.42	22.32
Broad bean	2.79	9.37	22.11	5.31	10.07	18.94
$LSD_{5\%}$	1.39	3.12	4.92	5.98	3.22	9.99

*Summary of LAI_{cerial} and LAI_{legume}

Conclusions

The intercrops indicated higher soil canopy cover in comparison with the pure stands. This resulted in the increase of light interception by canopy. This fact is proved by the factor of cross-correlation between LAI and %F (light fraction) during both periods (r=0.935, p<0.001, Table 4). Shade was clearly a key factor in weed suppression for weed dry matter and weed density. The correlations coefficient between, %F (light fraction), and WDM were higher than -0.587 (p<0.001, Table 4). Concluding, the intercrop system can reduce the weed density and weed biomass, in OA, under Mediterranean condition.

Tab. 9: Correlation matrix between L.A.I., light interception (%F) and Weed dry Matter (WDM)-(r and p level)

	LAI	%F (light fraction)
WDM	-0.527(p=0.003)	-0.587(p=0.001)
LAI	--	0.935 (p=0.001)

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Intercropping of oilseeds and faba beans

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Key words: row distance, plant available nitrogen (PAN), resource use efficiency, land equivalent ratio (LER)

Abstract

Intercrops are considered as less susceptible to pests and diseases and may inhibit weeds more efficiently resulting in enhanced yields and profitability. N_2 fixation of legumes is an important nitrogen (N) input factor of Organic Farming systems and results in partly unused plant available soil N (PAN) in sole cropped faba beans. Simultaneously cultivated oilseeds may function as sinks for PAN and enhance biodiversity with all positive aspects. In this respect we investigated several oilseeds intercropped with faba beans at different row distances. Depending on row distance we analysed e.g. the use of soil nutrients and land equivalent ratio (LER). Intercropped oilseeds depleted PAN between FB rows significantly in early development. In 2007 yield performance was impaired by the extreme weather conditions. Under these circumstances LER > 1 in intercrops at wider row distance suggests facilitative interactions and some kind of compensation.

Introduction

In earlier studies accumulation of soil nitrate under faba beans (FB) (*Vicia faba* L.) was observed even during growth – especially between rows and in deeper soil layers (Justus 1996, Justus and Köpke 1995). This nutrient source is unused by FB and vulnerable to leaching but may be used by an intercropped oilseed (OS) which explores soil more efficiently. Hauggaard-Nielsen et al. (2008) found that the proportion of plant N derived from N_2 fixation by grain legumes was higher when intercropped with barley compared with grain legume sole crop (SC). Thus, a non-legume intercrop (IC) component competes for soil nitrate and may enhance N_2 fixation by legume. Besides more efficient use of nutrients, e.g. N, less susceptibility to pests and diseases as well as less weed infestation were reported for intercrops (Hauggaard-Nielsen et al. 2008, Paulsen et al. 2007). We cultivated safflower (*Carthamus tinctorius* L.), mustard (*Sinapis alba* L.) and linseed (*Linum usitatissimum* L.) as SC as well as IC with FB. Depending on row distance, we analysed the use of plant available nitrogen (PAN), yield performance and grain quality. The aim of the study was to determine the most suitable OS for intercropping with FB at optimized row distance, for optimized use of growth factors resulting in a land equivalent ratio (LER) > 1.

Materials and methods

The field experiments were carried out at Wiesengut experimental farm for Organic Agriculture in Hennef (Germany) on a clayey-silty to sandy-silty floodplain sediment. A preliminary field trial was performed in 2006; the first main experiment followed in 2007. Weather conditions were very different in the two years during growing season

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June to harvest in August: very hot and dry in 2006 (20.3°C, 135 mm $pcpn_{total}$, 695 sun $hours_{total}$) compared to high amounts of rainfall and relatively low temperatures in 2007 (18,4°C, 339 mm $pcpn_{total}$, 566 sun $hours_{total}$). FB cv. Limbo was grown in a two-species intercropping with safflower (cv. Sabina), mustard (cv. Martigena) or linseed (cv. Juliet), resp. (as well as false flax - *Camelina sativa* L. cv. Ligena in 2006, resp.) and as control without OS but with the same sowing density. In all intercropping treatments FB rows were 56.5 cm apart with two OS rows in between. Row distances between OS and FB rows were 5 cm and 18.5 cm resp. In 2007 all oilseeds (row distance: 17.0 cm) and FB (row distance: 28.0 cm) were also grown as SC. A completely randomized block design with four repetitions was used. Results of preliminary investigations in 2006 lead to an optimized sowing density and exclusion of false flax in the main experiment in 2007. Intercrops were drilled with the half sowing density of the corresponding SC, except for intercropped linseed which was drilled with 67% of linseed SC. Crops were cultivated according to organic management practice and hand harvested at flowering stage (2 x 0.5 m^2 /plot in 2006 and 2007) and at maturity (3 x 0.5 m^2 /plot in 2006 and 3 m^2 /plot in 2007 resp.). Harvested plant material was separated into fractions: shoots of FB and OS as well as weeds, grain and straw. 105°C dried and milled plant material was analysed for total N (elemental analyzer). LER_{Grain} was calculated by the sum of relative grain yields in IC referring to the corresponding SC: LER_{Grain}= [IC grain yield FB * (SC grain yield FB)$^{-1}$] + [IC grain yield OS * (SC grain yield OS)$^{-1}$]. Soil samples (0-90 cm) were taken in and between FB rows at FB´s juvenile and flowering stage as well as after harvest and analysed for PAN. Data analysis was conducted by ANOVA and post hoc test (Scheffé's test). Normal distribution and homogeneity of variance were assumed. In 2007 the assessed hail damage was correlated with the investigated parameters. Data sets with significant correlations were excluded from ANOVA.

Results and brief discussion

Preliminary investigations in 2006: The aim was to test the feasibility and to get some experience to design the main experiment in 2007. FB yield was diminished in all IC treatments compared to control (pure FB), but this could nearly be compensated for by the OS yield (Tab. 10). Mustard was the strongest competitor to FB resulting in lowest FB yield not compensated by mustard yield. In contrast, intercropping with safflower at narrow row distance achieved the highest combined grain yield despite significantly diminishing FB grain yield. This result was regarded as an effect of extremely high temperatures and water deficiency during July and August 2006. It is known that FB is very susceptible to drought which was increased in IC because of OS´s competition for water. Safflower prefers warm temperatures and tolerates dry weather conditions resulting in a compensation of decreased FB yield when grown intercropped. False flax achieved a very low grain and oil yield and was thus excluded in 2007. Oil content and fatty acid composition indicated a high grain quality of intercropped OS. N content of harvested FB grain was about 5.20% in all treatments. Analysis of soil samples showed that intercropped OS reduced soil nitrate between FB rows considerably (not significant). Since these results confirm to earlier results, the following data should be considered as a tendency: as soon as six weeks after sowing soil nitrate was curbed to 42% in wide row treatments compared with control. Afterwards at flowering stage, soil nitrate between FB rows was further diminished; now seen in both intercrop treatments. The soil nitrate was most efficiently depleted by intercropped mustard and safflower.

Depletion of soil N and yield performance in 2007: 53 days later sowing PAN between FB rows was significantly diminished by intercropped OS at wider row distance compared with sole cropped FB (56.5 cm). At FB´s flowering stage both IC treatments depleted soil N significantly (Figure 1). Mustard was the strongest sink for soil N (data not shown). Shoot biomass of FB harvested at flowering stage was not diminished by intercropped OS when compared with FB control (56.5 cm) but significantly lower than in FB SC with a row distance of 28 cm and twice as much the sowing density. The diminished FB shoot biomass in intercrops was nearly compensated for by OS`s shoot biomass resulting in no significant difference in combined shoot biomass between intercrops and sole cropped faba beans in that developmental stage. However, shoot biomass in FB SC (28 cm) was significantly higher than in FB SC (56.5 cm), caused by twice as much of the sowing density. Afterwards FB development was interfered with by hail damage. Damaged FB plants showed reduced pod insertion, grains per pod and thousand-seed weight (TSW), resulting in reduced grain yield compared with undamaged plants: in FB control, e.g., yield per individual plant was diminished by 67%. Since up to 73% of FB plants were damaged, a relative disadvantage for FB solecrops was given. In IC the reduced FB yield could not be compensated for by the OS yield and no significant difference was found in combined biomass between intercrops and FB sole crop treatments. Grain yields of mustard and linseed were impaired by pollen beetle (*Meligethes aeneus*) and birds resp., resulting in decreased grain yields (Tab. 10). The chilly, wet climate in July and August lead to the reduced grain yield of safflower compared with 2006. Enhanced LER_{Grain} values of 1.22 and 1.15 of intercropping with safflower and mustard resp. at wider row distance compared with sole cropping were determined under these circumstances and suggest facilitative interactions in mixed crops. On the contrary, LER_{Grain} values around 1 for intercropping at narrow row distance indicate competition between intercrops (Tab. 10).

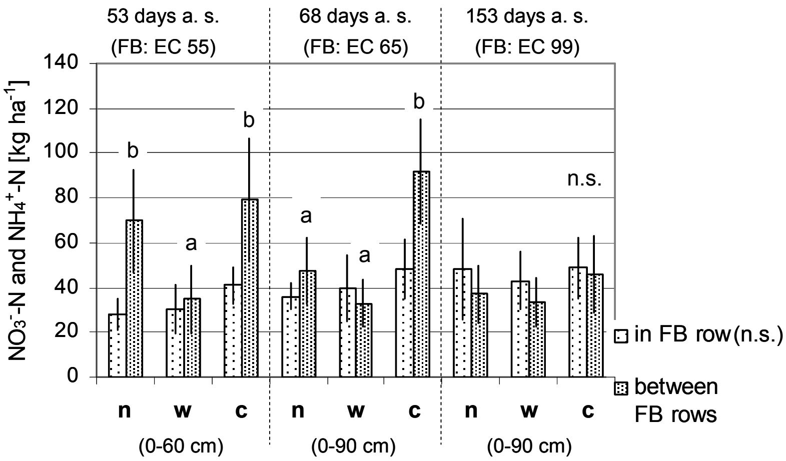

Figure 1: Plant available soil nitrogen under intercropped faba beans (FB) and oilseeds (OS) in 2007 depending on distance between FB and OS rows: n (narrow, 5 cm), w (wide, 18.5 cm), c (control without OS, 56.5 cm) – Data analysis conducted by ANOVA and Scheffé´s Test individual for the times of sampling; error bar: standard deviation

Tab. 10: Yields of intercrops (IC) and sole crops (SC) in 2006 and 2007

		2006			2007				
Oilseed	Row distance	FB-grain [tons ha^{-1}]	OS-grain [tons ha^{-1}]	Grain yield com [tons ha^{-1}]	FB-grain [tons ha^{-1}]	OS-grain [tons ha^{-1}]	Grain yield com [tons ha^{-1}]	Biomass com [tons ha^{-1}]	LER grain
Control	56.5 cm	1.85 c		1.85	1.50		1.50	5.16 ab	
Safflower-IC	narrow	1.29 ab	1.04	2.33	1.02	0.56	1.58	6.56 bc	1.01
	wide	1.07	0.91	1.99	1.30	0.64	1.94	7.48	1.22
Mustard-IC	narrow	0.88 a	0.64	1.52	1.14	0.26	1.40	5.83 abc	0.94
	wide	0.99	0.52	1.51	1.18	0.41	1.59	6.27	1.15
Linseed-IC	narrow	1.22 a	0.32	1.54	1.05	0.01	1.05	4.69 ab	
	wide	1.09	0.39	1.47	1.34	0.01	1.35	5.40	
False flax-IC	narrow	1.44 bc	0.13 *	1.57					
	wide	1.59	0.26	1.85					
FB-SC	28 cm				1.84		1.84	6.15 bc	
Safflower-SC	17.0 cm					1.24	1.24	7.68 c	
Mustard-SC	17.0 cm					0.82	0.82	5.47 abc	
Linseed-SC	17.0 cm					0.01	0.01	3.68 a	

FB: faba bean, OS: oilseed, IC: intercrops, SC: sole crops, com: combined; Different letters indicate a significant difference between intercropped OS (Scheffé's Test: $p<0.05$); * significant difference for $p<0.05$ between spacing; yields based on 100% dry matter

Conclusions

Intercropped OS and FB may have the potential for a more efficient use of resources compared to SC only. Under the extreme weather conditions in 2007 LER values > 1 were determined for IC treatments. However, this result was at least partly caused by the high percentage of hail-damaged FB plants and needs further investigation. Nutrient analysis indicated high quality of harvested grain and oil in 2006 (Data for 2007 are not available yet). But, there should be some limiting factors mentioned as well: in contrast to our hypothesis, the system is relatively susceptible to weed infestation, especially on fertile soil. Pollen beetles are difficult to control in Organic Farming and may cause total loss of brassica oilseeds. Extreme weather conditions affected crop maturity and lead to problems at IC harvest. Nevertheless, intercropped FB and OS have the potential to resist extreme conditions when facilitative interactions dominate.

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Comparison of cropping systems

Comparative analysis of conventional and organic farming systems: Nitrogen surpluses and nitrogen losses

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Key words: Nitrogen, nitrate, leaching, farming systems, nitrogen fixation

Abstract

Nutrient management is a key factor for both economic viability and environmental performance of farming systems. On 32 representative conventional and organic farms in Northern Germany, nutrient management was analyzed in the interdisciplinary monitoring project "COMPASS". Organic farms had significantly lower nitrogen (N) surpluses compared with conventional farms. The majority of organic farms had very low or even negative N surpluses, indicating insufficient N supply in the cropping system. Nitrogen leaching, however, was too high in many cases on both conventional and organic farms. Strategies for a more targeted nutrient supply in organic farming need to be developed and implemented.

Introduction

Nutrient-efficient farming is characterized by the minimization of nutrient losses to the environment while ensuring the necessary nutrient supply to crops and livestock. Organic farming is generally associated with sustainable nutrient management. Representative data from typical farms is scarce, however. Symbiotic N_2 fixation of legumes represents the most significant N input in organic farming. Even though both own and purchased organic fertilizers are applied on most organic farms, a sufficient N supply to crops cannot always be realized. On the other hand, N losses to the environment, e.g. through leaching, should be minimized.

In the present study, N fluxes and N leaching on 32 commercial farms in Northern Germany were analyzed in a 3-year monitoring project that allowed for a direct comparison of conventional and organic faming systems.

Materials and methods

The project "COMPASS" was carried out over the period 2004-2006 on commercial farms in Northern Germany. 16 pairs of farms were selected by two main criteria:

a. Farm type: Specialized arable farms, specialized dairy farms.

b. Intensity: Conventional farms, organic farms.

Within a pair of farms, a conventional farm and a comparable organic farm were located at the same site. This project set-up allowed for a direct comparison of conventional and organic farms under similar soil and environmental conditions. We analyzed 8 pairs of arable farms and 8 pairs of dairy farms. The comparability of farms within a pair was assured by comparable farm size, and similar specialization under the prevailing soil conditions. In dairy farming, the stocking rate was generally lower on organic farms (mean: 0.86 LSU ha-1 vs. 1.46 LSU ha-1 on conventional dairy farms).

Farm management was documented accurately, covering all aspects of crop and animal production. Additionally, we sampled forage yields, forage quality, botanical diversity of grassland, and symbiotic N2 fixation of legumes on representative fields. Symbiotic N2 fixation was determined according to Høgh-Jensen et al. (2004). N balances were calculated for all 32 farms. N input included purchased fertilizers, feedstuffs and livestock, and N_2 fixation. N output was the sum of sold crops, animals, milk, and manure. From the difference between N input and N output at the farm scale, NH_3 emissions during manure storage and application were subtracted.

N leaching was determined on 8 selected farms. We used suction cups during the leaching periods (November-April) of 2004-2005 and 2005-2006 in representative fields of selected crops (see Table 1).

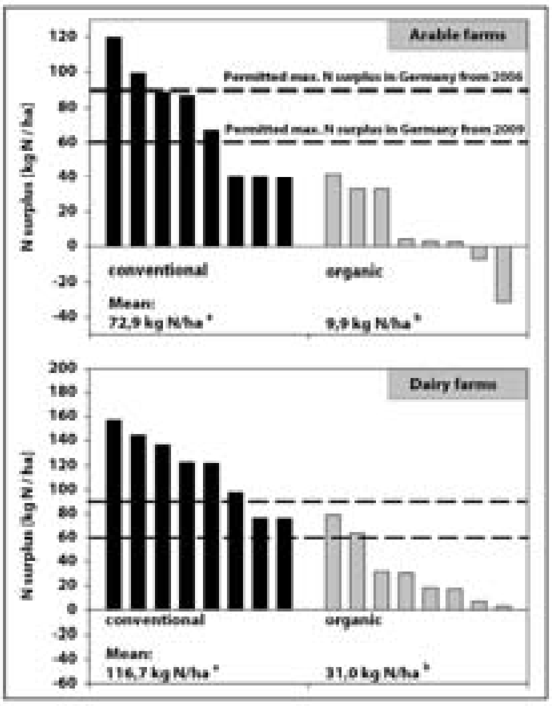
18 (arable crops) or 24 (permanent grassland) suction cups were installed per field. N concentrations (NO3-N + NH4-N + Norganic) in the leaching water (sampled at weekly intervals) were measured photometrically with an autoanalyzer. Total N leaching per winter [kg N/ha] was calculated as the sum-product of N concentrations and amounts of leaching water over the sampling period. In a separate experiment (split-plot with four replicates, large plots of >600 m²), N turnover and N leaching were measured after the renewal of an organically managed permanent grassland sward on a sandy soil (ploughed in spring or autumn).

Results and discussion

Farm-gate N surpluses (indicating the total potential N loss to the environment) were significantly higher in conventional farming compared with organic farming, with generally higher N surpluses on dairy farms compared wiith arable farms (Figure 1). This is in line with some former studies (e.g., Dalgaard et al., 1998). Other investigations, however, did not find systematic differences in N surpluses between conventional and organic farms (e.g., Hansen et al., 2000). The majority of analyzed conventional farms – both arable and dairy farms – need to improve their N management in order to fulfil future requirements. The large variation among individual farms clearly shows the potential for improvement. Some conventional farms already show that efficient nutrient management is possible without yield losses. Amongst conventional farms, there was no significant correlation between N surpluses and crop yields or milk yields, respectively. Weak points in conventional agriculture were mainly associated with N fertilization. In many cases, mineral N application to crops was far too high, or nutrients in slurry were not accounted for. Replacement rates frequently exceeded 35%, and the feeding ration was not always well adjusted.

In contrast, the majority of organic farms suffered from low or even negative N surpluses at the farm scale, which indicates a lack of nitrogen (Figure 1). The main reasons for variation in N surpluses were the proportion of legumes in the crop rotation and N_2 fixation rates of legume crops. For instance, the proportion of grass/clover in the crop rotation of organic arable farms varied from 0% to 53% (mean: 19%). N_2 fixation rates ranged between 45 kg N/ha (Persian clover *[Trifolium resupinatum],* mulched) and 339 kg N/ha (red clover *[Trifolium pratense]*, mixed cutting/mulching). N_2 fixation rates of red clover/perennial ryegrass (*Lolium perenne*) swards were in the range 150-250 kg N/ha, depending on the proportion of red clover, soil type, and cutting, mulching or grazing treatment. Some organic arable farms tried to maximize cash crop production by eliminating grass/clover from the crop rotation. N input was realized only through N_2-fixing cover crops, undersown clover in cereals, or purchased organic fertilizers. Even though this strategy could be opportune from an economic point of view, declining soil fertility and increasing weed levels might limit cash crop yields of these systems in the long run. Another weak point on organic farms was the adjustment of feeding rations to lactating cows. Both milk yields and animal health could be improved significantly by constantly providing a well-adjusted ration.

Figure 1: Net N surplus of conventional and organic farms, mean of 2004-2006.



a, b significantly different for P<0.05

Significant N leaching losses were observed in both conventional and organic farming (Table 1). In organic farming, the 'critical N load', which corresponds to a mean concentration of 50 mg/l nitrate in leaching water, was exceeded if grass/clover was ploughed in autumn (followed by winter wheat), a finding supported by a number of other authors (e.g., Dreymann, 2005). The same occurred after silage maize harvest on sandy soils. Organic silage maize was grown after grass/clover ploughed in spring. Additionally, high amounts of slurry and manure were applied, which is not necessary, since the N supply to silage maize is already ensured by the mineralization of grass/clover residues. Neither conventional nor organic maize fields had a winter cover crop. On grassland and in cash crop production, N leaching losses were significantly affected by N input (mainly N fertilizer, slurry, and excrements) and N surpluses at the field scale. In silage maize production, however, this relationship was absent. Mineralization of soil organic matter seemed to have a much stronger effect on N leaching since these fields have been fertilized with manure and slurry for many years, which accumulated a large pool of soil nitrogen. Extremely high N leaching losses of 115-125 kg N/ha were observed in the first winter after the renewal of organically managed permanent grassland (data not shown). It made no significant difference if the grass sward was ploughed in spring or autumn. Mineralization of organic matter from the grass sward released very high amounts of N that could hardly be utilized until the following leaching period. As a consequence, grassland should be maintained in good condition as long as possible in order to postpone the renewal of grassland swards.

Tab. 1: N leaching (kg N ha^{-1} yr^{-1}; sum of NO_3-N + NH_4-N + organic N) in representative crops on conventional and organic farms. Mean of 18-24 suction cups per field, averaged over leaching periods 2004-2005 and 2005-2006.

Farm	**Winter wheat** *after oilseed rape (c) or grass/clover (o)*		**Oilseed rape (c) or grass/ clover (o)** *after cereals*		*After* **silage maize**		**Permanent grassland** *(1 cutting + grazing)*	
	Arable farms		**Arable farms**		**Dairy farms**		**Dairy farms**	
conventional	32.1	L	28.7	L	22.1	L	40.1	L
organic	45.4	L	13.2	L	27.8	L	26.2	L
conventional	45.5	L	42.2	L	52.4	S	38.2	S
organic	37.5	L	15.2	L	65.5	S	19.5	S

L: loamy soils, S: sandy soils

Conclusions

Organic farms were characterized by lower N surpluses and - in most cases - lower N leaching losses compared with conventional farms. N leaching on organic farms, however, still exceeded a 'critical N load' in most crops. Options for improved N management in organic farming include the layout of rotations, grass/clover management, more efficient utilization of manure, and better adjustment of feeding.

Acknowledgments

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Nitrogen use efficiency of cereals in arable organic farming

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Key words: crop rotation, spring barley, winter wheat, winter rye, nitrogen supply.

Abstract

The effect of nitrogen (N) supply and weeds on grain yield of spring barley, winter wheat and winter rye was investigated from 1997 to 2004 in an organic farming crop rotation experiment in Denmark on three soil types varying from coarse sand to sandy loam. Two experimental factors were included in the experiment in a factorial design: 1) catch crop (with and without), and 2) manure (with and without). The apparent recovery efficiency of N in grains (nitrogen use efficiency, NUE) from NH_4-N in applied manure varied from 29 to 38% in spring barley and from 23 to 44% in winter cereals. The NUE of above-ground N in catch crops sampled in November prior to the spring barley varied from 16 to 52%, with the highest value on the coarse sandy soil and the lowest value on the sandy loam soil. The NUE of N accumulated in grass-clover cuttings varied from 14 to 39%, with the lowest value on the coarse sandy soil, most likely because of high rates of N leaching. The NUE declined with increasing amounts of N accumulated in the grass-clover cuttings. This indicates that grain yields can be improved by removing the grass-clover cuttings and applying the N contained in the cuttings in spring to the cereal crops, possibly after fermentation in a biogas reactor.

Introduction

The productivity of arable crops in organic farming is restricted by the supply of nitrogen (N) (Olesen et al., 2007), and there is a need for sources of N in addition to manure to meet the N demand of cereals crops. Biological N fixation (BNF) is one of the primary sources of N in organic farming (Berry et al., 2002). The N supply through BNF will directly affect yields of legume crops. However, other crops will need to benefit from BNF through N recycled in manure or through crop residues returned to the soil. In systems with grass-clover for grazing or as green manures, a major input of N from BNF is returned to the soil by incorporating the grass-clover pasture. Similar inputs are obtained from crop residues of grain legumes and from catch crops.

In the analysis of experiments with application of fertiliser N, the apparent recovery efficiency of applied N is typically taken as a measure of the N use efficiency (NUE) (Cassman et al., 1998). NUE is usually calculated as the difference in N uptake between fertilised plots and an unfertilised control. However, it may also be calculated as the slope of a regression on crop N uptake (either N in total above-ground biomass or in grain yield) versus applied fertiliser N. In this paper we analyse the effects of N input through green manures, crop residues, catch crops and animal manure on grain yield and N uptake in spring barley and winter cereals.

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Materials and methods

A crop rotation experiment was initiated in 1996/97 at three sites in Denmark (Olesen et al., 2000). The sites represented different soil types and climate regions (Jyndevad: coarse sand; Foulum: loamy sand; and Flakkebjerg: sandy loam) in Denmark. In this paper we present results for cereals in a 4-course rotation with a pulse crop, spring barley, grass-clover and winter cereal. The pulse crop was a mixture of pea and barley in 1997 to 2000, lupin in 2001, a mixture of lupin and barley at Foulum and Flakkebjerg in 2002 to 2004, and a mixture of field bean, lupin, and barley at Jyndevad in 2002 to 2004. The cereal and pulse crops were grown for grain harvest. The grass-clover was undersown in the spring barley in spring, and it was subsequently managed as a green manure crop with mulching of the cuttings. The grass-clover was followed by winter wheat, except for Jyndevad in 2001 to 2004, where it was followed by winter rye. All straw was left in the field. Weed harrowing was used where possible to control weeds in cereals and legumes. The experiment was irrigated at Jyndevad.

The experimental factors were 1) catch crop (with and without catch crop) and 2) manure (with and without animal manure applied as slurry). All crops in all rotations were represented every year in two replicates (blocks) in a two-factorial randomised design with plot sizes varying from 169 to 378 m^2. The plots receiving manure were supplied with anaerobically stored slurry at rates such that the amount of NH_4-N corresponded to 40% of the N demand of the specific rotation based on a Danish national standard (Plantedirektoratet, 1997). In the catch crop treatment, a mixture of perennial ryegrass, chicory and various legume species were used.

Grain yields were measured at maturity using a combine harvester. Samples of total above-ground biomass were taken in each plot at growth stage 59 in spring barley and winter cereals. Each sample was separated into barley, grass-clover, and weeds for assessing weed pressure. To determine the amount of crop residues returned to the soil, samples of total above-ground biomass were taken at growth stage 85, 1-2 weeks before yellow maturity in the pulse and cereal crops. Similar samples were taken about 1 November to measure the above-ground biomass of catch crops and weeds. Samples of total above-ground biomass in the grass-clover were taken at each cut. The dry matter content of grains and plant samples were determined after oven drying at 80 C for 24 hours. Total N in the grains and plant samples were determined on finely milled samples from each plot by the Dumas method. Total N was not determined in the plant samples taken at GS 59. The amount of straw and other residues left on the soil after harvest of the previous crops was estimated from the samples of above-ground plant material taken at growth stage 85 by subtracting the grain dry matter yield.

The grain yield and grain N uptake in spring barley and winter cereals were related to inputs of N in various forms and to the weed pressure using linear regression. The following regression equation was used for spring barley:

$$Y = a_y + a_1 N_{man} + a_2 N_{res} + a_3 N_{Nov} + a_4 R_{wgc} \quad (1)$$

The following equation was used for winter cereals:

$$Y = b_y + b_1 N_{man} + b_2 N_{gc} + b_3 N_{gc}^{\ 2} + b_4 R_{wgc} \quad (2)$$

where a_y *and* b_y are effects of year, and a_1-a_4 and b_1-b_4 are regression coefficients. N_{man} is ammoniacal N in the applied manure (kg N/ha), N_{res} is N in the above-ground residues from the previous crop (kg N/ha), N_{Nov} is N in the above-ground plant parts on 1 November (kg N/ha) prior to spring barley, N_{gc} is accumulated N in the above-ground biomass of the previous grass-clover (kg N/ha), and R_{wgc} is weed and grass-clover biomass as per cent of total above-ground dry weight at growth stage 59.

Results

There were generally consistent yield benefits from N in manure, with average grain yield increases of approximately 20 kg DM/ha per kg NH_4-N in manure, with slightly lower values at Flakkebjerg for both spring barley and winter wheat (Tables 1 and 2). The apparent N recovery efficiency (NUE), taken as the slope of N uptake in grain versus the N input in manure was highest at Foulum and similar at Jyndevad and Flakkebjerg for both crops (see coefficients of N_{man} under grain N uptake, which is the recovery efficiency (NUE)).

N in above-ground residues of pulses insignificantly affected grain yield and N uptake in spring barley (Table 1). Grain yields of winter wheat responded strongly to accumulated N in the mulched grass-clover cuttings, especially at Flakkebjerg (Table 2). However, this response was non-linear, as seen by the negative coefficient for N_{gc}^2, which results in a saturation response. This means that the NUE is reduced with increasing N input, resulting in NUE values of only 9, 14 and 16% at Jyndevad, Foulum and Flakkebjerg, respectively, for an N input in grass-clover of 300 kg N/ha.

The grain yield response of spring barley to N in the catch crop samples in November showed large site differences, with considerably higher responses at Jyndevad compared with Flakkebjerg (Table 1). The associated NUE showed similar site differences, but the NUE for spring barley from N in the catch crop was always higher than the NUE for winter cereals from N in grass-clover (compare Tables 1 and 2).

There were negative effects of weeds and an undersown catch crop or grass-clover on cereal yields. The effects of weeds on NUE were considerably more pronounced for winter cereals compared with spring barley (compare Tables 1 and 2).

Discussion

The results demonstrate that the yield benefits and the NUE from manure application are considerably more consistent across sites than the effects of various types of N in green manure or crop residues. The lower yield benefits from manure application at Flakkebjerg compared with the other sites can probably be explained by higher ammonia volatilisation due to reduced infiltration of the slurry on this soil type.

A large part of the site differences in grain yield response to inputs of N in grass-clover and catch crops can probably be explained by differences in N leaching during winter. The combination of a sandy soil and relatively high rainfall gives a high risk of N leaching at Jyndevad compared with the other sites. The soil at Flakkebjerg has the highest N retention and the lowest rainfall. The benefits of using catch crops in terms of retaining N in the system are therefore highest at Jyndevad and lowest at Flakkebjerg. The risk of losing N from the autumn-ploughed grass-clover is similarly highest at Jyndevad and lowest at Flakkebjerg, resulting in large differences in the NUE of N in grass-clover.

The low NUE of N in grass-clover at Jyndevad and the non-linear response of yield to increasing N input in grass-clover suggests that the N supply to the cereal crops may be improved by harvesting the grass-clover cuttings and applying them to the crops in spring in the form of manure, possibly after anaerobic digestion in a biogas reactor.

Tab. 1: Regression coefficients from regression of grain yield and N uptake of spring barley, 1998-2004, on ammoniacal N in manure (Nman), N in the above-ground residues of the previous crop (Nres), N in above-ground weeds and catch crop in November prior to spring barley (NNov), and weeds and undersown grass-clover as percentages of total above-ground dry weight at growth stage 59 in spring barley (Rwgc).

Variable	Location	N_{man}	N_{res}	N_{Nov}	R_{wgc}
Grain DM yield	Jyndevad	23.0	2.3	32.1	-29
(kg DM/ha/yr)	Foulum	20.9	-0.1	15.4	-44
	Flakkebjerg	16.9	3.3	9.6	-23
Grain N uptake	Jyndevad	0.29	0.04	0.52	-0.49
(kg N/ha/yr)	Foulum	0.38	0.03	0.33	0.67
(NUE)	Flakkebjerg	0.30	0.05	0.16	0.07

Tab. 2: Regression coefficients from regression of grain yield and N uptake of winter cereals, 1998-2004, on ammoniacal N in manure (Nman), N in above-ground biomass at time of cutting in the previous grass-clover (Ngc) and weeds and undersown grass-clover as percentage of total above-ground dry weight at growth stage 59 in winter cereals (Rwgc).

Variable	Location	N_{man}	N_{gc}	N_{gc}^2	R_{wgc}
Grain DM yield	Jyndevad	17.2	4.4	-0.004	-32
(kg DM/ha/yr)	Foulum	22.4	9.9	-0.011	-18
	Flakkebjerg	12.0	14.6	-0.016	-92
Grain N uptake	Jyndevad	0.23	0.09	-0.00006	-0.6
(kg N/ha/yr)	Foulum	0.44	0.21	-0.00022	-0.5
(NUE)	Flakkebjerg	0.23	0.27	-0.00030	-1.7

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Performance of Organic Grain Cropping Systems in Long-Term Experiments

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Key words: organic farming, no-tillage, crop rotation, soil carbon, weed control

Abstract

Organic farming and conventional no-tillage farming systems share many of the same benefits from protecting and improving soils. A review of recent results from two long-term systems experiments in the mid-Atlantic region of the U.S.A. demonstrates that organic cropping systems with organic amendments can increase soil carbon, nitrogen, and yield potential more than conventional no-tillage, despite the use of tillage in organic systems. However, reduced-tillage organic systems present challenges for weed control, particularly with simple rotations typical of conventional grain cropping systems. Organic systems that employ more complex rotations including a hay crop have demonstrated greater potential for improved weed control, increased nitrogen availability, and increased yields.

Introduction

Conventional grain production in the mid-Atlantic region of the U.S. is characterized by short rotations [primarily maize (*Zea mays* L.), soybean (*Glycine max* L. Merr.), and wheat (*Triticum aestivum* L.)] and reduced- or no-tillage planting practices on soils that are relatively low in organic matter and drought-prone. No-tillage systems have been particularly successful in this region for soil conservation, building soil organic matter, capturing and retaining soil moisture, and reducing runoff as well as nutrient and pesticide losses into the Chesapeake Bay watershed. There has been increasing interest in organic grain production in recent years because of premium prices and potential environmental benefits to the Chesapeake Bay region. However, there are challenges in adapting organic approaches to the conventional model of short-rotation, no-tillage grain production because longer rotations are usually recommended for organic farming and tillage is usually required for seedbed preparation and weed control. Two long-term experiments were established at the USDA-ARS Beltsville Agricultural Research Center in Beltsville, Maryland, to compare the performance of conventional and organic grain production systems. The Sustainable Agriculture Demonstration Project (SADP) was initiated in 1994 to compare the sustainability of four reduced-tillage cropping systems. The Farming Systems Project (FSP) was established in 1996 to compare three rotation lengths of organic cropping systems with two conventional systems.

Materials and methods

SADP. The SADP was conducted on a droughty, sloping site in a randomized complete block with four replicates. Four cropping systems were included in this long-term experiment, but only two will be discussed here: 1) a standard Mid-Atlantic no-

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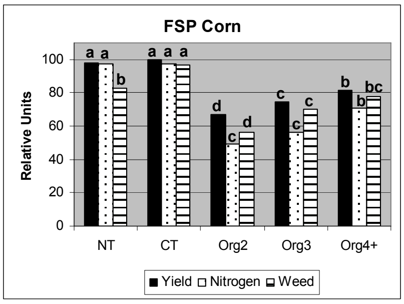
tillage system (NT) with recommended herbicide and nitrogen inputs; and 2) a chisel plow-based organic system (OR) with cover crops and manure for nutrients and post-planting cultivation for weed control. The NT system followed a two-year maize-wheat/double-crop soybean rotation, while OR followed a three-year maize-soybean-wheat rotation. This systems comparison was conducted from 1994 to 2002, followed by a uniformity trial in which all plots were planted to maize according to the NT system from 2003 to 2005. Further details of the experimental methods are described in Teasdale et al. (2007).

FSP. This long-term experiment was conducted on relatively level Coastal Plain soils in a randomized complete block design with four replicates. The five cropping systems included: 1) a conventional no-till maize-soybean-wheat/soybean rotation (NT); 2) a conventional chisel-till maize-soybean-wheat/soybean rotation (CT); 3) a two-year organic maize-soybean rotation (Org2); 4) a three-year organic maize-soybean-wheat rotation (Org3); and 5) a four- to six-year organic maize-soybean-wheat-hay rotation (Org4+). Hairy vetch and manure were the nutrient sources for Org2 and Org3, while hay and manure provided nutrients for Org4+. Each phase of each rotation was included as a split plot in each year. Further details of the experimental methods and analyses are described in Cavigelli et al. (2008).

Results

FSP. Maize yields at FSP were similar in NT and CT but were lower in the three organic systems (Figure 1). Among the organic systems, maize yield increased as the length of rotation increased. Nitrogen availability and weed control exhibited a similar pattern of response as did maize yield (Figure 1), suggesting that these variables were important determinants of maize yield (Cavigelli et al. 2008).



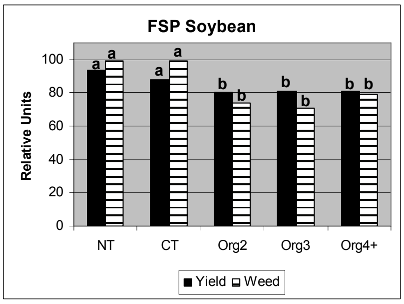


Figure 1: Average crop yield, nitrogen availability (based on fertilizer rates or estimated mineralization from organic sources), and weed control at the FSP. Relative unit of 100 = 10 Mg ha^{-1} maize grain, 5 Mg ha^{-1} soybean grain, 170 kg ha^{-1} nitrogen, and 100 % weed control. Bars within variables with the same letter are not significantly different ($P<0.05$).

Generally the legumes preceding maize provided insufficient nitrogen and supplemental manure was limited because manure application rates were phosphorus-based and this site was high in soil phosphorus. Weed control improved as organic rotation length increased because there were fewer niches for weed adaptation in the longer, more phenologically diverse rotations (Teasdale et al. 2004). An analysis of covariance demonstrated that nitrogen availability accounted for 70-

75% of the yield differences between organic and conventional systems, while weed control accounted for 21-25% and maize population for 3-5% (Cavigelli et al. 2008).

FSP full-season soybean grain yields were similar in the two conventional systems and similar among the three organic systems but higher in the conventional than the organic systems (Figure 1). Differences in soybean yield were accounted for exclusively by differences in weed control among systems.

SADP. Maize grain yield averaged over nine years, 1994 to 2002, was 28% lower in OR than in NT (Teasdale et al. 2007). Reduced yields in OR were accounted for primarily by competition with weeds. A reduced-tillage approach to weed control was used for OR whereby a winter annual cover crop (crimson clover before maize) was flail mowed with the expectation that surface residue would suppress early-season weeds and that escaped weeds would be controlled by between-row cultivation with a high-residue cultivator. This approach did not successfully control annual weeds and a substantial seedbank of broadleaf and grass weeds built up in the soil.

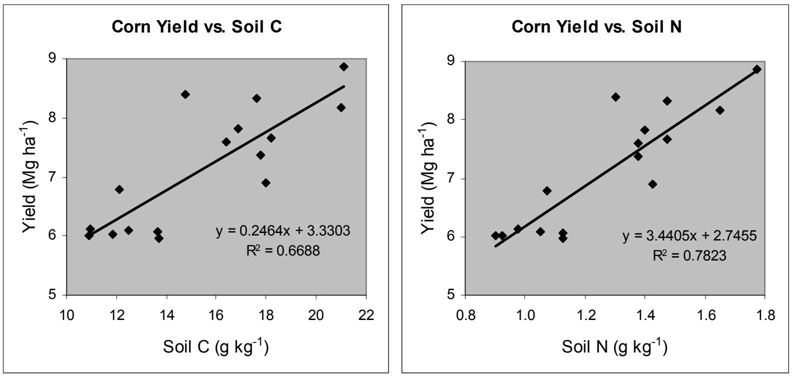


Figure 2: Uniformity trial maize yield (2003 to 2005) as a function of combustible soil carbon and nitrogen at 0 to 15 cm depth at the conclusion of the SADP systems comparison (1994 to 2002).

At the conclusion of the SADP systems comparison in 2002, soil carbon and soil nitrogen were significantly increased in the OR compared to the NT system (Teasdale et al. 2007). The OR system had supplemental carbon inputs of manure in addition to plant residue inputs that accounted for higher carbon inputs in this system than in NT. All plots were planted to maize grown according to NT system operations during a uniformity trial from 2003 to 2005. Maize grown on plots with a history of OR yielded 18% higher than those with a history of NT during this uniformity trial (Teasdale et al. 2007). Yields in OR and NT during this uniformity trial were highly correlated with 0-15 cm soil carbon and nitrogen at the conclusion of the experiment (Figure 2). Soil carbon and nitrogen at 6-12 cm were less correlated with yield (R^2 = 0.37 and 0.33, respectively). Thus, it is likely that yields were higher in plots with a history of OR rather than NT because of improved soil conditions and nitrogen availability as a result of increased soil carbon and nitrogen, primarily in the surface 0 to 15 cm of soil. Higher maize ear leaf nitrogen and higher soil nitrate levels at the maize six-leaf stage in OR than NT confirmed that there was higher nitrogen availability in the OR system.

Discussion

Organic farming has many of the same goals and benefits for soil improvement as conventional no-tillage systems. A simulation study of SADP where all systems had either no or reduced tillage predicted similar annual soil erosion losses among the four systems (Watkins et al. 2002), while a simulation of FSP based on soil aggregate distribution showed erosion potential of CT > Org3 > NT (Green et al. 2005). Results of SADP research showed that soil carbon and nitrogen concentration and maize yield potential were increased in OR compared to NT, and preliminary data from FSP shows similar results (Cavigelli, personal communication). This suggests that organic farming systems with organic amendments can provide greater long-term soil improvement than conventional no-tillage systems, despite the use of tillage in organic systems. Manure- and legume-based organic farming systems from nine long-term experiments across the U.S. also increased soil organic carbon and nitrogen compared with conventional systems (Marriott and Wander 2006).

This research also demonstrates that the soil-building benefits of organic farming may not be realized because of the difficulty of controlling weeds in organic systems, particularly, reduced-tillage organic systems. Additional research is needed to develop reliable weed management for reduced-tillage organic farming. Advances in equipment design (The Rodale Institute 2008) have led to improved control of annual weeds by rolling cover crops to form a dense, tight mat of residue in no-tillage organic systems. In addition, FSP research (Teasdale et al. 2004) has shown that more diversified organic systems with perennial hay crops in the rotation maintain a lower weed seedbank and lower weed abundance than those following simpler grain crop rotations such as those used in the SADP research. Utilizing rotations with perennial hay crops would benefit organic systems not only by reducing weed populations but also by eliminating tillage during a significant portion of the rotation. Therefore, with inclusion of a perennial crop, the soil-building benefits of no-tillage could be obtained during the perennial phase of the rotation and the negative consequences of tillage during the grain crop phase would be minimized.

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Effects of an organic and a conventional cropping system on soil fertility

Boldrini, A.[1], Benincasa, P., Gigliotti, G., Businelli, D. & Guiducci, M.

Key words: crop rotation, nitrogen, phosphorus, potassium, carbon

Abstract

An experiment was started in 1998 in Central Italy to evaluate changes in soil fertility and the risk of N loss in an organic (ORG) and a conventional low input (CONV) cropping system. At the end of a 6-year rotation, ORG caused a higher plant biomass incorporation into the soil and thus a higher soil soluble organic carbon. The N surplus in ORG was 32% higher than in CONV, while no differences were recorded on N content in the top soil, so that ORG implicated a higher N loss from that soil layer. In ORG we recorded a higher phosphatase activity but a lower available soil P (due to application of rock phosphate in sub-alkaline soil) and a lower exchangeable K.

Introduction

Nutrient management in organic systems is based on atmospheric nitrogen (N) fixation, combined with recycling of nutrients via bulky organic materials, such as farmyard manure and crop residues, with only inputs of permitted fertilizers. Organic systems are expected to improve soil quality parameters and reduce N leaching (Haas et al., 2002), but this is not always confirmed. Actually, these systems have been criticized for relying on reserves of soil phosphorus (P) and potassium (K) built up by fertilizer additions prior to organic management (Heathwaite, 1997; Løes and Øgaard, 2001), and for increasing residual N exposed to leaching (Kirchmann and Bergström, 2001, Torstensson et al., 2006). This research is aimed to evaluate changes on soil quality indicators in an organic and a conventional low input cropping system over a long term rotation.

Materials and methods

An experiment was started in 1998 in Central Italy (43°N, 165 m a.s.l.) to compare an organic (ORG) and a conventional low input (CONV) system in two contiguous fields, both clay loam, pH 7.8 and with same initial contents of SOM, total N, available P and exchangeable K. The conversion to organic of the ORG field had been started in 1996. Both fields were divided in six sectors (A1, A2, B1, B2, C1, C2) to reproduce the steady-state running of a 6-year rotation in a farm and test several food crops concurrently. In each cropping system a randomized block design with 3 or 4 replicates (depending on year and crop) was adopted. The same sequence of cash crops over the 6 years was adopted in both systems (Table 1). The nutrient supply was assured by green manures, pelleted poultry manure (4% N, 4% P_2O_5, 3% K_2O), rock phosphate (P_2O_5 17% soluble in formic acid 2% concentrated) and potassium sulfate (50% K_2O) in ORG; by green manure (only until 2000) and mineral fertilizers in CONV.

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Tab. 1: Six-year crop rotations in the six field sectors in organic (ORG) and conventional low input (CONV) cropping systems. Green manure crops (GM) were adopted in ORG and CONV until 2000, only in ORG afterwards. The N supply (kg ha^{-1}) from fertilizers in ORG/CONV system is reported in brackets.

Sector	Years					
	1999	2000	2001	2002	2003	2004
A1	bean (40/0)	spelt (40/40)	GM1+ maize (40/150)	GM4+ soybean (0/0)	GM1+ pepper (0/200)	wheat (0/80)
A2	bean (40/0)	wheat (80/80)	GM1+ pepper (40/175)	GM4+ maize (40/40)	GM1+ tomato (0/200)	wheat (0/80)
B1	field bean (0/0)	GM3+ pepper (100/100)	pea (40/0)	wheat (80/80)	GM2+ maize (0/150)	GM3+ tomato (60/160)
B2	field bean (0/0)	GM3+ maize (100/100)	field bean (40/0)	wheat (80/80)	pea (0/0)	GM3+ pepper (60/200)
C1	GM1+ pepper (0/70)	bean (40/0)	spelt (80/80)	GM1+ tomato (60/200)	wheat (40/80)	field bean (0/0)
C2	GM1+ millet (20/135)	bean (40/0)	wheat (80/80)	GM1+ pepper (60/200)	wheat (40/80)	GM1+ maize (40/150)

GM1: field bean; GM2: field bean+rapesed; GM3: hairy vetch; GM4: barley.

Above-ground biomass and N accumulation (Kjeldahl method) and partitioning between marketable yield and residues were determined at the end of each crop. The biomass incorporated into the soil was calculated as the sum of crop residues and green manures. Apparent residual N in the soil (ΔN, kg ha^{-1}) (i.e. the soil-crop component of the soil surface budget) (Aarts et al., 2000) was calculated at the end of each crop cycle as: N input with fertilizers plus legume Ndfa (i.e derived from atmosphere via symbiotic fixation, estimated as in Boldrini et al., 2007) minus N off-take with marketable yield removal. At the end of the 6-year rotation four 0-0.40 m soil cores per sector were taken to determine: total organic carbon (TOC); water extractable organic carbon (WEOC); total soil N content, as mineral N (i.e. either $N0_2$-N + NO_3-N or NH_4-N) (Bremner and Keeney, 1966) plus organic-N (i.e. reduced-N obtained by Kjeldahl minus NH_4-N); available P (Olsen method); phosphodiesterase activity; exchangeable K (ammonium acetate method). Data were submitted to analysis of variance according to a hierarchical design (crops within systems).

Results

As an average over the 6 years and the six field sectors, both the total biomass yield and biomass incorporated into the soil were higher in ORG than in CONV (+13% and +26%, respectively) while marketable yield was 12% lower in ORG (Table 2). Actually, incorporated biomass was the 74% of the total in ORG and the 66% in CONV. The ΔN (Table 2) was 32% higher in ORG than in CONV.

Tab. 2: Average values over 6-year and 6-sectors of total biomass, biomass incorporated into the soil, marketable yield and N surplus (∆N) per year for an organic (ORG) and a conventional low input (CONV) cropping system.

Systems	**Total biomass** (t ha^{-1} d.m.)	**Incorporated biomass** (t ha^{-1} d.m.)	**Marketable yield** (t ha^{-1} d.m.)	**∆N** (kg ha^{-1})
ORG	12.9	9.5	3.4	41
CONV	11.4	7.5	3.9	31
Pooled SD	*1.34*	*1.21*	*0.46*	*2.3*

At the end of the 6-year rotation, no significant differences were observed between the two systems for TOC in the 0-0.40 m top soil, while WEOC was 13% higher in ORG than in CONV (Table 3). In that soil layer, total N content was not significantly different in the two systems, available P was 21% lower and phosphatase activity 14% higher in ORG than in CONV, exchangeable K was significantly but slightly higher in CONV.

Tab. 3: Total organic carbon (TOC), water extractable organic carbon (WEOC) total N, available P, P-diesterase activity, and exchangeable K in the 0-0.40 m soil layer for an organic (ORG) and a conventional low input (CONV) farming system at the end of a 6-year crop rotation.

Systems	TOC (g kg^{-1})	WEOC (mg kg^{-1})	Total N **(g kg^{-1})**	Avail. P **(mg kg^{-1})**	P-diesterase (µmol p-NP g^{-1} h^{-1})	Exch. K (mg kg^{-1})
ORG	9.84	52.9	0.80	18.7	55.7	180.4
CONV	9.30	47.0	0.82	23.6	48.9	192.9
Pooled SD	*0.050*	*9.04*	*0.110*	*3.85*	*4.78*	*15.57*

Discussion

The higher total biomass yield in ORG is the consequence of the regular use of green manure crops before summer cereals and vegetables (Table 2). On the contrary, the lower total and marketable biomass yield of cash crops in ORG, especially in spring-summer crops, was due to either a lower nutrient availability from green manures and organic fertilizers or to a higher competition of weeds in ORG (particularly for summer grain legumes). As well, the higher ∆N in ORG with respect to CONV (Table 2) was determined by both a 17% lower cash crop N off-take (data not shown) and the imprecise N availability (as total amount and timing of release) from green manuring and organic fertilisers, that caused a lower N fertilisation efficiency. On the contrary the total N input (i.e. N from fertilizers + legume Ndfa) was similar in the two systems (100 kg ha^{-1} per year on average) even though with a 3.5 times higher estimated legume Ndfa in ORG than in CONV, as already reported for this trial by Boldrini et al. (2007). The lack of difference for TOC between systems and the higher WEOC in ORG (Table 3) are probably consequent to no use of amendments and incorporation of greater plant biomass in ORG. In fact, plant tissues contain a high quantity of simple organic molecules that increase WEOC. The not statistically different total N content in the 0-0.40 m top soil layer in the two systems suggests that the higher ∆N recorded in ORG should have implicated a higher N loss from that soil layer. However, the invariance for total N and TOC between systems need to be further checked in the future, since changes might need more time to be detectable. The lower available P in

ORG, was likely due to the fertiliser-P form applied in this experimentation; in fact the main amount of phosphate in ORG was added as Ca triphosphate that, in a soil with a sub-alkaline pH value, tends to transform to very insoluble forms as apatites. Indeed, organic P fertilisers will be preferred for our soils in the future. The phosphatase activity, instead, was higher in ORG, where the final product of reaction (available P) was less concentrated and where the substrate for enzyme activity (organic P) was higher. The significant but slight difference on exchangeable K cannot be traced back to the fertiliser form, that was the same in both systems, and need to be further confirmed in the future to advance any hypothesis on why it originates.

Conclusions

As compared to the conventional low input cropping system, the organic system increased biomass supply to the soil and thus soil soluble organic carbon. Moreover, the organic system increased N surplus, but the total N content in the top 0.40 m soil at the end of the 6-year rotation did not vary, so that the surplus of N was necessarily lost from that soil layer. The organic system also increased phosphatase activity but the use of rock phosphate in our sub-alkaline soil reduced available soil P. Finally, the organic soil showed a slightly lower exchangeable K. A longer time-interval will allow to better evaluate effects on those soil fertility indicators. In any case, our experiment already confirms that the supposed benefits of organic systems on soil fertility and environment are not to be taken for granted, but depend on the adoption of suitable cultivation strategies such as those that may increase N use efficiency and reduce N loss from the soil (Kirchmann and Bergström, 2001; Torstensson et al., 2006).

Acknowledgments

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A comparison of organically and conventionally grown vegetable crops: results from a 4-year field experiment

Tabaglio, V.[1], Gavazzi, C.[2] & Nervo, G.[3]

Key words: organic farming, conventional farming, vegetable crops

Abstract

A four-year field trial (2004-2007) was carried out to compare performances of organic and conventional farming systems in the Po Valley (Northern Italy). Four vegetable crops were grown in the sequence: 2004 – processing tomato; 2005 – bean followed by savoy cabbage; 2006 – processing tomato; and 2007 – zucchini. The experimental design was a split-plot with four replicates, the management system being the main factor (OF, organic farming vs. CF, conventional farming) with the rate of nitrogen fertilisation as the secondary factor. N efficiency of the organic fertilizers was assumed as being 50-75%). In all four of the years studied, the two farming systems did not show significant differences in marketable yields for any vegetable crops. The reduction in OF compared with CF was 17% for tomato-2004 and 2% for zucchini; in contrast, for cabbage and tomato-2006 the yields in OF were 10% and 3% higher respectively.

Introduction

Conventional vegetable growers who want to convert to organic farming systems have to pass through a 3-year transition period before their farms can be qualified for organic certification. Most of the research indicates that in the first transition year, yields of several conventionally grown vegetables are higher than those of organically grown vegetables (Gregori and Prestamburgo, 1996). However, in the following years yields of tomato (*Lycopersicon lycopersicum* L.) (Steffen *et al.*, 1995) and bean (*Phaseolus vulgaris* L.) (Temple *et al.*, 1994) were not statistically different between the two farming systems. In contrast, Sellen *et al.* (1995) report that in the second and third transition years, yields and net income from organically grown vegetables were still lower than those for conventional crops. Since in Italy there is limited knowledge of both vegetable crop productivity during the transition phase and the evolution of soil fertility, a composite project was set up (ORTOFRUBIO, funded by Mi.P.A.A.F., Italian Ministry of Agriculture) to evaluate the quantitative and qualitative potential and the environmental aspects of organic farming, of which this research is only one part.

Materials and methods

The field experiment was set up in 2004 at Montanaso Lombardo (LO, Northern Italy) on a *fine loamy, mixed, superactive, mesic Ultic Haplustalf* (Soil Taxonomy) or a *Haplic Alisol* (FAO), moderately acid (pH = 5.6 in H_2O), low in total N (0.072%), organic matter (1.21%), and exchangeable K (57 mg kg^{-1}), but high in available P (35

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Tab. 1: Nitrogen fertilisation scheme during the experimental period

Year and crop	Organic Farming	Conventional Farming
2004: tomato	200 kg N ha^{-1} (*)	100 kg N ha^{-1} as NH_4NO_3 (26% N)
2005: bean (spring) savoy cabbage (autumn)	 no fertilisation 160 kg N ha^{-1} (*)	 no fertilisation 120 kg N ha^{-1} as NH_4NO_3 (26% N)
2006: tomato	200 kg N ha^{-1} (*)	100 kg N ha^{-1} as NH_4NO_3 (26% N)
2007: zucchini	60 kg N ha^{-1} (*)	60 kg N ha^{-1} as $Ca(NO_3)_2$ (15.5% N)

(*) as organic fertiliser (Fertorganico, Ilsa, granular, 11% N) at ploughing.
During the conversion period, N efficiency is lower in OF than in CF, so the comparison of organic N has been based on a value equal to 50-75% of inorganic N.

mg kg^{-1}). The field was previously cropped conventionally for two years under corn and two under wheat. The experimental design used was a split-plot with four replicates; the main factor was the farming system (organic farming, *OF* vs. conventional farming, *CF*), with the rate of applied nitrogen as the secondary factor (*N0*, control plots; *N1*, fertilised plots; the annual rates applied are shown in table 1). The sub-plot was 5.4 m wide and 10 m long.

Four vegetable crops were grown in the sequence: 2004 – tomato (Podium F1); 2005 – bean (cv. Taylor) followed by savoy cabbage (*Brassica oleracea* L. var. *sabauda*, cv. Montalto Dora); 2006 – tomato (Podium F1); and 2007 – zucchini (*Cucurbita pepo* L., Altea F1). Because of the low availability in the soil, 250 kg K_2O ha^{-1} as potassium sulphate (50% K) was applied annually at ploughing, to both the CF and the OF plots. In 2004, after the tomato harvest, 8000 kg ha^{-1} of lime (80% CaO) was used to adjust soil acidity in all the plots. As tomato and bean crops were watered by sprinkler, for the zucchini drip irrigation was adopted. Weed control was carried out using herbicides and cultivation in the CF plots, while a PP woven fabric film was used as mulch in the OF plots. Pest control, when necessary, was ensured by spraying with copper, sulphur, propolis, and biopesticides derived from plants (pyrethrum, rotenone, spinosad) in OF, whereas copper and chemical pesticides were used in CF. In 2004 and 2006, immediately after the tomato crop, a cover crop of Italian ryegrass (*Lolium multiflorum* Lam. var. *italicum*) was grown on the OF plots, then ploughed in before bean (2005) and zucchini (2007) were planted. Crop yields were determined for sample areas of 3.90-15 m^2 depending on the crop; marketable and discarded fruit weight, total biomass weight, and some important morphological and qualitative features were measured. ANOVA was performed for statistical analysis of all data (MSTAT-C Software); the LSDs were calculated for $P<0.05$ and $P<0.01$ levels.

Results and Discussion

Year 2004 – Processing tomato (figure 1). In the first year of the trial, marketable yields were not statistically different between the farming systems, according to Mazzoncini *et al.* (2000), although CF yielded about 13 Mg ha^{-1} more than OF. As regards the effect of fertilisation, only one case of statistical significance (P□0.05) was obtained: the fertilised plots yielded 163% more non-ripening fruits than N0 plots (24 vs. 9 Mg ha^{-1}). No significant interaction was found. The main qualitative traits of the marketable fruits were quite similar between the two farming systems (Nervo *et al.*, 2007).

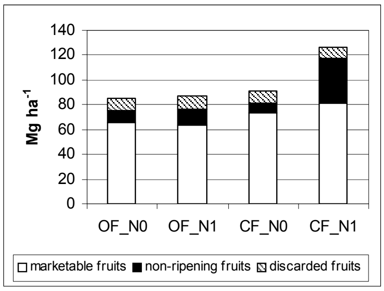

Figure 1: Processing tomato yields in 2004

Year 2005 – Bean (figure 2). No statistical differences in yields were obtained, although total biomass and bean seeds were higher in CF than in OF (7.6 vs. 4.9 and 1.78 vs. 1.21 Mg ha^{-1}, respectively); neither fertilisation, nor interaction with the farming system, had any effect. The absence of significant effects for bean may in part be due to increased soil variability caused by the liming.

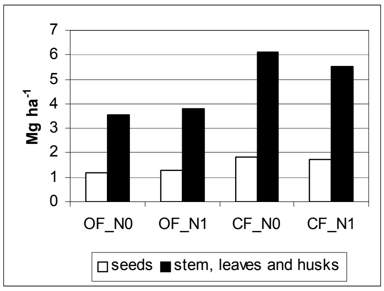

Figure 2: Bean yields in 2005

Year 2005 – Savoy cabbage (figure 3). Yields were not statistically different between farming methods, although the OF marketable yield was about 3 Mg ha^{-1} higher than CF. Nitrogen fertilisation and its interaction with the farming method was not statistically different, but the average weight of the marketable head in the fertilised organic sub-plots (OF-N1) was over 500 g higher than in the corresponding CF-N1 sub-plots (3 086 vs. 2 527 g).

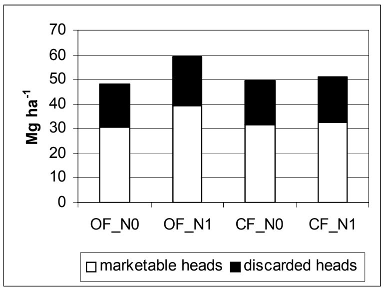

Figure 3: Savoy cabbage yields in 2005

Year 2006 – Processing tomato (figure 4). For the second tomato crop the marketable yields were not significantly different between the two farming systems. However, in the third year of the conversion period, OF yielded a higher percentage of marketable fruits (82%) than CF (68%). As in 2004, the non-ripening fruit yield of the fertilised plots (N1) was significantly higher than for control plots (N0), by more than 14 Mg ha^{-1}.The qualitative parameters of the marketable fruits, all included in values ranging from satisfactory to optimal, showed no significant differences; nitrogen fertilisation also had no effect on fruit quality, except for the acidity (Nervo *et al.*, *2007*). By the third conversion year, yield and quality of organically grown marketable tomato were competitive compared to those conventionally grown, partly because of the choice of the well-adapted and productive genotype Podium F1 (Dadomo *et al.*, 2002).

Year 2007 – Zucchini (figure 5). The two farming systems did not show any significant differences in marketable yield and fruit number. However, fertilisation was

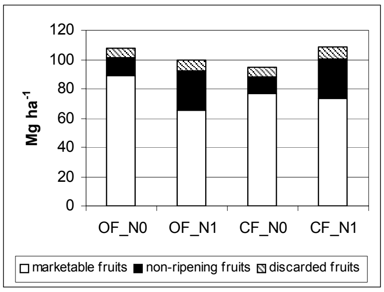

Figure 4: Processing tomato yields in 2006

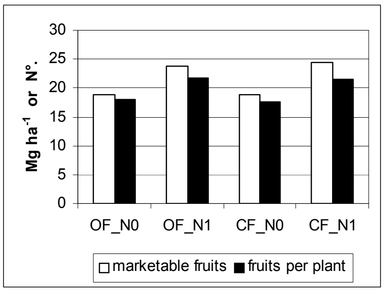

Figure 5: Zucchini yields in 2007

statistically significant for both parameters ($P \le 0.001$). N1 yielded 28% more marketable fruits than N0 (24.1 vs. 18.8 Mg ha^{-1}) with 22 vs. 18 fruits per plant. The use of the highly adaptable genotype Altea F1 (Azzimonti *et al.*, 2007) permitted optimal yields under both farming systems.

Conclusions

The yield performance during the 4-year period of the trial was quite good for all the vegetable crops, except bean. The changes which occurred in the soil did not significantly reduce the yields of organically grown compared with conventionally grown vegetable crops. The decrease in marketable yield in OF was 17% for tomato-2004 and 2% for zucchini; in contrast, for cabbage and tomato-2006 yields were 10% and 3% higher respectively.

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Comparative dynamics of tea (*Camellia sinensis* L.) roots under organic and conventional management systems with special reference to water use.

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Key words: organic, tea, roots, water use

Abstract

Comparative measurements were carried out in the on-going, long-term organic and conventional comparison "TRI OR-CON" trial at the Tea Research Institute of Sri Lanka. The tea was grown organically using tea waste (TW), neem oil cake (NOC), compost (COM) as soil amendments using IFOAM guidelines, which were compared with tea grown conventionally (CONV) with recommended synthetic inputs. Responses of the tea yield, root system and mass volume sap flow were studied.

The tea bushes showed comparable responses between all the treatments, the differences of which were not statistically significant: They exhibited similar yield, root distribution, growth, extension rates, mortality, mass volume flow of water and water use efficiency (WUE). The organically grown (ORG) tea bushes invested more roots in deeper soil layers than the CONV bushes.

The results showed that in terms of plant growth, managing tea organically is as equally feasible as managing tea in the conventional manner.

Introduction

Sri Lanka is the pioneer in organic tea production. However, organic systems provide more management challenges than conventional systems. Organic cultivation is often blamed for higher cost of production and low productivity, mainly owing to limited technology available (Peck, 2004). The comparative responses of the tea (*Camellia sinensis* L.) shoots in organic and conventional systems have been previously reported (Mohotti et al., 2001). However, there is very scarce information on the comparative responses of the tea root system in organic and conventional systems of tea, with even little information on the comparative studies on water relations.

Therefore, this study was carried out to examine and compare the behaviour of the root system and study the sap flow of field grown mature tea, grown under organic and conventional management systems.

Materials and methods

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This study was carried out in the on-going, long-term, organic and conventional comparison "TRI OR-CON" trial, established at St Coombs estate, Tea Research Institute, Talawakelle, Sri Lanka (latitude 6°55', longitude 80°40', altitude 1382 m amsl) during January 2004 to September 2006. The long-term average annual rainfall in this region is 2250mm and maximum and minimum temperature 22.8^{0}C and 14.2^{0}C.

The experiment consisted of approximately ten year-old tea bushes of the cultivar DT1, in a land area of approximately 1.6 ha, consisting about 20,000 bushes. Three treatments were managed organically according to IFOAM guidelines viz. TW, NOC and COM (TW and COM were given at 2kg per bush and NOC at 500g per bush, twice a year, which contained N%:P%:K% 2.4:0.4:1.7, 2.8:0.5:1.1 and 1.6:3.7:0.3 respectively). These were compared with tea grown conventionally (CONV), using recommended inorganic fertilizer and other recommended management practices by the Tea Research Institute (N:P:K at 270:123:200 kg ha^{-1} $year^{-1}$). The treatments were arranged in a randomised complete block design with four replicates. Two sub-plots each consisting approximately 25 bushes were separately maintained in each plot for monitoring yield. The bushes were plucked weekly and a representative sample was oven dried at 95 °C for extrapolation of yield per ha.

Three experiments were carried out in order to study the root dynamics and water relations: In the first experiment (January 2004), the distribution of the tea root system was studied. Soil was sampled in fixed volumes of (3375 cm^2) using a soil core sampler, at different distances from the base of the tea bush and at different depths. The roots were hand-separated and measurements on the root length and weights were taken. Soil N, P, K, organic C (OC) and soil moisture (MC) contents were analyzed using standard methods. Data were statistically analyzed using GLM procedure in SAS statistical package and the means were separated using Duncan's Multiple Range Test.

In the second experiment, root windows that were constructed in 10 bushes in each treatment, using a plane glass fixed to a metal frame, were used. Root maps were drawn in two-week intervals, during December 2005 to September 2006. Root growth rate, extension rate, regeneration and mortality were measured using the root maps. Data were statistically analyzed using GLM procedure.

In the third experiment, sap flow was monitored using sap flow sensors (Thermal Logic, USA) using the heat-pulse technique, which was fixed to a data logger, in November and December 2005. An average rainfall of 114 mm was received during this period (long-term average is 112mm). Only TW and CONV treatments were included in the experiment due to practical limitations. Water use efficiency (WUE) was calculated as the ratio between dry matter accumulation and mass flow per day. Soil moisture content was measured weekly by drying soil samples at 105°C. Data were statistically analyzed using GLM procedure.

Results

The yield and soil nutrient contents were not statistically significant at P=0.05 (data not shown). Differences were significant with soil OC (at P>0.0013) and probably resultantly in soil MC (at P>0.0027) during a relatively dry period (in experiment 1, 25.8%, 23.4%, 25.9% and 22.7% in TW, NOC, COM and CONV respectively).

The root distribution parameters (i.e. root weight, total root length) did not significantly differ (at P=0.05) between the treatments. The total root (young and mature) fresh weights were not significant at P=0.05, but when expressed as a percentage of roots in different depths (Figure 1b), showed that in organic treatments, more roots were concentrated in the deeper layers of soil (i.e. 37% and 35% in 15-30cm and 30-45cm depths respectively in overall ORG treatments vs 31% and 31% respectively in CONV) while in CONV, more roots were concentrated in the topmost layer of soil (38% as against 29% in overall ORG treatments) (Figure 1b).

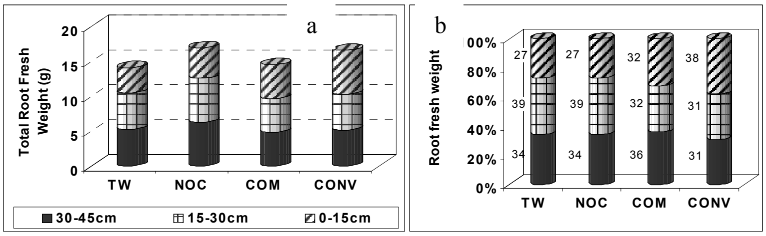

Figure 1a: Distribution of tea roots in different soil depths and figure 1b: root fresh weight as a percentage of the total, in each soil depth.

Feeder root growth rate (Figure 2a), length, mortality and extension rate (data not shown) did not significantly differ between the treatments. However, root regeneration rate (Figure 2b) as measured by the number of root tips at each measurement, was significantly higher in ORG plants compared with the CONV.

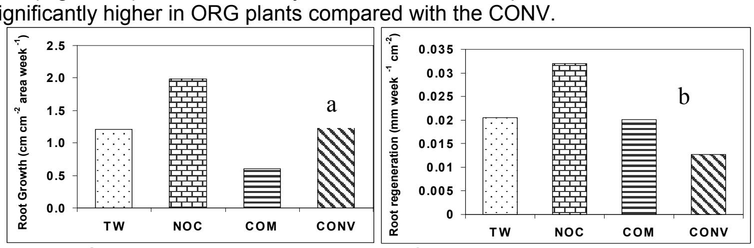

Figure 2: Growth and regeneration rates of tea roots.

Sap flow studies showed that the volume flow was slightly higher (not significant at P=0.05) in the CONV treatment (Figure 3a). However, TW showed higher water use efficiency (WUE) compared to CONV (Figure 3b). During this study, the soil moisture content did not differ significantly (34.78% and 34.81% in TW and CONV respectively).

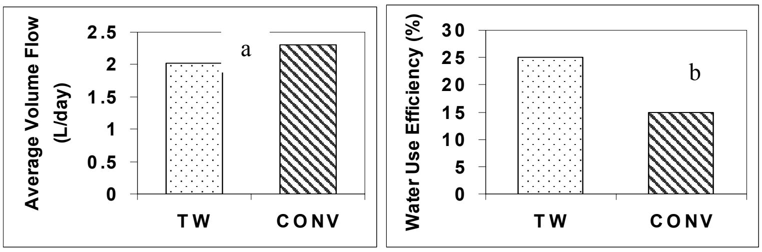

Figure 3a: Average volume sap flow and b. water use efficiency.

Discussion

The tea bushes grown organically and conventionally showed similar performances in terms of root growth and yield. These results agree with earlier observations made on comparisons between organic and conventional systems of young tea (Mohotti et al., 2001) and some other crops such as apple (Reganold et al., 2000), corn (Lang, 2005), tomatoes (Mitchell et al., 2007) and soybean(Lang, 2005; Prasad, 2005).

Organically grown tea also seemed to invest on a deeper root system compared to the conventionally grown tea, as reported earlier by Mohotti et al. (2001) in young tea and similarly in other crops such as soybean (Prasad, 2005). These differences could also be seen in the WUE, as the TW exhibited higher WUE than CONV. The volume sap flow was comparable in both CONV and TW. The results also show that the plants in organic systems use the resources more usefully than the CONV systems. Repeating the sap flow studies during a dry season can be suggested. In this study, organic cultivation did not change the soil nutrient content, but improved the organic carbon content in soil. Resultantly, during dry periods organically managed soils held more moisture.

Conclusions

The study emphasizes that organically and conventionally grown tea exhibit similar growth performances, in terms of the responses of the root and shoot systems. This shows the feasibility of growing tea organically, without affecting the yield or plant performance.

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Effects of arbuscular mycorrhizal fungi and free-living nitrogen-fixing bacteria on growth characteristics of corn (*Zea mays* L.) under organic and conventional cropping systems

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Keywords: Organic and low input cropping systems, mycorrhiza, free-living nitrogen-fixing bacteria.

Abstract

In recent years, biological fertilizers have received special attention in sustainable agriculture. Inoculation with arbuscular mycorrhizal fungi and free-living nitrogen-fixing bacteria had significant effects on corn photosynthesis and yield; the highest photosynthesis rate and yield were obtained with dual inoculation with fungus plus bacteria. These outcomes were also affected by cropping systems, but to a lesser extent. Therefore in organic and low input cropping systems, a combination of mycorrhiza and free-living bacteria performed satisfactorily.

Introduction

Biological fertilizers are gaining importance in sustainable cropping systems. Application of mycorrhiza and nonsymbiotic nitrogen-fixing bacteria have been shown to enhance soil fertility and availability of nutrients for plants (Cardoso et al. 2006, Dodd, 2000), and to increase photosynthesis and water use efficiency (Estrada-Luna & Davies, 2003; Auge 2000; Gosling et al. 2006; Wu & Xia 2006), and also resistance to biotic and nonbiotic stresses (Jeffries et al. 2003).

Materials and Methods

An experiment based on a randomised complete block design with split plots and three replications was conducted in the Research Farm of Ferdowsi University of Mashhad in 2006 to evaluate the effects of biofertilizers on corn under four different cropping systems. The cropping systems, including high, medium and low input and also an organic system were allocated to the main plots, and four inoculation treatments including application of *Glomus intraradices* (mycorrhiza), *Azotobacter paspali* (bacteria), *Azospirillum brasilense* (bacteria), a combination of fungus plus two bacteria, plus a control (no inoculation) were allocated to the subplots. Specification of the cropping systems is shown in table 1. Nutrient contents of the manure used were 2.36, 0.59, and 2.08 % N, P and K respectively. Original nutrient contents of the soil were: 800, 37 and 400 ppm N, P and K respectively. Corn seeds inoculated with fungus and bacteria (except the control plots) were planted in rows 75 cm apart with 25 cm between plants in the row. During the growth period, photosynthesis rate (using LC*i*, ADC Ltd., UK), dry matter yield and finally seed yield (14% moisture content) were measured. The statistical method used was the analysis of variance (ANOVA). Data were analyzed with Minitab software Ver. 13, and means were compared with

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Duncan’s multiple range test. The probability level for the determination of significance was 0.05.

Tab. 1: Amounts of input consumption and agronomic practices in different cropping systems.

Inputs	Cropping systems			
	High input	Medium input	Low input	Organic
1- Soil amendments (times)				
Tillage (Moldboard plow)	2	1	-	-
Disk	3	3	3	1
Leveler	3	3	2	1
2- N-P_2O_5-K_2O (kg ha^{-1})	220:150:100	170:100:50	120:50:0	-
3- Cattle manure (t ha^{-1})	-	-	-	60
4- chemical control of plant pests and disease (times)	2	1	-	-
5- Chemical control of weeds (times)	3	2	1	hand control

Results and Discussion

Inoculation with fungus and/or bacteria increased the photosynthesis rate (Fig. 1). This has also been found elsewhere (Panwar, 1991; Wu & Xia, 2006) and has been reported to be associated with higher stomatal conductance (Wu & Xia, 2006) and stimulation of photosynthesis by providing extra sink for the assimilates (Wright et al. 1998).

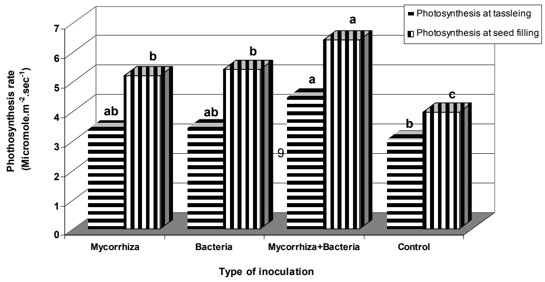

Figure 1: Rate of photosynthesis at two stages of plant growth due to the type of inoculation. In each stage, means that follow the same letters have no significant difference (p<0.05).

Application of a combination of a fungus and bacteria showed the highest dry matter yield (Fig. 2). Such results have also been reported by others (Panwar, 1991; Sanches-Blanco et al. 2004). However, there are cases with no effect reported (Wright et al. 1998).

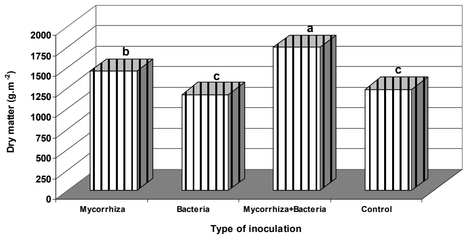

Figure 2: Corn dry matter yield with different type of inoculations.
Means that follow the same letters have no significant difference ($p<0.05$)

In Fig. 3 seed yield changes associated with cropping systems are shown. In general, there were no consistent differences between cropping systems. In other words, seed yield has not changed much by type of cropping systems; this could be an indication of similar performance of organic systems compared with even a high input cropping system. Pimentel et al. (2005) reported that energy efficiency and yield may increase in organic farming compared with conventional systems.

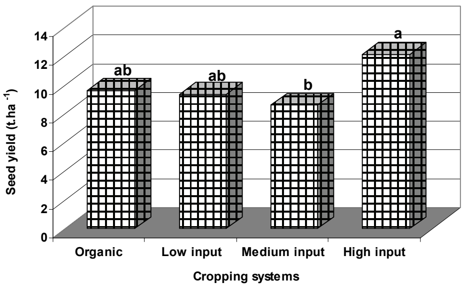

Figure 3: Corn seed yield with different cropping systems.
Means that follow the same letters have no significant difference ($p<0.05$)

Conclusion

It appears that in general, application of biofertilizers in promising and there are good reasons to believe that organic systems could perform satisfactorily in terms of yield compared with systems using other externally applied inputs. There were no significant interactions between two factors in the criteria measured. However, this experiment is being repeated for the second year to clarify the results.

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Cropping Intensity and Organic Amendments in Transitional Farming Systems: Effects on Soil Fertility, Weeds, Diseases and Insects

Wander, M[1]., Eastman, C., Zaborski, E., Eastburn, D., Masiunas, J., Engiseth, N. Ugarte, C., Marzano, S.-Y. & Rosa, I.

Key words: Organic transition strategies; farming systems; soil quality, plant quality,

Abstract

The Windsor Organic Research Trial (WORT) is a farming systems experiment initiated in 2003 to investigate alternative strategies for transitioning to certified organic vegetable production that compares the influence of transition schemes that differ in management intensity (cropping, tillage) and organic matter inputs on weeds; soil organic matter and nutrient availability; soil invertebrate communities; and the relationship between soil fertility, plant health and insect/disease pressure. Soil quality was improved during transition in all systems. Conventional soil tests were unable to document differences among systems that were reflected in biotic indicators. The pasture-based transition system was superior.

Introduction

The WORT study is an interdisciplinary project carried out in partnership between the Illinois Natural History Survey (INHS) and University of Illinois. The project was an outgrowth of efforts that began in 2001–02: with experienced organic growers who became our advisors. Six acres were planted to winter rye cover crop in 2002. The broad objectives were to: to compare the influence of transition schemes that differ in: management intensity (cropping, tillage) and organic matter inputs on: weed populations, soil organic matter and fertility, soil invertebrates, and the relationship between soil fertility, plant health and insect/disease pressure.

Materials and methods

Three farming systems (treatments) representing different cropping intensities: 1) high-intensity transition (intensive vegetable production), 2) intermediate-intensity transition (organic cash-grain), and 3) low-intensity transition (perennial ley system). Treatments are divided into sub-treatments representing different strategies for organic matter and fertility management: a) plant inputs (e.g., cover crops) providing all organic inputs and N fertility, b) plant inputs plus composts, or c) plant inputs plus fresh wastes or manure. These transition strategies are being evaluated using a systems research approach. Baseline data was collected for comparison with variables at the completion of transition (2006). The site is a randomized complete block with four replicates that include fertility treatments applied as a split plot within. Priorities established separately for each farming system-based transition scheme determined amendment applications. Sawdust-pack dairy manure and compost were applied to appropriate subplots in fall 2003 for the medium-intensity system and in spring 2004 for the other systems based on anticipated nutrient needs. Initial soil test

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values (pH, P, K) were in the high to very high range for all plots; thus, no separate additions of lime or mineral K sources were made. Manure and compost were added to appropriate subplots in all systems in fall 2005; winter rye was broadcast and incorporated in the high- and medium-intensity treatments only. Rotations are summarized in Table 1. The ley treatment plots were tilled under in spring 2006, and the rye in the other treatments was mowed and incorporated. For 2006, three varieties of tomatoes and peppers were grown across all systems. Plastic mulch and straw was used to control weeds in the vegetable crop system in 2003. In all years, weeds emerged were controlled in the vegetable- and row crop transition systems as time allowed using both mechanical and hand methods. Mowing and selected hoing of thistle were used in the ley system. Rotation and crop choice were the principal tools used to control diseases and pests. Scoting for pests was used to determine application need. Entrust (Spinosad) was applied in 2004 for control of cabbage caterpillar complex. Blue Ballet (a hubbard-type squash) was planted in 2005 as a perimeter trap crop for squash insects with Pyganic EC (Pyrethrum) applied if needed.

Soil-cores to 1 m were taken in 2003 & 2006 and work on biological attributes began in 2004. Variables considered include standard soil texts for pH, extractable P, K, base cations, total soil organic matter and particulate organic matter (POM) after Mariott and Wander (2006), nematode community information after Bongers and Ferris (1999), soil N mineralization potential (PMN & ISNT) (after and Khan et al. 2001). Disease ratings were taken each year in the field. Soil samples taken throughout the study were used in greenhouse-based bioassays to evaluate their disease suppression characteristics against: *Rhizoctonia* root and stem rot, *Phytophthora* root and stem rot, and sudden death syndrome. The influence of cropping intensity on predatory arthropods, such as spiders and ground beetles was evaluated during the transition phase of the study. Pitfall trapping was carried out each year to assess abundance/activity of ground beetles and other feeders on insect prey and/or weed seeds. Bait stations and quadrat sampling were carried out in 2003 and 2004. Emerged weed counts and seedbank estimations were carried out annually. Plant assays included measurement of yield with harvests in the vegetable crop system being carried out to estimate direct and whole sale markets. Tomato fruit quality (BRIX, pH) were evaluated in the Roma variety in 2003 and 2006. Ascorbic acid was determined in 2006.

Results

Transition strategies used did not differ in their ability to build soils. Standard tests indicate fertility was improved in all cases by conversion to organic management (Tab 2). The only difference among systems was their ability to change soil pH; pH was increased in the low input pasture-based scenario. The calcium-to-magnesium ratio, which was already above the 7.5 value recommended by many, increased under organic management. Nematode maturity Index determinations during transition indicated that the nematode community was dominated by bacterial and fungal feeding nematodes that influence N mineralization. This was consistent with high levels of plant available N. In 2006, regardless of amendment type, all three transition strategies maintained target POM-C concentrations and contained labile N concentrations (PMN, ISNT) that were high and possibly in excess. This is suggested by the nematode enrichment index (EI) which indicates the presence of bacterial and fungal feeding nematodes responsive to N-enrichment. High structure index (SI) values suggest the nematode community was diverse and complex at the start of the transition year. Values fell under intensive vegetable cultivation regardless of history.

Up until 2006, we saw no effect of cropping system or type of organic amendment on levels of disease severity or root system characteristics in the field. Diseases observed on tomatoes in 2006 included *Septoria* leaf and fruit spot, anthracnose, and some virus infections. Pepper diseases included bacterial spot and *Phytophthora* fruit rot. Levels of *Septoria* and anthracnose on tomatoes were significantly affected by previous cropping history and by type of organic amendment.

Tab. 1: Rotation and field management summary

Date		*Pasture (Ley)*		*Row crop*		**Vegetable crop**	
		Crop	_Mgt[¥]_	_Crop_	_Mgt_	_Crop_	_Mgt_
03	W			Winter rye		Winter rye	
	S	Alfalfa, Red	¥		T		2XT
	S	cover, Alsike	2Xt	Soybean	3Xt	Tomato	3Xt;Mul;LF
	F	clover,		Winter wheat			
04	W	Timothy,				Fallow	t
	S	Orchard				Winter pea	
	S	grass	M&C	Fallow		Broccoli	3XT;2Xt;M&C
	F			Hairy vetch	M&C		t
05	W					Wheat & Vetch	
	S			Field corn	T		T
	S				4Xt	Winter squash	
	F		M&C	Winter rye	M&C		2Xt; M&C
06	W					Winter rye	t
	S	Tomatoes	1X2	Tomato	1X2	Tomato	1X2
	S		2X3		2X3		2X3

[¥] Where T= disruptive tillage by aggressive means using moldboard plowing, spading or bed shaping; t= soil disturbances caused by field cultivation or disking. The number eg: (2X) indicates the frequency of the operation during the season. M&C indicates the times when manure and compost were added to appropriate subplots. “Mul” refers to the use of plastic and wheat straw mulch and ‘LF” identifies when ≈ 0.5 L of dilute liquid fish emulsion was applied to M & C plots.

The lowest levels of *Septoria* leaf spot were in the low-intensity (ley) and high-intensity (vegetable) system plots; highest levels occurred in the intermediate-intensity (grain crops) plots. *Septoria* severity also was higher in non-amended subplots than in subplots receiving compost or manure. Anthracnose levels were highest in the high-intensity system plots and in subplots not amended with compost or manure. For bacterial spot on peppers, incidence levels were highest in the intermediate-intensity plots and lowest in the high-intensity plots. Bacterial spot levels were not significantly affected by amendment treatments. Based on greenhouse bioassays, we see a general reduction in disease severity and an increase in root system length and volume over the four years of the study. The number of emerged weeds per plot in the different systems decreased between 2003 and 2006. In 2003, the ley-system had the most weeds, but in subsequent years it had fewer weeds than the other systems. Weed species composition changed depending on management intensity and year, while weed species diversity in the seed bank increased between 2003 and 2005. Fewer lambsquarters (*Chenopodium album*) emerged due to later plantings, but there were more pigweed and waterhemp (Amaranthus spp.). Common purslane (*Portulaca oleracea*) was first found in 2005. Increasing weed pressure was encountered during 2006 & 2007. There was little evidence that soil fertility management altered insect pest abundance during the course of the study. Investigations of abundance of carabid beetles (*Pterostichus melanarius*) conducted during the first two years of transition showed that the ley-system supported larger carabid beetle populations.

Tab. 2: Changes in soil properties (0-6") during four year transition from conventional cash grain based system to organic vegetable crop production

Year		Bray P	K	Ca	Mg	SOC	C/N	pH
		ppm				(%)		
2003		53a	167a	2228a	245a	2.21a	11.9a	6.76
2006		61b	261b	3062b	321b	2.36b	12.7b	6.8
2003	ley□							6.7a
2006	ley							6.9b
		ppm						
		0.03	0.0001	0.0001	0.0001	0.1	0.006	.08

□Differences in pH were significant only in the pasture-based system

In 2006, when plots were eligible for organic certification, yields differed as a result of management with yields after the perennial-ley always exceeding those in the intermediate and high intensity annual cropping systems. Yields did not differ among the intermediate intensity grain and high intensity vegetable system for any of the tomato varieties but there was a significant increase in yield where fertilizers were applied within those treatments. Yields of 'Roma' tomatoes were higher in 2003 than in 2006. Water and weed management are likely contributing factors. Fruit quality differed among varieties but did not vary based on management past except for brix, which were significantly greater in 'Classica' tomatoes grown in vegetable transition plots than in 'Classica ' tomatoes grown after ley-transition.

Conclusions

The three transition systems compared maintained different environmental conditions during transition that were apparent in beetle and nematode communities and disease suppression evaluated in the green house, appeared to increase in all instances. The ley system minimized increases in weed populations. Despite extremely different management pasts, soil quality was improved during transition in all systems. Conventional soil tests were unable to document differences that were apparent in nematode community structure, disease incidence in the field and yields achieved. These results indicate that the pasture-based transition system is superior

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Sustainable management

Residues in beeswax after conversion to organic beekeeping

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Key words: beekeeping / beeswax / acaricide/ residue / *Apis mellifera*

Abstract

Beekeepers interested in converting their honey farms to organic management must replace old combs with organic foundations. The experiment described in this paper compares two methods of replacement of old combs, "fast" (5 combs per year) and "slow" (2 combs per year), by measuring the levels of acaricide residues in the newly built combs. Considered acaricides were coumaphos (Perizin and Asuntol), fluvalinate (Apistan) and clorfenvinphos (Supona). Significant differences between the two replacement groups were observed only for the Apistan group in the third year, confirming high lipophilicity of fluvalinate. The residue levels in the newly built combs three years after beginning the conversion were significantly lower than initial levels for all products. Direct contamination of the combs was evaluated at the beginning of the trial and was found to be highest in Asuntol-treated hives and lowest in Perizin-treated hives. Residues in honey exceeding EU Maximum Residue Limit were found only in the case of Asuntol.

Introduction

Beekeeping is one of the Italian agricultural sectors in which the organic production method has registered a great proportion of adherents: the number of organic beehives rose from 48000 in 2001 to 72000 in 2005 (SINAB, 2006). According to the EU Reg.1804/99 the conversion of traditionally managed honey farms to organic production methods must be carried out by substituting all the combs in the hive with foundations obtained from organic beekeeping. The implementation Decree issued by the Italian Ministry of Forestry and Agriculture Policies on 29/03/2001, specifies that this substitution should take place within 3 years to limit contamination of new combs. It has in fact been shown that some acaricides, due to their lipophilic nature, can contaminate both the combs present in the hive during the chemical treatment (direct contamination) and the new combs built by the bees (indirect contamination) even 18 months after the treatment (van Buren, 1992). Experiments by Bogdanov et al. (1998) showed that acaricide residues in beehive products decreased according to the order: brood combs>honey combs>> honey. While acaricide levels in honey are found to be generally lower than the accepted MRL levels, in comb wax the residues tend to accumulate (Wallner, 1999) and, if the levels are high, residues can pass into honey (Kochansky, 2001).

The experiment described in this paper aimed at comparing two conversion methods in which substitution of old combs took place over two or more years. The experiment also gave us a chance to evaluate the differences in direct and indirect contamination of the selected acaricides, by analysing residue levels in old and newly built combs in the years following the interruption of traditional acaricide treatments.

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Materials and methods

The experiment was carried out in apiaries consisting of 15-20 hives each, in which the beehives had been treated with on of the following commercial products for at least 5 preceding years:

- Perizin® (Bayer), active ingredient: coumaphos. Registered for use on honeybees;
- Asuntol® (Bayer), active ingredient: coumaphos. registered for use on cattle, sheep and dogs. The beekeeper used 0.5 g of Asuntol 50 powder mixed with icing sugar to disperse over the combs;
- Apistan® (Vita Europe), active ingredient: fluvalinate. Registered for use on honeybees;
- Supona® (Cyanamid), active ingredient: chlorfenvinphos. Registered as a cattle dip. The beekeeper impregnated wooden strips with 1 ml of a.i. and placed them at the entrance of the hive.

The hives in each apiary were equally divided between the two replacement methods, which differed in the time scale of comb substitution with residue-free foundations: in one group of hives the conversion took place in 2 years, replacing 5 combs each year ("fast replacement"); in the other group 2 combs per year were replaced ("slow replacement"). During the experiment, *Varroa destructor* infestation was controlled according to organic beekeeping methods (thymol-based products in August and oxalic acid sucrose solution in November or December).

Initial levels of residues (and thus direct contamination of the wax by the applied acaricide) were determined in year 2000 by sampling combs which had been present in the hive for at least 4 years ("old combs"). Collection of new comb wax, honey cap and honey samples were carried out until 2003, when conversion was over for the fast replacement hives, and a single overall sample was collected. Samples from all combs described below were collected by cutting out portions measuring 15 cm x 15 cm, whereas honey caps and honey were collected after honey extraction. The residues in the newly built combs were also used to determine the indirect contamination caused by each product. The samples were analysed for presence of residues of the acaricide pertinent to each apiary by the laboratory of the Istituto Nazionale di Apicoltura (certified UNI CEI EN ISO/IEC 17025).

Comparisons between the mean wax residue levels of the two replacement techniques were carried out using one-way analysis of variance (ANOVA). To establish differences among different aged combs of a same group (same a.i.), Scheffé's multiple comparison procedure in GLM analysis was used at the P=0.05 significance level.

Results

The only difference in the kind of replacement occurred in the 2003 overall sampling in the hives that had been treated with Apistan (P=0.034), where the mean level of residues was lower in the fast replacement group. For the other products no significant differences were observed between the two kinds of replacement in any of the considered years (Tab. 1).

Tab.1: Mean residue levels (µg/kg ± SE, n= number of samples) in the brood comb wax in the two different replacement groups (fast and slow).

Product	Comb replacement	Old combs (2000)	New combs (2001)	New combs (2002)	New combs (overall 2003)
Perizin	FAST	272 ± 80, n=8	154 ± 69, n=8	N.D., n=9	21 ± 7, n=23
	SLOW	199 ± 63, n=7	329 ± 14, n=7	N.D., n=6	16 ± 3, n=18
Asuntol	FAST	4969 ± 590, n=12	973 ± 261, n=9	37 ± 14, n=12	183 ± 37, n=12
	SLOW	3588 ± 728, n=7	1260 ± 461, n=7	56 ± 20, n=7	213 ± 49, n=21
Apistan	FAST	3787 ± 1448, n=5	913 ± 247, n=6	139 ± 65, n=4	205 ± 44, n=10 [a]
	SLOW	3475 ± 886, n=8	1256 ± 303, n=5	316 ± 60, n=8	468 ± 87, n=16 [b]
Supona	FAST	673 ± 195, n=5	251 ± 76, n=7	76 ± 40, n=6	40 ± 11, n=16
	SLOW	793 ± 133, n=5	188 ± 50, n=5	34 ± 4, n=8	19 ± 3, n=17

The overall 2003 value refers to comb wax built in 2001 and 2002 for the “fast replacement” group and in 2001, 2002 and 2003 for the “slow replacement” group. Different letters in the Apistan (fluvalinate) row indicate significant differences (P=0,034). N.D.= not detectable.

Residue levels due to direct contamination were found to respect the following order: Asuntol > Apistan >> Supona > Perizin. To establish differences in the indirect contamination of newly built brood and super combs in hives treated with different products data from the replacement groups were pooled, as the differences between the 2 replacement theses were not statistically significant (with the exception of Apistan in the 2003 overall sampling, which has however been shown as a whole in figure 3). Results are shown in figures 1 to 4, where contamination is expressed as mean residue levels (± SE) of coumaphos in the brood-combs and honey-combs. Different letters over bars indicate significant differences (P < 0.01) calculated separately for brood combs and for honey combs. The year in brackets indicates time of sampling.

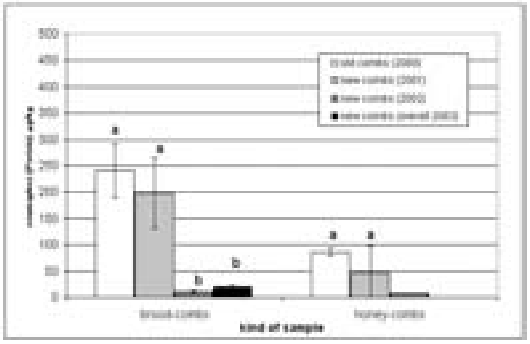

Figure 1: Wax contamination in hives treated with Perizin (coumaphos) until year 2000. Samples of honey-combs were collected from individual supers in 2000 and 2001 and as a single apiary sample in 2002.

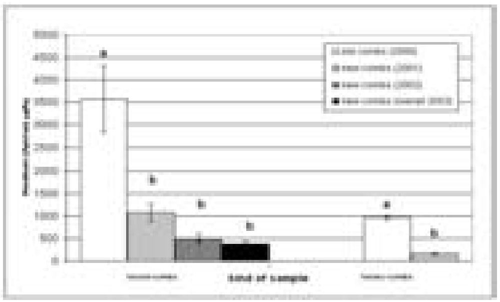

Figure 2: Wax contamination in hives treated with Apistan (fluvalinate) until year 2000. Samples of honey-combs were collected from individual supers in 2000 and 2001 (only new combs).

Discussion

Comb wax at the end of experiment contained residues of the previously used acaricides (compared to initial concentrations: 4% Supona, 5% Asuntol, 8% Perizin and 10% Apistan), independently from the speed of replacement. This confirms that a complete renewal of the brood combs in the hive over 2 or more years is not sufficient to guarantee complete absence of residues of some of the used products (not only for the unregistered Asuntol but even in the case of Apistan). The decision adopted by many Organic Farming Control Bodies in Italy, to accept certain levels of residues in brood comb wax in the initial years of organic management, therefore appears justified. The same allowance is also valid for the melted honey-cap wax used to be transformed in foundations by the converting beekeepers. The risks of using coumaphos in the unregistered product Asuntol, in terms of high levels of residues which may contaminate honey for human consumption, are confirmed by this study.

Acknowledgments

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Sustainable management of foxtail meadows through hay making at seed maturity

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Key words: grassland management, meadow foxtail, *Alopecurus pratensis*, self-reseeding, botanical composition

Abstract

Harvesting meadows at early heading of the grasses yields large quantities of high quality forage but might in the long term cause the swards to deteriorate due to the lack of formation of mature seeds. We studied 4 cutting regimes on a foxtail meadow to define which would maintain the foxtail population naturally and is acceptable in terms of forage quality. The 1st cut of the different cutting regimes was done either at early shooting, shooting, early heading or seed maturity of Alopecurus pratensis *L.. The 2nd cut of the 3 first treatments was simultaneous to the 1st cut of the 4th treatment and was ground dried to allow the seeds to fall on the soil. When the meadow was harvested regularly at early heading of* A. pratensis*, its botanical composition deteriorated within 5 years and its yield decreased. With a 1st cut at seed maturity,* A. pratensis *produced the most seeds and its proportion in the sward increased, but the forage had the lowest quality. In the treatments with the 1st cut at early shooting or at shooting,* A. pratensis *produced significant quantities of seeds during the 2nd regrowth, maintained its population and forage of intermediate quality was produced. Sustainable production of quality forage on intensive foxtail meadows might be achieved by periodically having the 1st cut at shooting and using the second regrowth at seed maturity for ground dried hay.*

Introduction

In order to harvest large quantities of high quality forage, the first cut of intensively used meadows is usually carried out when the inflorescence of the main grass species is emerging. This cutting regime neither allows the grasses to produce seeds, nor triggers their tillering (Gillet, M., 1980), and therefore may cause a considerable decrease in the proportion of forage grasses in the sward in the long term. The disappearance of good forage grasses can be avoided by regular overseeding with commercial seeds, but organically produced seeds of adapted genotypes are not always available. This is especially true for species that are not very widely grown like meadow foxtail (*Alopecurus pratensis* L.). On the other hand, meadow foxtail is a very interesting grass species for growing conditions unfavourable to ryegrass species. This study aimed to define a sustainable intensive management of foxtail meadows allowing the grass to produce seeds with a minimum loss of forage quality.

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Materials and methods

Four cutting regimes were applied over 5 years to an intensive permanent meadow with about 40 % initial yield proportion of *A. pratensis*. The cutting regimes differed from each other by the date of the 1st cut, which was either at early shooting (ESh), shooting (Sh), early heading (EHe) or seed maturity (SMa) of *A. pratensis*. The 2nd cut of ESh, Sh and EHe was simultaneous to the 1st cut of SMa, allowing plants of *A. pratensis* to reach seed maturity in ESh and Sh. The 15 m^2 permanent plots were harvested 6 times per year in ESh, Sh and EHe and 5 times in SMa. At the 2nd cut (1st cut of SMa) the forage was ground dried on each plot and the number of seeds falling on the soil during hay making assessed by placing 4 Petri dishes 8.5 cm in diameter in the soil. The botanical composition of the plots was estimated yearly in May according to Dietl (1995), modified to 12 yield proportion classes. The energy value (MJ NEL kg^{-1} DM) of the forage (200 g subsamples) was evaluated based on the digestibility of organic matter according to Tilley and Terry (1963). The plots were arranged in a randomized complete block design with 4 replicates. Differences between treatments are shown as the results of the combined ANOVA over the years 1 to 5 for the number of seeds produced (after square-root transformation of the data) and as the results of ANOVAs on the year 1 or year 5 data for the yield and the proportion of *A. pratensis*.

Results

In SMa the average quantity of *A. pratensis* seeds that fell on the soil was 31 kg ha^{-1} yr^{-1} (Tab. 1), with large differences between the years (from 7 to 66 kg ha^{-1}). The quantity of matured seeds of *A. pratensis* produced in ESh and Sh reached 29 to 60 %, and 15 to 63 %, of the seed quantity produced in SMa respectively (Fig. 1A). Only very few seeds were produced in EHe. From the 1st to the 5th experimental year, the yield proportion of *A. pratensis* strongly increased in SMa, was maintained in ESh and Sh, and strongly decreased in EHe (Fig. 1B). In EHe, the decrease in *A. pratensis* was compensated by an increase in the proportion of *Poa trivialis* L. and *Taraxacum officinale* agg., which are low yielding species. Correspondingly, the annual dry matter yield of the EHe treatment was 12.8 t ha^{-1} in year 1 but decreased to only 10.2 t ha^{-1} in year 5 (Tab. 1). This trend of decreasing yield was not observed in the other cutting regimes. The annual yield in ESh and SMa was therefore lower than in EHe in year 1, but was higher in year 5 (Fig. 1C). The energy value of the forage harvested at the 1st cut was lower in EHe than in ESh and Sh (Fig. 1D). By the 2nd cut (1st cut in SMa), the energy value of the forage was lowest in SMa and highest in EHe. From the 3rd cut onwards, no difference in energy value was observed between the treatments.

Discussion

When harvested every year at early heading, the population of *A. pratensis* was not able to regenerate itself with seedlings and its proportion in the meadow strongly declined. *A. pratensis* can also propagate vegetatively by short stolons, but because apical dominance is strong at heading (Murphy & Briske, 1992), cutting at this stage is probably also unfavourable to stolon formation. Consequently, the botanical composition of the sward deteriorated within 5 years and the yield decreased. This cutting regime should therefore be modified to sustain the population of *A. pratensis* in order to avoid problems with undesired plant species, which once established, are very difficult to control in organic farming. The population of *A. pratensis* was promoted by a 1st cut at seed maturity, when the plants could produce the most seeds. This indicates that reproduction by seeds is an important process for *A. pratensis* populations. But this cutting regime yielded the forage with the lowest quality and lodging was a problem for the very late harvest of this nutrient-rich meadow. In the two cutting regimes with a very early 1st cut and a late 2nd cut (ESh and Sh), the lower seed production than in SMa shows that many of the apexes were removed at the 1st cut. Nevertheless, *A. pratensis* still produced significant quantities of matured seeds and was able to maintain its population in the meadow. Under these two cutting regimes, *P. trivialis* and *T. officinale* were not able to increase their population and the total yield of the sward was maintained.

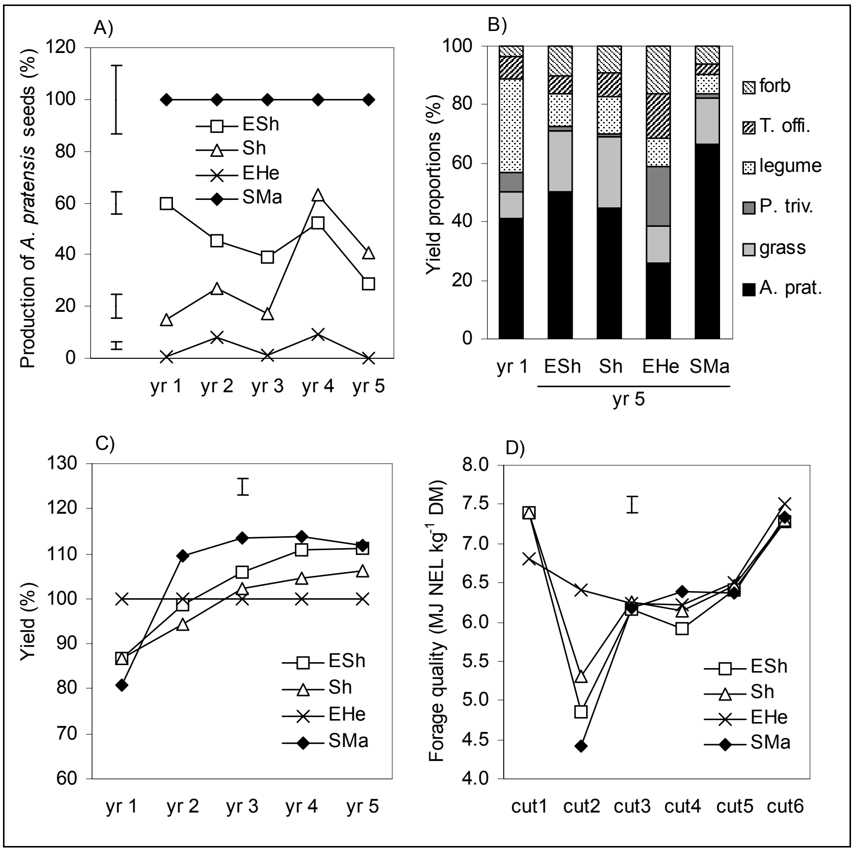

Figure 1: A) Production of *A. pratensis* seeds in the different cutting regimes from the 1st to the 5th experimental year (yr 1 to yr 5) given in percent of the seed quantity produced in SMa, B) Botanical composition of the sward in May, in yr 1 and after 5 years of differing cutting regime, C) Evolution of the annual yield from yr 1 to yr 5 given in percent of the yield in EHe, D) Energy value of the forage at each cut of yr 5 for the different cutting regimes. ESh = 1st cut at early shooting, Sh = 1st cut at shooting, EHe = 1st cut at early heading, SMa = 1st cut at seed maturity, A. prat. = *Alopecurus pratensis*, grass = other forage grass species, P. triv. =

Poa trivialis, legume = legume species, T. offi. = *Taraxacum officinale*, forb = other forb species. Error bars = averaged s.e.m (n = 4; in A) given in % of mean of SMa).

Tab. 1: Quantity of *Alopecurus pratensis* seeds produced, yield and proportion of *A. pratensis* (*A. prat.*) in the sward in the different cutting regimes. In a column, the means followed by a common letter are not significantly different at the 5% level by LSD.

	Seeds (kg ha^{-1} yr^{-1})	Yield (t DM ha^{-1} yr^{-1})		*A. prat.* (%)
Cutting regimes	Mean yr 1 to 5	yr 1	yr 5	yr 5
1^{st} cut at early shooting (ESh)	16 b	11.1 a	11.3 b	50 b
1^{st} cut at shooting (Sh)	10 b	11.1 a	10.8 ab	45 b
1^{st} cut at early heading (EHe)	1 a	12.8 b	10.2 a	26 a
1^{st} cut at seed maturity (SMa)	31 c	10.3 a	11.4 b	67 c

In ESh and Sh, energy rich forage was harvested at the 1^{st} cut and the energy value of the forage harvested at seed maturity (2^{nd} cut for ESh and Sh and 1^{st} cut for SMa) was better than in SMa. ESh and Sh therefore allowed a considerable reduction in forage quality losses compared to SMa. Moreover, it reduced the problem of lodging. Because individual grass plants live for many years (Treshow M. & Harper K., 1974), yearly seed production is probably unnecessary. To periodically change from a 1^{st} cut at early heading to a 1^{st} utilisation at shooting followed by a 2^{nd} cut at seed maturity might therefore be a good compromise in achieving a sustainable production of forage with satisfactory quality on foxtail meadows.

Conclusions

Harvesting foxtail meadows every year at early heading of *A. pratensis* leads to an increasing proportion of undesired plant species and a decreasing yield. Sustainable management of foxtail meadows can be achieved by allowing the formation of mature *A. pratensis* seeds. An early first utilisation at the shooting stage of *A. pratensis* followed by a second cut at seed maturity with ground drying of the forage can fulfil this requirement with a minimum loss in average forage quality.

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Plant genetic resources in mountain oases of northern Oman[1]

Gebauer, J.[2], Luedeling, E.[3], Hammer, K.[4] & Buerkert, A.[5]

Key words: crop diversity, genetic erosion, indigenous knowledge, multicropping systems

Abstract

In this study we assessed the genetic resources of three mountain oases in the al-Hajar range using a GIS-based field survey and farmer interviews. While arid conditions prevail throughout the mountain range, the different elevations of the oases in the Jabal al Akhdar mountains provide markedly differing agro-climatic conditions. Overall, 107 different crop species were identified belonging to 39 families. Species number was highest among fruits (33 spp.), followed by vegetables (24 spp.). Intensive irrigation allows cultivation of a broad range of species at all oases. However, the number of species varied significantly among sites. Fruit species diversity and homogeneity of the distribution of individual fruit species was highest at Balad Seet and lowest at Maqta, as indicated by respective Shannon indices of 1.00 and 0.39 and evenness values of 32% and 16%. Century plant, faba bean and lentil were identified as relict crops, supporting oral reports of past cultivation and providing evidence of genetic erosion. Overall greatest species similarity was found between Balad Seet and Al Jabal al Akhdar, as indicated by a Sørensen coefficient of similarity of 67%. Overall the study shows a location-specific but surprisingly diverse mosaic of crops in Omani mountain oases that merits further studies and conservation efforts.

Introduction

As in many other oil-producing countries in the Middle East, the economy and infrastructure of the Sultanate of Oman are developing at a rapid pace. Asphalt roads, housing and other amenities are being built to fulfil the needs of a fast-growing nation. In the mountain region of northern Oman, fascinating and sustainable agricultural systems have persisted for millennia in which agricultural and horticultural crops are intensively cultivated in traditional, mainly subsistence-oriented oasis systems (Nagieb et al. 2004, Buerkert et al. 2005). Fields consist of small man-made terrace systems, which are often squeezed between cliffs. Because of their green vegetation, pleasant microclimate, and availability of fresh water, the oases contrast strikingly with the dry

[1] This contribution is an extract of the recently published paper: Gebauer J., Luedeling E., Hammer K., Nagieb M. and Buerkert A. (2007): Mountain oases in northern Oman: an environment for evolution and *in situ* conservation of plant genetic resources. Genet. Resour. Crop Evol. 54: 465-481.

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[5] As [2]

and rough hyperarid landscape of northern Oman, and in recent years have gained increasing interests from scientists and tourists alike.

Materials and methods

Our survey was conducted in the Al-Hajar Mountains in northern Oman and comprised three spring-fed oases that have existed in this area for centuries to millennia and whose characteristics are listed in Table 1. Balad Seet and Al Jabal al Akhdar are located in the western Al-Hajar Mountains (Al Gharbi), while Maqta is situated in the eastern Al-Hajar Mountains (Ash Sharqi). Geo-referenced digital maps of the oases were produced from satellite images and low altitude aerial photography. The field work was conducted during August and September 2005 and March and April 2006. In the three oases each individual terrace was visited, resulting in a total of 1907 survey plots. In addition, three extensive palm groves at Balad Seet (8.88 ha) and 17 palm groves at Maqta (3.6 ha) were also studied in detail. Different farmers in each oasis were interviewed about the local names and primary uses of each species.

Tab. 1: Characteristics of the three study oases in northern Oman.

Characteristics	Balad Seet	Maqta	Al Jabal al Akhdar
Type of oasis	Core oasis	Scattered oasis	Core oasis
Altitude (m a.s.l.)	950 – 1020	930 – 1180	1750 – 1930
Mean annual rainfall (mm)	100	148[a]	336
Rainfall range (mm)	30 – 240	42 – 255[a]	128 – 901
Mean Temperature (°C)	23	[b]	19
Temperature range (°C)	3 – 43	[b]	-4[c] – 32
Terraced land (ha)	13.48	4.40	13.92
Number of springs	12	22	2
Available water (m^3 d^{-1})	601	115	856
Water m^3 ha^{-1} d^{-1}	44.8	25.6	65.6
Number of houses	120	73	147
Number of inhabitants	650	200	330
Number of households	80	73	45
Number of survey plots	385 agricultural fields and 3 palm groves	130 agricultural fields and 17 palm groves	375 agricultural fields and 1017 orchard terraces

[a]Based on records from Ibra (2003 – 2005), 48 km west of Maqta,

[b]no data available,

[c]according to World Conservation Union (1987)

Results

In total, 107 different plant species belonging to 84 genera and 39 families were identified. Amongst the 39 families, Leguminosae (11 spp.), Gramineae (10 spp.), Rosaceae (7 spp.), Rutaceae (7 spp.) and Solanaceae (6 spp.) have the highest numbers of species. 91% of species are of exotic origin, while the remaining ones are indigenous to northern Oman. Of the 107 taxa found in the oases, 46 species are woody perennials and 61 are herbaceous crops. With a total of 85 cultivated species, Balad Seet was the oasis richest in species. The analysis of the species distribution among the three oases revealed that 27 species were common to Balad Seet, Maqta and Al Jabal al Akhdar (Figure 1). In general, fruits were the use category with the highest number of species (Figure 2). Fruit species diversity and homogeneity of the distribution of individual fruit species was highest at Balad Seet and lowest at Maqta as indicated by respective Shannon indices of 1.00 and 0.39 and evenness values of 32% and 16%. Century plant (*Agave americana* L.), faba bean (*Vicia faba* L. var. *minor* Peterm. em. Harz), and lentil (*Lens culinaris* Medik.) were identified as relict crops. Overall greatest species similarity was found between Balad Seet and Al Jabal al Akhdar, as indicated by a Sørensen coefficient of similarity of 67%.

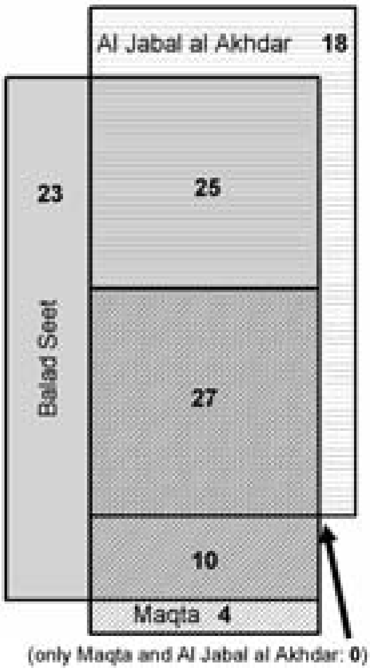

Figure 1: Species distribution among the three oases. The areas shown in the graph are proportional to the relative numbers of species.

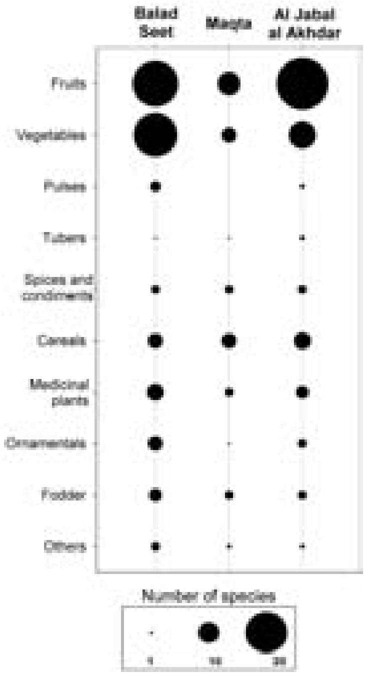

Figure 2: Abundance of plant species of different use categories in the three oases in northern Oman.

Discussion

With a total of 107 different plant species, the number of crops was very high in comparison to other small-scale cropping systems under arid or semi-arid conditions (Hammer and Perrino 1985, Ceccolini 2002, Gebauer 2005). Fruit species richness was highest at Al Jabal al Akhdar, comprising 25 species. However, the Shannon indices indicated that species diversity was slightly higher at Balad Seet compared with Al Jabal al Akhdar. This is reflected in the highly heterogeneous distribution of individual fruit species at Al Jabal al Akhdar compared with Balad Seet, which translates to evenness values of 30% (Al Jabal al Akhdar) and 32% (Balad Seet). The occurrence of some individual plants in the fields and field borders supports the local oral records that some decades ago landraces of these species were widely cultivated. The complete loss of a species is only a last step in a long way of disappearance that reduces agricultural and horticultural biodiversity. Relict crops can also be considered as indicators of past genetic erosion (Hammer et al. 1999). According to the different climatic situations of the study oases (Table 1), some species were exclusively found under cooler or hotter conditions. This was especially obvious in the fruit category and is reflected by the Sørensen coefficients of similarity that were calculated to compare the three oases. The similarity between hot Maqta and cool Al Jabal al Akhdar is only 39%.

Conclusions

Germplasm collection activities, *in situ* conservation programs and interdisciplinary analysis of socioeconomic aspects or rural communications are urgently needed to better understand and preserve the heritage of these ancient agro-ecosystems.

Acknowledgments

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A Model for Pre-Estimation of Production of Organic Cotton in Iran; Case study of Khorasan Province

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Keywords: organic product, organic cotton, farm size, economics, modeling.

Abstract

Organic farming and organic production methods have gained importance in agriculture from environmental point of view as well as economical and social stand points. The purpose of this study was to propose a model in order to estimate the cotton production in organic farms of Khorasan province, Iran. Production of organic cotton was obtained through surveys of 241 farms in 2007, partial elasticity of production of different inputs were derived from Cobb-Douglass production function. The results revealed that the cotton production decreased by 34.2 percent when the chemical factors were eliminated. The drop off yield of organic fields in large farms (more than 10 ha) is higher than small (less than 5 ha) and medium (5 to 10 ha) size farms due to over-use of chemicals and fertilizers. Also, the maximum yield in conventional system was derived from mild region (3.044 t/ha), while the minimum belonged to warm region (1.48 t/ha). If organic products are to develop, it is recommended that financial support (subsidy), extension education, and providing non-chemical inputs be provided to compensate the related production loss.

Introduction

The main concern of organic farmers and those who whish to shift to organic farming is that whether organic farming is profitable or not? Although some of organic farmers are motivated by economic objectives, most are inspired by more than economic intentions. Their main goal is to optimize land, animal, and plant interactions, preserve natural nutrient and energy flows, and enhance biodiversity, all of which contribute to sustainable agriculture (Eyhorn et al., 2007). There appears to be mixed results in studies related to change in yield through shifting from conventional agriculture to organic farming. Furthermore, while investments, research and development efforts are more focused on conventional agriculture rather than organic farming comparing these two systems from stand point of yield is not so sensible (Koocheki, 2004).

Khorasan province is one of the leading producers of cotton in Iran. With increasing importance of organic production systems due to high cost, it is not possible to examine different aspects of organic farming in greenhouse context. Therefore, an attempt was made to develop a model to estimate yield reduction in real farm situation due to shift from conventional agriculture to organic farming practices. As the estimation of parameters of this model is experimented under real farm situation, the results are more accurate than greenhouse experiments. Finally, we will compare organic and conventional cotton in three climate regions across three farm size.

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Material and Methods

In this study, a model is proposed to estimate the organic cotton productions. In fact the research emphasise is more on methodology than results. In order to estimate the organic production of cotton, there is a need to purge the chemical fertilizers, herbicides and pesticides effects from production function. For this propose, Cobb-Douglas production function (1) is estimated

$$Y_{cp} = A\sum_{i=1}^{8} X_i^{\alpha_i} e^u \qquad \textbf{(1)}$$

Where Y_{cp}, X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, A, u, α_i are cotton production, labor (person-day), acreage (hectare), seed (Kg), Water (number of irrigation rotation), chemical fertilizers (Kg), Pesticides (Liter), manure (ton), machinery (hour), coefficient of technology, random error term and parameters, respectively.

The factor elasticities (α_i) derived from estimation of production function. Value of factor elasticity revealed the amount of influence that specific factor has on production. Therefore, with purging the portion related to chemical factors from present production function (purifying the production), we can obtain cotton organic production of cotton.

$$Y_{op} = Y_{cp} - (E_{fe} \times Y_{cp} - E_{pe} \times Y_{cp}) = Y_{cp}\left[1 - \left(E_{fe} + E_{pe}\right)\right]$$

Where E_{fe}, E_{pe}, Y_{op} and Y_{cp} are the chemical fertilizers elasticity, pesticides elasticity, organic production and conventional production, respectively. In this way, the organic production can be calculated by using the developed model. Also, the percentage of production reduction (in organic situation) is computable via following formula:

$$\text{Production Reduction Percentage} = \frac{Y_{cp} - Y_{op}}{Y_{cp}} \times 100 \qquad (3)$$

Data were collected via a stratified random sampling. The cross-sectional data were gathered from 241 cotton producers of Khorasan (North, South and Razavi) provinces.

Results and Discussion

Equation 4 shows the results of Khorasan cotton production function. The variables X_1 (labor), X_5 (chemical fertilizers), X_6 (chemical pesticides and herbicides) and X_7 (manure) are statistically significant. The coefficient of determination (R^2) reveals that 35.6 percentage of variation in cotton production can be explained by labor, chemicals and manure factors. The factor elasticity for labor, acreage, seed, water, chemical fertilizers, pesticides, machinery and manure are 0.0718, 0.079, 0.079, 0.125, 0.152, 0.235, 0.107, 0.052 and 0.038, respectively. The estimated elasticities show that chemical fertilizer has maximum and the manure has minimum elasticity. Also, the farmers use labor, chemical fertilizers, pesticides and manure factors in second stage of production function.

$$Y_{cp} = -1.712(5.71^{*}) + 0.0718X_1(3.51^{*}) + 0.079X_2(1.4^{ns}) + 0.079X_3(1.24^{ns}) + .0152X_4(1.56^{ns}) + 0.235X_5(4.88^{*}) + 0.107X_6(2.73^{*}) + 0.052X_7(1.86^{***}) + 0.038X_8(1.27^{ns}) \quad R^2 = 0.356 \quad \bar{R}^2 = 0.333 \quad F = 16.001^{*} \tag{4}$$

$(^{*}\,significant\ in\ \%1\ level\ ^{***}\,significant\ in\ \%10\ level)$

After computation of equation (2) and (3), results show that the yield of organic and conventional cotton is 1.578 and 2.412 tons per hectare, respectively. Comparing these two figures indicate a 34.2 percent decline in production of organic cotton. This result is comparable with findings of many researchers reporting yield decease in organic products in transition period of about 16.7 to 50 percent period (Gunnarsson and Hansson, 2003; Sartori et al., 2005).

Tab. 1: The organic and conventional cotton yield in acreage levels

System	Acreage (ha)	Mean yield (t/ha)
Organic	Less than 5 5 to 10 More than 10	1.588 1.550 1.637
Conventional	Less than 5 5 to 10 More than 10	2.410 2.358 2.490
Decrease percentage	Less than 5 5 to 10 More than 10	34.20 34.17 34.27

The results in table (1) revealed that the maximum conventional cotton yield with 1.64 ton is for large scale (more than 10 ha). Also, the percentage reduction for the organic cotton yield in small (less than 5 ha), medium (5-10 ha) and large (more than 10 ha) scale is 34.20, 34.17 and 34.27, respectively. The maximum value is in large scale due to over-use of chemicals and fertilizers.

According to table (2), the maximum yield in conventional system is for mild region (3.044 t/ha), while the minimum is warm region (1.48 t/ha).

Tab. 2: The organic and conventional cotton yield in climatic regions

Climatic region	System	Mean yield (t/ha)
Cold	Organic Conventional Decrease percentage	1.73 2.63 34.18
Mild	Organic Conventional Decrease percentage	2.00 3.04 34.23
Warm	Organic Conventional Decrease percentage	1.48 2.25 34.22

In the next stage, the manure elasticity is increased as a scenario to determine how a unit of increase in cotton production causes an increase in manure share in production. Interestingly, table (4) revealed the simulation results due to increasing the manure share in cotton production to substitute with chemical fertilizers. On this basis, the manure significant affects on cotton production, but the average production won't be considerable by increasing in manure elasticity. As a result, the organic and conventional productions are the same whereas the manure elasticity increases by 0.53.

Tab. 4: Simulation an increase share of manure in cotton production

Elasticity	Production (t/ha)
0.052 (base)	1.587
0.07	1.616
0.09	1.648
0.11	1.680
0.13	1.713
0.15	1.747
0.17	1.781
0.19	1.816
0.53	2.420

Conclusion

As results indicates, supporting the farmers in primary stage for organic agriculture (transition phase); through credit facilities and extension services, and etc. will encourage farmers to shift to organic products and decrease imports. Therefore, we suggest planning for financial support. For example, subsidy payment for organic cotton in transition period is recommended. Moreover, training through extension education and providing non-chemical factors to compensate the related production loss is further suggested.

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Effects of reduced tillage on soil organic carbon and microbial activity in a clayey soil

Berner, A.[1], Fließbach, A.[1], Nietlispach, B.[1] & Mäder, P.[1]

Key words: soil fertility; cultivation; soil organic matter; crop farming; reduced tillage

Abstract

In a long-term field trial recently launched (2002-2011), located in Frick (878 mm mean annual precipitation) near Basle, Switzerland, the effect of reduced tillage on soil fertility indicators and crop yield was studied in a heavy soil (45% clay) in a crop rotation under organic farming conditions. We present the results of soil analyses after three cropping years (2002-2005). Soil organic carbon (C_{org}) increased over that period by 7.4% (+1.5 g C_{org} kg^{-1} soil) in the 0-10 cm soil layer in the reduced tillage plots, while it remained constant in the ploughed plots. Soil microbial carbon (C_{mic}) and dehydrogenase activity (DHA, TTC-reduction) were 28% higher in reduced-tillage plots in this soil layer. Biological soil quality as calculated by C_{mic} to C_{org} was 15% enhanced under reduced tillage. In the 10-20 cm soil layer no significant C_{org}, C_{mic}, C_{mic} to C_{org} and DHA differences between the tillage schemes were found. It is suggested that reduced tillage improves important indicators of soil fertility during the conversion period. Long-term aspects of soil fertility, crop yield and weed infestation need investigation over a prolonged experimental period.

Introduction

Reduced tillage diminishes soil erosion and enhances soil fertility. In organic farming, problems remain to be solved with respect to weed competition, slug control and plant nutrition (Peigné et al., 2007). Long-term experiments have revealed that soil turning with a plough is necessary after several years in order to gain satisfactory yields (Hampl, 2005; Kainz et al., 2005; Pekrun et al., 2003). By turning the soil layers, however, the benefits of reduced tillage may vanish within a year (Stockfisch et al., 1999). The experiment on a clayey soil presented here seeks to broaden the available experience with reduced tillage under organic conditions. Tillage, fertilization and the use of biodynamic preparations were combined, mimicking different agricultural organic farming systems.

Materials and methods

In autumn 2002, we established in Frick, Switzerland, a field experiment comprising the following factors, each at two levels:

Soil tillage Ploughing system (mouldboard plough, 15 cm deep, followed by rotary harrow, 5 cm deep) *versus* reduced tillage system (chisel plough[2], 15 cm deep, followed by rotary harrow[3], 5 cm deep).

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[2] WeCo-Dyn-System of the EcoDyn company, Schwanau, Germany

[3] Rotary harrow of the Rau company, Weilheim, Germany.

Fertilization Slurry alone *versus* manure compost and slurry (both systems at a level of 1.4 livestock units).

Biodynamic preparations With *versus* without biodynamic compost and field preparations[1] (the latter applied three times a year).

The three factors – tillage, fertilization, preparations – were fully factorized. This resulted in eight treatments, each replicated four times. The 32 plots were arranged in a split-plot design. Plot size was 12 x 12 m, allowing the use of common-size farming equipment.

Soil cores were taken at the beginning in autumn 2002, and again in spring 2005 (n = 32). The clay soil at the experimental site initially contained mean levels of 2.2% organic carbon (C_{org}) and 45% clay, and had a pH of 7.1 (H_2O). C_{org} was analysed by wet oxidation, microbial biomass (C_{mic}, N_{mic}) by chloroform fumigation extraction and dehydrogenase activity by TTC reduction. The mean annual precipitation in the experimental period was 878 mm.

Before the experiment started, the field site was uniformly planted with silage maize in 2002. The crop rotation in the first three years (2002-2005), being the period to which the results presented here refer, was winter wheat, oat-clover intercropping, sunflower and spelt. Two years of grass-clover were planted in 2006-2007. Wheat grains and straw were harvested and removed from the field.

Data were analysed by three-way analysis of variance (ANOVA). In this paper, first results of the soil analyses from 2005 are presented.

Results

Within three years, C_{org} levels in the 0-10 cm soil layer rose in reduced-tillage soils by 7.4% (+1.5 g C_{org} kg^{-1} soil) as compared to the ploughed soils (Fig. 1a). Microbial biomass (C_{mic}, N_{mic}) and DHA were 26-28% higher in reduced tillage at the same soil depth (Fig. 1b). The C_{mic} to C_{org} ratio was increased by 15% under reduced tillage. For these parameters, we found no significant interactions between the factors of tillage, fertilization and biodynamic preparations. In the 10-20 cm soil layer no significant differences in soil properties were found.

The yields of the cereals wheat and spelt were 14% and 8% lower in reduced-tillage plots compared to ploughed plots. Sunflower yield was slightly higher in reduced-tillage plots. Application of slurry only delivered a 5% higher grain yield with wheat. The biodynamic preparations had no effects on yield.

Discussion

The increase of C_{org} under reduced tillage in our experiment can be explained by large amounts of carbon contained in the roots of the crops, and especially in the biomass of the sunflower residues which were incorporated into the soil. This matches the findings of Alvarez (2005), Ogle et al. (2005) and Teasdale et al. (2007). In other experiments, a reduction of C_{org} in deeper soil layers compensated the enhancement of C_{org} in the upper soil layers (Wright et al., 2005). Angers et al. (1993) reported that a sufficient amount of plant biomass incorporation is a prerequisite for enhanced C_{org}, including under reduced tillage as in the experiment described. The high plant

[1] see http://www.sciencemag.org/cgi/content/full/296/5573/1694/DC1

biomass input in our experiment resulted in increased microbial biomass in the 0-10 cm top soil layer. Weber and Emmerling (2005) studied soil microbial activity in a ten-year tillage experiment, finding soil microbial activity to be enhanced by 30% following layer cultivation with a chisel plough and by 21% following two-layer ploughing in the 0-15 cm surface layer.

Yield reduction in reduced tillage plots in our experiment was substantially lower than that found in various comparable studies, e.g. the results reported by Kainz et al. (2005) where crop yields dropped by up to 35%.

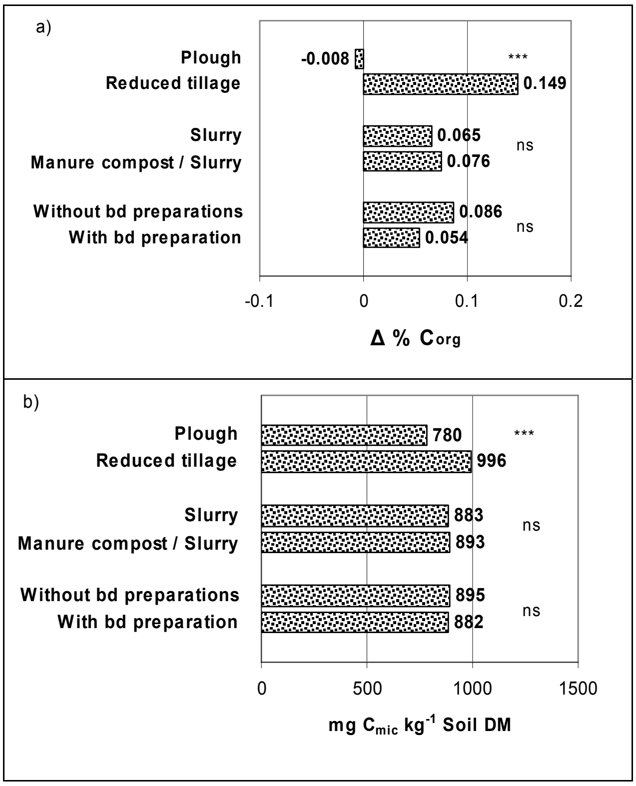

Figure 1: (a) Development in C_{org} between 2002-2005. Zero line means no change of C_{org} in the three experimental years. Note that 0.1 % C_{org} change corresponds to 1 mg C_{org} kg^{-1} soil. (b) Microbial biomass (C_{mic}) 2005 at 0-10 cm soil depth. A three-way ANOVA was calculated for C_{org} and C_{mic} for the three factors tillage, fertilization and biodynamic preparations at two levels each (n = 16).

Conclusions

Based on the results obtained, we can conclude that reduced tillage is viable under organic farming conditions in the conversion phase, even on a clay soil.

Furthermore, the results suggest that reduced tillage is feasible both with manure compost and slurry fertilization. Since there were no interactions between the three factors of tillage, fertilization and biodynamic preparations, neither for yields nor for soil fertility indicators, we are unable to suggest any combinations of these farming practices for optimal conversion to reduced tillage under organic farming conditions. The long-term effects of the reduced tillage system need to be assessed to elucidate their impact on soil fertility indicators and yield performance from the point of view of carbon sequestration and weed competition.

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A new approach to soil tillage for organic vegetable production: permanent beds

Védie, H.[1], Berry, D.[2], Leclerc, B.[3], Grébert, D.[4] & Lhôte, J.M.[5]

Key words : organic vegetable production, soil tillage, permanent beds, soil fertility

Abstract

The effect of controlled traffic with permanent crop beds was compared to mouldboard ploughing in France for organic vegetable production. Four trials were carried out over a period of three to seven years at four sites with different pedo-climatic conditions. Variable results were obtained, depending on soil type (susceptibility to compaction), tillage machinery type, vegetable type (root or not, grown from seed or transplant) and weed development. However, permanent crop beds with controlled traffic generally improved biological activity and reduced labour demand.

Introduction

In vegetable production, rapid succession of several crops during the year leads to intensive vehicle traffic, sometimes on wet soils, and therefore to soil compaction. Reduced tillage technique developed for vegetable crops by Wenz and Mussler in Germany (Deveyer et al., 2001) offers a new type of tillage management with permanent beds: no mouldboard ploughing, permanent wheel tracks and preferential use of tine machines. A national network was created in France in 2005 to study new approaches of tillage in organic farming, associating several trials on arable farms (results reported in these proceedings by Peigné et al.) and four trials in vegetable production. We studied the feasibility of permanent crop beds under various soil, climate and crop rotation conditions. The aim was to answer the following questions: is it possible to avoid ploughing in vegetable crops ? What are the requirements for the successful adoption of a permanent bed system? What are the consequences on soil fertility, crop development and weed control?

Materials and methods

Four trial plots are included in this study with two soil tillage treatments on a randomised block design with 2 or 3 replicates : controlled traffic tillage with Permanent Beds ("PB") compared with Conventional tillage ("C"). Sites conditions are shown in table 1. Permanent Beds (PB) : wheel tracks were the same from the beginning of the trials, regardless of the cultural practice. The crop bed (1.2 m to 1.5 m wide depending on the site) was free from any compaction due to vehicle traffic. Tine machines were preferentially used for this treatment with "Actisol" and some specific equipment developed at each site (Berry D., Taulet A., 2006). Conventional tillage (C):

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wheel tracks were not controlled. Mouldboard ploughing was the reference at three sites, with use of rotary equipment. Same fertilisation as in PB.

Measurements and observations were the same for the four experimental sites: evolution of the physical (cultivated soil profile (Roger-Estrade J. et al., 2004)), chemical (organic matter, nitrogen, phosphorus, potassium, magnesium), and biological fertility (microbial biomass (Chaussod et al., 1988) and activity, earthworm activity); crop performance (yield and quality); weed pressure and labour times.

Tab. 1: main characteristics for the four experimental sites

Site	A Rhône-Alpes	B Nord	C Charentes	D Provence
Beginning	2001	2003	2005	2005
Soil texture (% clay/silt/sand)	26 / 47 / 27	27 / 49 / 24	28 / 42 / 30	22 / 62 / 16
Rainfall (mm/nb days)	1000 mm / 86 days	680 mm / 120 days	716 mm / 77 days	660 mm / 45 days
Crop rotation	2001 : leek + GM* 2002 : lettuce 2003 : carrot + GM 2004 : cabbage 2005 : GM + spinach 2006 : leek	2003 : turnip 2004 : carrot 2005 : pea + GM 2006 : onion 2007 : turnip	2005 : carrot 2006 : leek 2007 : potato	2005 : squash 2006 : melon + GM 2007 : onion & Japanese radish

** GM : Green Manure*

Results

Physical, chemical and biological fertility:

- The reduced tillage with permanent bed system tended to increase soil compaction, especially in the 10-30 cm layer. The proportion of non-compacted clods (with internal structural state □) was higher for PB in the surface layer (0-10cm) and lower underneath. This observation was very clear for the most recent sites (C and D), but not for the oldest one (site A), where PB had been used for seven years. Compaction under the PB can also affect the culture bed on the sides (lateral compaction); this effect seemed to decrease with time (sites A and B).

- Cultivation using permanent beds had little impact on organic matter, except for a slight increase of the labile organic carbon (diameter > 50 µm). On the contrary, it enhanced the microbial activity, which can be measured through potential mineralisations of carbon (C) and nitrogen (N) (Table 2). For site D, the different measurements were not in favour of PB compared to conventional tillage because of the soil compaction problems.

- After three to six years of cultivation using PB, macrofauna activity did not significantly increase (data not shown). Nevertheless, structure from biological activity is higher in less compacted cultivated soil profiles.

Crop performance: The permanent bed tillage system did not affect the yield of the main vegetable crops measured on crop bed, but the quality of root vegetables decreased. Carrot and Japanese radish roots harvested at three of the four trials were deformed, because of the more compacted soil. Weed control was a real problem for one site only (site B), where perennial weed (*Sonchus spp.*) development affected some crops yield such as peas.

Labour time: The implements used on the permanent beds that are not driven by the tractor's power take-off allow faster cultivation speeds and thus reduce the labour time for soil preparation. In the seven-year study at trial site A, the average cultivation time using a tractor was reduced by 30% (Table 3).

Tab. 2: Evolution of organic matter, microbial biomass and potential mineralisation (C: conventional tillage – PB: Permanent Beds)

Site	A (0-25 cm)		B (0-25 cm)		C (0-12 cm)		D (0-25 cm)	
Treatment	C	PB	C	PB	C	PB	C	PB
Total org.C (g/kg)	13.6	15.3	15	14.8	17.1	18.6	15.1	14.3
Labile org. C [1] (%total C)	18.1	20.2	21	23	24.4	31.1	24	22
Microbial Biomass (mgC/kg)	462 **(b)**	506 **(a)**	442 **(b)**	554 **(a)**	352	410	285	209
C Mineralisation (mg/kg/28days)	240 **(b)**	297 **(a)**	288	369	403	381	398	360
N Mineralisation (mg/kg/28days)	21.1	22.2	20.2 **(b)**	29 **(a)**	22.1	20.7	42.4 **(a)**	32.2 **(b)**

[1] labile organic carbon : diameter > 50 µm - a,b: significant for P<0,05

Tab. 3: Compared labour time at site A (minute/70-m long crop bed)

	Conventional tillage (plough)	Permanent beds	Time reduction (%)
Leek 2001	47 min	21 min	55 %
Lettuce 2002	42 min	32 min	24 %
Carrot 2003	68 min	48 min	30 %
Cabbage 2004	78 min	59 min	31 %
Spinach 2005	40 min	34 min	18 %
Leek 2006	64 min	49 min	23 %
Average decrease of labour time			- 30 %

Discussion

The different consequences of soil tillage with permanent beds, depending on the pedo-climatic and crop conditions, are summed up in Figure 1:

- Cultivation time with permanent beds has a strong impact on the results: mixed or poor results are obtained at the three-year-old sites, whereas all parameters (biological and physical soil properties, crop results, time savings) positively evolve at the seven-year-old site. As with any emerging technology, many years are needed before obtaining satisfactory results: adapting the cultivation techniques and using adapted custom-built tillage equipment (there is very little reduced tillage equipment available for vegetables). Soil texture is an essential factor: in soils with poor structural stability, such as the silty soil on site D with 66 % silt, "deep" soil tillage down to 25 cm is essential for permanent beds to compensate for self-compressing.

- Weed pressure (perennial weeds), can seriously hinder the elimination of ploughing.

- Finally, for sown vegetables, a particular attention must be paid to the careful preparation of the seedbed, which is difficult without rotary equipments.

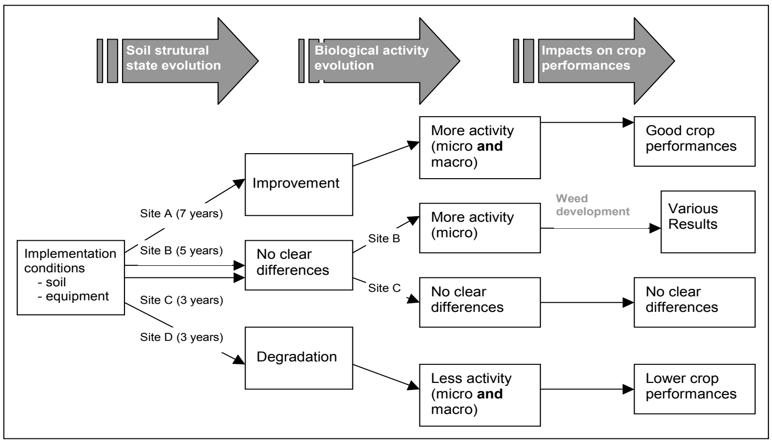

Figure 1: Permanent bed impact on soil fertility and crop performances in terms of implementation conditions and time, in comparison to conventional tillage

Conclusions

The results show that it is possible to eliminate ploughing for the cultivation of organic vegetable crops. There are very few references with conservation tillage with vegetable crops, and almost none with a permanent bed system. Our study shows that it is an interesting alternative that improves soil biological activity and decreases labour time using tractor, leading to significant energy savings. However, this method has limitations depending on pedo-climatic conditions and the lack of suitable equipment, which lead to various results.

Further researches are required to specify the soil tillage techniques according to pedological conditions (silty soils, for instance), to improve weed control and to ensure the incorporation of fresh organic matter (crop residues and green manure).

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Green manures and pulses

Grain yield of different winter pea genotypes in pure and mixed stands

Urbatzka, P.[1], Graß, R.[1], Schüler, C.[1], Schliephake, U.[2], Trautz, D.[2] & Heß, J.[1]

Key words: cropping, winter pea, mixed stands

Abstract

In organic farming, harvest of spring peas is a problem because of the often high density of weeds, but also the low yield stability. In the present experiments, seven different genotypes of winter peas (six regular types and one semi-leafless type) and one spring pea (semi-leafless) were examined between 2004 and 2007 in pure and mixed stands (with cereals) in terms of their suitability as a harvest crop at two different sites per season in Germany (experimental fields of the University of Kassel Frankenhausen (2004-2007), Hebenshausen (2004) and the experimental farm of the University of Applied Sciences Osnabrueck, Waldhof (2005-2007).

Grain yields of the regular leaf type in mixed stands during the first three years varied because of varying N supply (preceding crops and weather conditions). When availability of N was relatively low, pea grain yield ranged between 2.5 and 4.0 t ha^{-1} in Frankenhausen and 1.5 and 2.5 t ha^{-1} in Waldhof, and were at levels comparable to spring pea yield, which varied from 2.0-3.4 to 1.5 t ha^{-1}, respectively. In addition, mixtures contribute rye yield. At a relatively high N supply, pea yields were relatively low, but rye yields relatively high. Crude protein concentration and concentration of some amino acids (lysine, tryptophan and arginine) partially were significantly ($p<0.05$) higher in the regular leaf types than in the semi-leafless types.

Introduction

Winter pea is an old crop that has hardly been cultivated in recent decades because of the increasing imports of soybean and higher inputs of mineral fertilizers. The cultivation of regular leaf types, however, is advantageous compared to spring peas because of their efficient suppression of weeds (Graß 2003), higher yield stability (Stelling 1996), and higher yield potential (Charles 2001).The objective of the study was to investigate different genotypes of winter peas for winter hardiness and the value of cultivating them in organic farming.

Materials and methods

Field experiments were conducted in 2003/2004 on both experimental sites of thee University of Kassel, Domäne Frankenhausen (DFH; loam on loess) and Hebenshausen (HEB; loam), and during 2004/2005 and 2006/2007 on DFH and the experimental farm of the University of Applied Sciences Osnabrueck, Waldhof (WH;

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loamy sand), respectively. Four colourful flower, regular leaf type winter pea genotypes from the gene bank Gatersleben (convariety speciosum; cv. Griechische, Nischkes Riesengebirgs, Unrra and Wuerttembergische) were compared with a white flower, semi-leafless and two colourful flower, regular leaf type EU cultivars (convariety sativum and speciosum; cv. Spirit in 2004, Cheyenne in 2005-2007, and Assas and EFB 33), as well as a white flower, semi-leafless spring pea (cv. Santana). Peas were cultivated in pure stands and two substitutive mixtures with cereals (rye, cv. Danko; spring oats, cv. Aragon (2004)) and spring barley cv. Ria (2005-2007), respectively. The substitutive mixtures consisted of 25 % (M1) and 50 % (M2) of pea pure stands (80 germinable seeds m^{-2}). The experimental design was a Latin square (DFH 2004), a randomized complete block design (HEB 2004), and a split plot design in 2005-2007 (n=4). The size of plots for sampling at harvest was 20 m^2 (DFH, HEB) and 9 m^2 (WH).

Determination of nutritive quality was done by NIRS analysis (total N by Kjeldahl). Also, amino acids in pea grains of treatment M2 were determined via NIRS and by wet chemistry according to the EU and AOAC 994.12-method (Anonymous 1998, Llames and Fontaine 1994; tryptophan: Anonymous 2000, Fontaine 1998).

Results and Discussion

While the four genotypes and the EU cultivar EFB 33 consistently did not suffer from considerable losses from frost, both French cultivars Cheyenne and Assas faced severe losses as a result of weather conditions during winters 2005-2006 and 2006-2007 (data not shown) at some experimental sites, e.g. at DFH, even with complete losses in winter 2002-2003 (Urbatzka et al. 2005). As a consequence these two cultivars do not show sufficient winter hardiness for cultivation at sites with comparable climatic conditions.

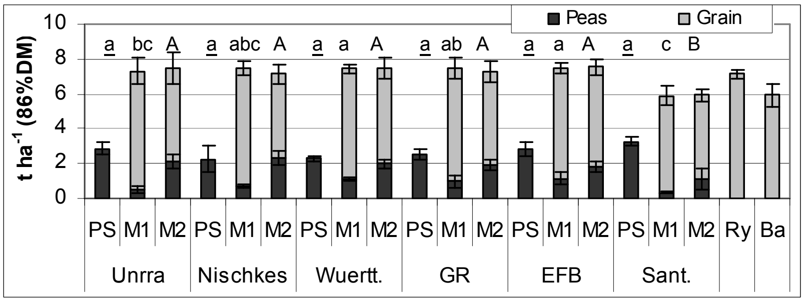

Figure 1: Pea and cereal grain yields at DFH (2006) (RY=Rye; Ba=barley; error bars = standard deviation; different letters denote significant differences between cultivars in terms of pea grain yield (T - test): small underlined letters for pure stands at p<0.05; small letters for M1 at p<0.05; large letters for M2 at p<0.001; significant interactions for cultivar by mixture)

Grain yield of regular leaf type winter peas in mixtures varied considerably depending on the preceding crop and weather conditions in autumn and the consequent N availability (DFH and HEB): at a relatively high N supply winter rye gave 4 to 7 t ha^{-1} and therefore had the highest impact on total crop yield of mixtures, whereas pea yield ranged from 0.5 to 2.0 t ha^{-1} (HEB 2004, DFH 2006, Figure 1)).

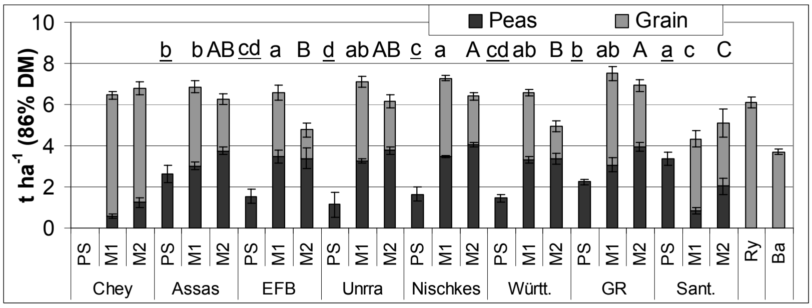

Figure 2: Pea and cereal grain yield at DFH (2005) (ry=rye; ba=barley; error bars = standard deviation; different letters denote significant differences between cultivars in pea grain yield (t-test without Cheyenne because of loss from mice): small underlined letters for pure stands at p<0.05; small letters for M1 at p<0.05; capital letters for M2 at p<0.001; significant interactions for cultivar by mixture)

At a lower N supply the same winter pea genotypes yielded between 2.5 and 4.0 t ha^{-1} (DFH 2004 and 2005) (Figure 2). As a result of a prolonged period with high precipitation and losses from birds, yield at WH from all treatments could be assessed only in 2006. The regular leaf type winter peas yielded between 1.0 and 2.0 t ha^{-1}, while grain yield of rye varied between 1.5 and 2.5 t ha^{-1}. The examined winter pea genotypes in pure stands are not suitable because of their tendency to laying down (data not shown), although only in some cases did yields differ significantly from spring peas in pure stands (Figures 1 and 2). Spring peas in pure stands yielded between 2.0 and 3.4 t ha^{-1} (DFH and HEB), depending on the degree of weed infestation, whilst at WH around 1.5 t ha^{-1} was harvested in both years. In mixtures, yields of this genotype corresponded with the expected values.

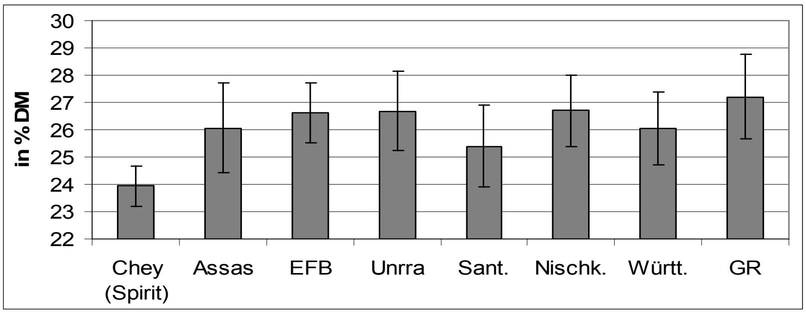

Figure 3: Crude protein concentration of pea grain, mean of three years, two sites and three stand densities (pure, M1 and M2) (error bar = standard deviation)

The yield of regular leaf type winter pea in mixture was comparable with that of spring pea in pure stands in the majority of experiments, with a supplement of the additional rye yield. Moreover, weed infestation in winter pea mixed stands was consistently at a very low level, while in pure spring peas, weed control was obligatory (data not shown). Cultivation of winter pea/rye mixtures should follow cereals in order to avoid excessive growth of rye that could otherwise suppress the growth of peas.

Crude protein content of regular leaf-type winter peas tended to be slightly higher than for spring pea Santana, and was consistently higher than with the semi-leafless winter peas Cheyenne and Spirit (Figure 3). Amino acids concentration of regular leaf type is comparable with semi-leafless winter peas, but the concentrations of lysine, tryptophan and arginine were partly significantly ($p<0.05$) higher than with the semi-leafless types (data not shown). This may be of particular importance in pig and poultry nutrition, since the two amino acids lysine and tryptophan are limiting.

Data from the year 2007 will be presented at the conference.

Conclusions

In terms of grain harvest, the four provenances and the EU cultivar EFB 33 in mixture can be regarded as an alternative to spring peas, as they may be expected to reach comparable yields of the same quality. Besides, problems such as severe weed infestation observed in cultivation of spring peas do not appear to be a problem in winter pea cropping.

Acknowledgments

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Annual clovers and medics in living mulch systems: Competition and effect on N supply and soil fertility

Baresel, J. P.[1] & Reents, H.-J.[1]

Key words: genetic resources, legumes, crop farming, plant nutrition, living mulch

Abstract

The potential of a large number of species of self-reseeding annual clovers and medics as continuous ground cover in living mulch systems with cereals in southern Germany and their effect on N supply and soil properties were assessed. Adapted legume species could be identified. The competition of the legumes on rye was limited but not on wheat. Positive effects on N supply and on indicators of soil fertility could be evidenced

Introduction

Living mulch systems are characterised by a continuous ground cover, in the most cases legumes, and by minimum tillage (see Hiltbrunner, 2005). They are of interest mainly for Organic Farming (OF). The potential advantages of such systems are an improved N supply (and thus, in the case of wheat, a better baking quality), less problems of erosion, an improvement of the biological soil characteristics and a reduced input of energy.

In Germany, almost exclusively white clover has been used as ground cover in LM systems. Scientific studies and practical experience from the past years show, that the competition of this relatively aggressive species with its undetermined growth cycle is too strong (Neumann, 2005). The aim of the present study was to asses the potential of annual self-reseeding species, which, due to their determined growth cycle, are potentially better adapted.

The following aspects are highlighted in the present contribution: (1) May annual self-reseeding species be found, which are potentially suitable as living mulches, adapted to German climatic conditions and which are able to re-establish from seed over consecutive years? (2) Are the competitive relationships really more favourable in annual than in perennial legume species? (4) Which contribution to N supply and soil fertility may be expected?

Materials and methods

In 2002 and 2003, a screening of 500 genotypes and 50 species (mainly *Medicago* and *Trifolium* species) was performed by spaced plant evaluation and replicated plot experiments, assessing mainly adaptation to German climate and growth characteristics (survival, persistence, biomass, canopy height, see Baresel et al. 2004). For subsequent studies *Trifolium subterraneum* (TS), *T. campestre* (TC), *Medicago orbicularis* (MO) and *M. minima (MM)* were selected, which turned out to be adapted to southern German climatic and, due to their growth characteristics, were supposed to be suitable for LM systems. With these species, from 2004 to 2006, 11

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field experiments were performed; due to hailstorms and a particularly cold winter in 2005/2006, a part of them could not be fully evaluated. To enable the assessment of the effect of the legumes on N supply, in some of the experiments an N-poor position within the rotation was chosen, which explains the low yield levels in those experiments. All experiments were performed in organically managed farms in southern Bavaria (Germany) on sandy loam soils.

In the first year of each experiments, the legumes were sown together with the main crop, i.e. Winter wheat (cv. „Tiger“) of winter rye (cv. „Walet“) in the second half of August. Early planting is necessary to permit a good development of the legume swards before winter. As controls, plots with perennial legumes (*T. repens* and *M. lupulina*) and *M. truncatula* as well as cereals alone were planted. *M. truncatula* grows quickly in autumn, but is not winter hardy; the use of such frost-killed LM may be a way to reduce competition. In October of the subsequent year, winter cereals (rye and wheat) were planted into the swards of legumes, which meanwhile were re-established from seed (see over-view in Table 1). To prepare a seedbed and to reduce competition by the legumes, a partial tillage was performed combining a strip rototiller with a seed drill. Double rows of cereals were sown into the strips; the distances were 48 cm between and 8 cm within the double rows. In the control plots without legumes, a conventional soil tillage was performed and the cereals were drilled commonly with a density of 400 grains/m² and a row distance of 12,5 cm (Experiments 1-6).

Nitrogen uptake of the above-ground-biomass of legumes, cereals and weeds, soil mineral N as well as, in a part of the experiments, the particulate organic matter (POM) were assessed to valuate the effect of the living mulches on N supply.

Results and Discussion

Within the frame of this contribution, only selected results, highlighting aspects of competition and effects on N supply and soil fertility, can be reported.

In normal winters (2002-2005), the legumes were only little damaged by frost, permitting a good recovery of the legume swards in spring. Only in 2005/2006, after a long period of severe frost and snow (with the formation of a layer of ice), more plants were damaged by frost than in other years. All species tested in the LM experiments (with exception of *M. truncatula*) were able to persist over several years by self-reseeding. In contrast to perennial species, the growth of all annual legumes finished after seed

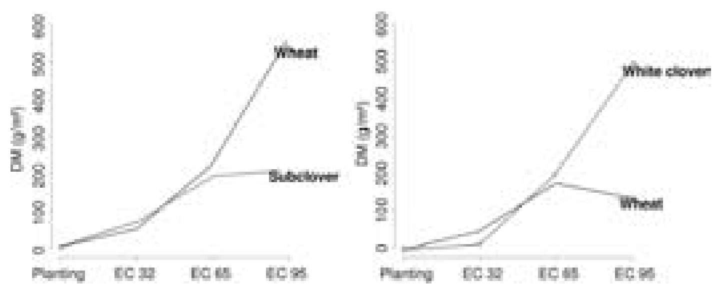

Figure 1: Development of biomasses in living mulch systems with Wheat and subclover, resp. White clover in the year of first establishment (in 2004)

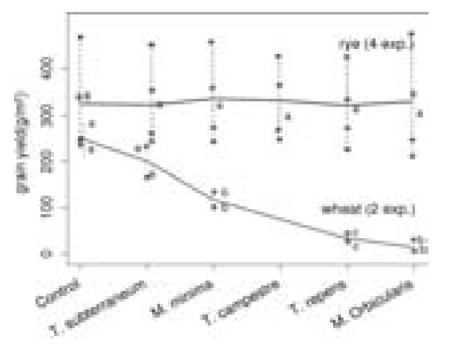

Figure 2: Yield of Rye and Wheat in various living mulches in the year of first establishment. (t-test / Bonferroni; p<0,05).

ripening. Thus, the competitive relationships were more in favour of the cereals, compared to white clover (Fig. 1). This was particularly the case, when the cereals were sown into existing swards, but also in the year of establishment. In the experiments established in 2004, with rye as main crop, white clover was suppressed already from the early development stages; this might be also due to the dry conditions during early development of the white clover.

No reduction of yield of rye due to competition by ground cover legumes could be observed (Fig. 2). For *M. truncatula* (which were killed by frost, leaving moderate amounts of additional organic matter in the soil), a slight yield increase could be observed. For wheat (due to the cold winter in 2005/2006) only the data of one experiment are available: according to the legume species, yield reduction ranged from 20% in *T. subterraneum* to 100 % in *M. orbicularis*, whose development was, due to a moist and relatively cool summer, particularly strong (Fig. 2). In the experiments established in 2005, where the legumes were killed by the frost, no yield reduction by subterranean clover could be observed.

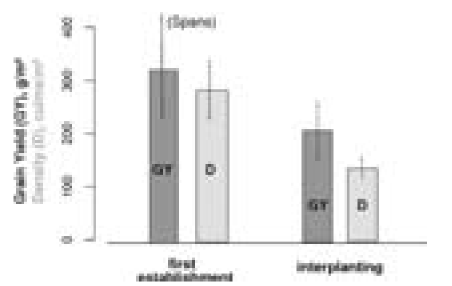

Figure 3: Comparison of cereal yields and plant densities in the year of establishment and interplanting in existing legume swards

Considerably lower yields were achieved sowing cereals in already established swards of subterranean clover (Fig. 3). This was caused by the seeding technique, which requires large distances between the double rows and leads to low plant densities. Cereal and legume biomass are negatively correlated depending on the legume and cereal species as well as on the N supply. Thus, the effect on the N supply varies widely (Fig. 4). N input and output were in an equilibrium at a yield level (for rye) of 5 t/ha. Beneficial effects on indicators of soil fertility such as soil POM content, Aggregate stability and the occurrence of AM spores (Fig. 5) could be revealed.

Conclusions

(1) Annual self-reseeding species could be identified, which were suit-able as living mulches, adapted to German climatic conditions and which are able to re-establish

from seed over more consecutive years. (2) These species were less competitive with the cereals than LM systems with white clover. (3) The contribution to the N supply of the agricultural system is modest and negatively correlated with grain yield; an equilibrium may be achieved with grain yields around 5 t/ha. (4) Due to the continuous ground cover and reduced soil tillage, the soil fertility may be improved. (5) Cultivation and seeding techniques need further improvement in order to make the system practicable for farmers.

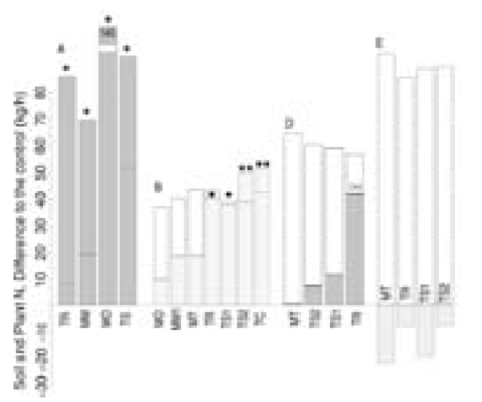

Figure 4: Effect of different legume living mulches on total N, i.e. plant biomass N, soil mineral N and N bound in the POM fraction. (Difference to the control: **: p<0,01; *: p <0.05, (+): p < 0.1, t-test /Bonferroni)

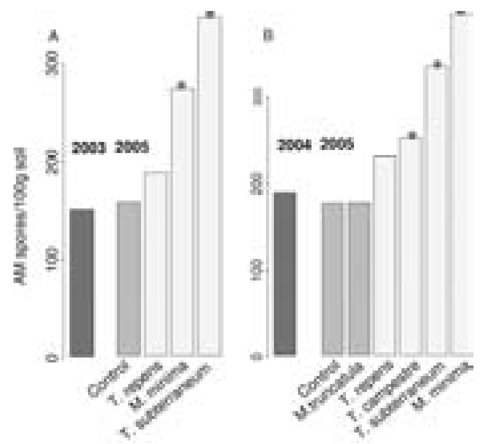

Figure 5: Effect of various living mulches on the occurrence of AM spores compared to the spore density before the establishment of the living mulches (left bar) (*: p <0,05,t-test, / Bonferroni)

Acknowledgments

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Effect of green manure on weeds and soil fertility in two organic experimental agroecosystems of different ages. Results from 2 years.

Migliorini, P.[1], Vazzana, C.[1] & Moschini, V.[1]

Key words: green manure, organic fertilisers, weeds, soil fertility, Mediterranean organic farming

Abstract

In order to acquire more information about green manure practices in the Mediterranean environment, green-manure crops from two seasons (2003/2004 and 2004/2005) were compared and evaluated in two agroecosystems ("Old Organic" and "Young Organic") of the Montepaldi Long Term Organic Experiment in Tuscany. Data collection included green manure crop (biomass, weeds competition capacity, N and C content), weed biodiversity on maize, and soil fertility characteristics over three periods (in October before sowing the green manure, in April before the incorporation of the green-manure in the soil, and in September at the maize harvest). The different green manure species produced no significant effects on the weeds and N% and C% in the soil. Weeds characteristics (weed species and Shannon Index) showed statistically significant differences among the two agroecosystems, even though the initial condition of the two soils were similar.

Introduction

The maintenance and enhancement of soil fertility can be difficult in Mediterranean arable organic farms, often managed without animal husbandry. In order to maintain N balance, the use of commercial organic fertilisers has increased in Italy (Migliorini, 2005). Generally, in the conversion phase, farmers prefer to substitute chemical fertilisers with organic fertilisers despite the high cost and the uncertain quality of these products. This, in contrast with Organic Agricultural principles and regulations, causes a negative organic matter balance on farm crop rotation and an increase in external inputs. The introduction of green-manure practices in the rotation is potentially a more sustainable practice, enchaining biodiversity (planned component) and soil fertility (close nutrient cycling, soil cover) on the farm level **(**Mäder et al., 2002). More information about these practices in the Mediterranean area are needed (Drinkwater et al, 1998): i.e. correct choice of species, biomass and N production and C/N ratio content. All of the latter depend on their adaptability to specific soil and climate conditions, as well as on the stability of the agroecosystem. This paper reports the findings of two years of experiments, aimed at studying N and C accumulation and availability in the soil by green manure for the maize crop in two organic experimental agroecosystems of different ages.

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Materials and methods

In the 2 years 2003/2004 and 2004/2005 green-manure crops were compared and evaluated in field trials. . The experiments were carried out in the Montepaldi Long Term Organic Experiment (MOLTE) site, active since 1991 and situated in Tuscany, in 2 organic micro-agroecosystems: a) "Old Organic" (surface area of 5.2 ha, organic since 1991) and b) "Young Organic" (surface area of 5.2 ha, organic since 2001). Both experimental areas were divided in 4 fields of 1.3 hectares (260 m x 50 m) each. Following local land use, a four-year crop rotation was adopted: green manure + maize – hard wheat + red clover – red clover – barley. The average annual precipitation and mean air temperature for 2003-2005 were 800 mm and 15.5 °C, respectively. The experimental data analyzed included: aerial biomass (DM) of different green-manure crops and weeds; the effect on maize weed biodiversity (number of individuals/m^2, species/m^2 and Shannon index) and soil fertility (complete analysis once a year in October; total N and total C coinciding with the incorporation of the green-manure in the soil and the maize harvest. The green-manure crops were sown in autumn (26/09/03 and 15/10/04) and then ploughed under and incorporated into the soil in early spring (6/04/03 and 10/04/04), before the preparation of the soil for seeding the maize crop. As no irrigation was provided, the maize variety (*Zea mays var*) chosen was in the 250/300 FAO class (95-105 days). In both years, the field trial was laid out in a split-plot block design with 4 replicates. The experimental fields changed due to crop rotation but barley always preceded the green manure crop The green-manure species and seed density were: field (horse) bean (*Vicia faba L var. minor*) at 180 kg ha^{-1}, crimson clover (*Trifolium incarnatum L*) at 50 kg ha^{-1}, crimson clover+oats (*Avena sativa*) mixture at 22,5 and 60 kg ha^{-1} respectively. In 2004/05, the squarrosum clover (*Trifolium squarrosum L*) was substituted with crimson clover at a seed density of 30 kg ha^{-1} and t 15 kg ha^{-1} in the mixture, respectively. Differences between treatments were tested using the analysis of variance (ANOVA) for the following factors: year, type of agroecosystem, green-manure species. Mean comparisons were evaluated by the Bonferroni test with SYSTAT 9 software.

Results and discussion

Green-manure crops and weeds biomass (DM t/ha), the total nitrogen and total C/N content just prior to incorporation into the soil in the two cropping seasons are shown in Table 1. Due to inconsistent pedo-climatic conditions, particularly extreme variations in day-night temperatures, the green manure productions are not high compared to other experience in Central Italy (Guiducci et al, 2004). The factor "type of agrecosystem" did not produced statistically significant difference in the majority of the green manure characteristics. The variability of green-manure and weeds biomass between the two cropping seasons is very high. In fact, the more productive green manure crop was the clover+oat mixture in 03/04 (4.94 t/ha), with the field bean in 04/05 (2.79 t/ha). There is an inverse correlation (R=-0,644) between green manure crops and weeds biomass. In fact, the more productive crops are the most efficient in weed suppression. The N accumulation was highest in the field bean in 04/05 (157 kg/ha) due to a higher nitrogen concentration and in clover+oat mixture in 03/04 (124 kg/ha) due to a higher biomass. The effect of the source of variations for year, type of agroecosystems, green-manure crops and their interactions on maize weeds highlights some statistically significant differences. In particular (Table 2), the weed species and Shannon Index among the two agroecosystems were higher in the "old organic" system than in the "young organic".

Tab. 1: Effect of agroecosystem type and green manure species on crop andweed DM biomass production (t/ha),total Nitrogen (kg/ha) and the C/N accumulated in the total biomass in a 2 year field trial.

	2003/04					2004/05				
	GM DM	Weed DM	Total DM	Ntot uptake	C/N	GM DM	Weed DM	Total DM	Ntot uptake	C/N
	Ton/ha			kg/ha		Ton/ha			kg/ha	
Systems										
OO	1.52	1.75	3.28	83.45	12.011	1.30	1.33a	2.64	91.72a	10.415
YO	1.86	2.17	4.04	73.75	11.657	1.52	0.85b	2.37	76.06b	10.494
	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.	**	n.s.
GM										
C	0.00c	2.37a	2.37b	52.96b	11.169bc	0.00c	1.38	1.38c	45.16c	9.694c
GM1	0.47bc	3.18a	3.65ab	71.38b	11.659b	1.28b	1.09	2.37b	72.50b	10.910b
GM2	4.94a	0.52b	5.46a	124.13a	14.964a	1.57b	0.69	2.26bc	60.15bc	11.896a
GM3	1.37b	1.78ab	3.15b	65.93b	9.546c	2.79a	1.20	3.99a	157.75a	9.319c
	**	**	**	**	**	**	n.s.	**	**	**
S*GM										
OO*C	0.00	2.25	2.25	57.48	9.894cd	0.00	1.42	1.42c	51.52c	9.706c
OO*GM1	0.27	2.37	2.65	71.69	12.446bc	1.23	1.67	2.90abc	94.65b	10.350bc
OO*GM2	4.58	0.82	5.40	130.58	16.045a	1.14	0.64	1.79c	48.36c	12.215a
OO*GM3	1.24	1.57	2.82	74.04	9.660cd	2.83	1.60	4.44a	172.33a	9.390c
YO*C	0.00	2.50	2.50	48.45	12.443bc	0.00	1.34	1.34c	38.80c	9.681c
YO*GM1	0.67	3.98	4.65	71.06	10.872cd	1.33	0.51	1.84c	50.35c	11.470ab
YO*GM2	5.29	0.21	5.51	117.67	13.882ab	1.99	0.74	2.73bc	71.93bc	11.577a
YO*GM3	1.49	1.99	3.49	57.82	9.431d	2.76	0.79	3.55ab	143.17a	9.247c
	n.s.	n.s.	n.s.	n.s.	**	n.s.	n.s.	*	**	*

(GM: green manure; OO: old organic; YO: young organic; C: control; GM1: clover; GM2: clover+oat; GM3:field bean. In 2003/04 was used Crimson clover in 2004/05 Squarrosum clover. Values are the means of 3 samples in each thesis for 4 replicates in 2 fields for 4 years; ** significant for P<0.01 and * for P<0.05).

Tab. 2: weed characteristics of the two MOLTE agroecosystem in 2 years field trials

Systems	Weed number	Weed species	Shannon Index
	(n/mq)	(n/mq)	
Old Organic	65,789	4,969a	1,262a
Young Organic	56,617	3,578b	0,953b
significance	*n.s.*	****	****

(Values are the mean of 3 samples in each thesis for 4 replicates in 2 fields for 2 years; ** significant for P<0.01).

The relevance of the stability of the agroecosystem on the effect of treatments is even more important considering that the initial conditions of soil fertility in the four field trials (Table 3) were not different, except for P that was higher in the old organic system and K and N nitric that were higher in young organic. Data regarding soil N% and C% coinciding with the incorporation of green manure in April and at the harvesting of maize in September showed no significant differences statistically for the sources of variation: year, type of agroecosystem, type of green manure crop and their interactions (data not shown). This is in contrast with others researches (Thorup-Kristensen et al. 2003) that show a clear effect on soil N management, N uptake and grain yield. Probably, the no effect is due to the low production level of green-manure crops.

Tab. 3: Soil characteristics of the two MOLTE agroecosystem in 2 years trials.

AES	O.M. (%)	N tot (‰)	N nitric (ppm)	P available (ppm)	K exchange (ppm)	CN
Old organic	1,706	1,252	6,350b	62,900a	103,475b	8,180
Young organic	1,599	1,183	7,800a	53,600b	134,800a	8,311
significance	n.s.	n.s.	**	*	*	n.s.

(Values are the mean of 3 samples for 4 replicates in each fields for 2 years; ** significant for P<0.01 and * for P<0.05).

Conclusions

The maintaining of soil fertility is very important in organic farms. Green manure usage represents a viable and important practice and the correct choice of the suitable crops for the local conditions is a crucial factor in order to obtain sufficient biomass quantity and nutrient availability. In low productive organic systems, the level of stability reached after the conversion period can strongly influence the effects of green-manure biomass on weeds. However, there is not a significant effect on soil characteristics and potential productivity.

Acknowledgments

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Effect of undersowing winter wheat with legumes on the yield and quality of subsequent winter triticale crops

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Key words: undersowing, winter wheat, nitrogen catch crops, winter triticale, legumes

Abstract

The study presents results of a series of trials investigating the effects of undersowing nitrogen fixing crops (legumes) into winter wheat on the performance of the subsequent crop winter triticale. Trials were carried out between 2003 and 2006 at two sites in southern Bavaria, Germany. All species tested - black medic, birdsfoot trefoil, red clover, white clover and a legume-grass mixture - proved to be suitable. Compared to the "not-undersown" control treatment the undersown N-fixing crops had no statistically significant effect on the yield, protein content and other grain quality characteristics of the winter wheat crop, except for one site where protein yield was significantly higher in one year. There was also no difference in disease incidence between "undersown" and "not-undersown" winter wheat. Depending on the seasonal rainfall pattern the establishment of N-fixing crops in wheat had either a negative or a positive effect on the yield of the subsequent crop of winter triticale. Reductions in yield only occurred in the 03/04 season, which had an extremely dry summer in 2003. In the seasons 04/05 and 05/06, which had a more favourable distribution of annual precipitation, the establishment of certain legume crops increased the yield and protein content of winter triticale; however the effect was not statistically significant for all years and sites.

Introduction

For stockless organic arable farms the cultivation of legumes is the most important source of nitrogen. The study presented here investigated the effects of establishing an undersown N-fixing crop (small-grained forage legumes) in wheat on the yield and quality of grain of both the wheat and subsequent triticale crops. Legumes were undersown into an established winter wheat crop in spring, a procedure which is easy, cost-effective, and requires only a low labour input.

The study aimed to answer the following questions:

a) Which of the selected species of legumes are particularly suited for undersowing in winter wheat in the different sites included in the study?

b) Do the undersown legume crops affect the development of diseases, yield, protein content and other grain quality parameters in winter wheat?

c) Does the use of undersown N-fixing crops in wheat affect disease incidence, yield and grain quality in winter triticale crops grown after wheat?

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Materials and methods

Field trials were conducted in two sites in Southern Bavaria: Site S (Schönbrunn, region of Lower Bavaria) and site V (Viehhausen, region of Upper Bavaria). Site S is 385 m a.s.l., has an annual precipitation 730 mm, an average annual temperature of 7.8° C and a humus rich, sandy loam soil (brown earth). Site V is 480 m a.s.l. has an annual precipitation of 780 mm, an average annual temperature of 7.5° C, and a sandy loam soil (brown earth) with a lower humus content than site V. Both trial sites were on farms managed to organic farming standards since the mid 1990's. The trial was established on small plots (1.5m x 8m) as a 'Latin Square' design. The positions of winter wheat treatment plots in the subsequent triticale crop were identified by calibrating the corners of treatment plots from a fixed point in the field. The following species of legumes and seed-rates were tested: black medic (*Medicago lupulina*; 16 kg ha^{-1}); birdsfoot trefoil (*Lotus corniculatus*; 18 kg ha^{-1}), red clover (*Trifolium pratense*; 25 kg ha^{-1}), white clover (*Trifolium repens*; 10 kg ha^{-1}), legume-grass mixture (red clover, white clover, alfalfa (*Medicago sativa*), meadow fescue (*Festuca pratensis*), timothy (*Phleum pratense*), common oat-grass (*Arrhenaterum elatius*) – together 27 kg ha^{-1}). Legume crops were undersown after the last harrowing of the wheat in spring using a plot-drill. Crop assessments, analyses and reports were carried out according to the guidelines of the German 'Federal Office of Plant Variety testing and national listing' (Bundessortenamt 2006). The content of raw proteins was analysed according to the Kjehdahl method.

The study presented here includes results from a series of trials (winter wheat 7 trials, winter triticale 5 trials; 3 seasons in site "S" and 4 in site "V"). Owing to a lack of balance for sites and years the results have been summarised into 'environments'. For the statistical analysis of the individual experiments a mixed model with legume species as a fixed effect was used. Individual means were compared by the Least Significant Difference (LSD; Student-Newman-Keuls (SNK)) test. All analyses were carried out using the SAS statistical software.

Results

In the first year (2003) the development of N-fixing crops was affected by the extreme dry weather in summer (precipitation from July to September: 135 mm versus average annual precipitation of 267 mm). In 2003 white clover yield was only 0.1 t ha^{-1} dry matter (D.M.) while birdsfoot trefoil and black medic yielded 0.3 and 0.4 t ha^{-1} D.M. respectively. There was virtually no establishment of grass in plots undersown with the legume-grass mixture in 2003. In the two subsequent years (2004 and 2005) all catch crops established and developed satisfactorily in both sites.

In all 3 years, undersowing had no statistically significant effect on the yield of winter wheat when compared to control plots which were not undersown with legumes (individual results not shown). In most trials there was also no significant effect on disease incidence in wheat, grain protein content and other grain quality parameters (test weight, thousand kernel weight). However, in 2005 undersown winter wheat showed an increase in raw protein. This increase was significant for crops undersown with white clover, black medic or the legume-grass mixture, with black medic showing the highest content (10.8 % of raw protein D.M.), which was 1.1% more than in the non-undersown control.

In the 2003/2004 season all undersown legume crops caused highly significant ($p < 0.01$, SNK) lower yields of the subsequent winter triticale crop (fig 1). This is thought to have been due to additional water consumption of the legume crops having a negative effect on the pre-winter development of winter triticale. The grain protein content was, however, not affected.

Winter triticale, yield in t ha^{-1}, results from 5 trials

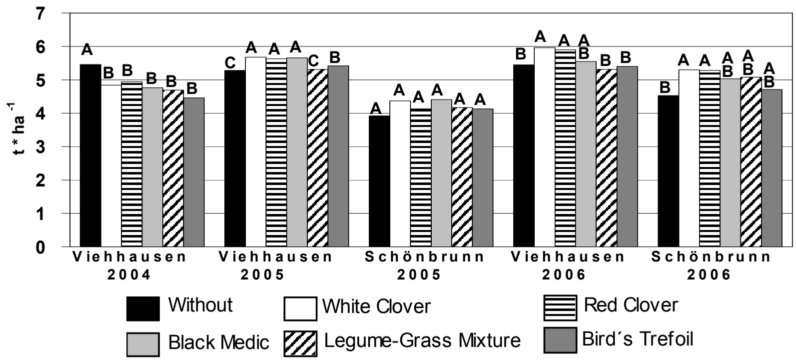

Figure 1: Crop yields of winter triticale in the 5 environments following winter wheat undersown with different species of legumes.

In all other environments undersown legume crops caused either the same or in individual cases significantly higher yields (fig 1). In three environments (V 2005, 2006; S 2006) white and red clover performed significantly ($p < 0.05$, SNK) better than all other treatments. Yields of winter triticale were higher after white clover, red clover or black medic than those of triticale grown after birdsfoot trefoil or the legume-grass mixture. The highest yields were obtained with white clover, as the N-fixing crop which increased yields by 0.77 t ha^{-1} (S 2006). Compared to plots without undersown legumes, the mean crop yield of triticale (mean of all environments, not shown) increased by 7% with white clover, 5% with red clover and 4% with black medic, but decreased by 1% with birdsfoot trefoil. The legume-grass mixture did not affect crop yield.

Discussion

Prior to the introduction of herbicides as the standard method of weed control undersowing of cereals with forage legumes was investigated as a method of weed control in Germany (Becker-Dillingen 1929, Klapp 1958). These studies were rediscovered and re-initiated in the late 1980's, especially in R&D focused on organic cereal production (Vandermeer 1989, Haas & Köpke 2000). Most published studies report positive effects of undersowing legumes on the yield of the subsequent crops such as wheat (Loes et al. 2006, Böhm 2007). This could be confirmed by the study presented here for triticale, a crop for which there was no published information with regard to green manure effects. The study also demonstrated that undersowing of winter wheat may increase baking quality in winter wheat, which addresses one of the main technological challenges in organic wheat production. Restrictions could be found for years with dry summers. Under those conditions undersown forage legumes do not perform well, nevertheless yields of subsequent crops are reduced. Further trials regarding the effects of undersowing legumes into winter rye with a subsequent spring oat crop are currently being conducted. The effect of undersowing on the yield of the subsequent spring oat crop is expected to be greater than the effects observed for winter triticale, due to the longer (up to 4 weeks) growing period of the undersown legume crop. If the crop rotation does already include a large proportion of legumes, undersowing may increase the risk of legume specific diseases (Klapp 1958).

Conclusions

The use of undersowing with small-grain legumes in organic cereal production systems is a safe approach in sites/seasons with sufficient water availability (annual precipitation 700 – 800 mm, average annual temperature 7.5 – 8° C, brown earth). The study identified a range of well-suited legume species for undersowing that do not negatively influence the winter wheat crops they are undersown into. We recommend red clover, white clover and black medic. A legume-grass mixture and birdsfoot trefoil are not advisable. The fact that undersowing resulted occasionally in positive effects on the quality (especially protein yield) in wheat further underpins the recommendation to use undersowing in organic cereal production. The finding that in extremely dry years yield reductions can occur in subsequent triticale crops, means that undersowing should only be recommended for sites with a good water supply.

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Contribution of N from frequently chopped green manure to a succeeding crop of barley

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Key words: cereals, plant residue, N recovery, soil N

Abstract

The aim of the present work was to study to what extent N in mulched green manure herbage contributes to spring barley grain yield the subsequent year. The green manure herbage was either chopped and left on stubble (GML) or removed (GMR). On silty clay loam with spring incorporated green manure the subsequent barley grain yield was 10% higher with GML than with GMR. The additional grain N yield of 4 kg ha^{-1} with GML corresponded to only 3 % of N in above-ground green manure biomass. On loamy soil with late autumn incorporated green manure the treatments did not affect the grain yield the subsequent year. How large part of the N that was lost through leaching or gaseous emissions and how large part that was built into soil organic matter was not measured. However, this investigation confirms that potential N losses from mowed green manure might be large. Alternative ways of using the herbage should be found.

Introduction

Nitrogen (N) supply in stockless organic cereal production is based on leguminous green manure plants within the crop rotation. In northern temperate regions both undersowing of clover in cereals and whole season green manure crops are used. Whole season green manure is managed by repeated mowing; this to control perennial weeds and encourage regrowth and N-fixation. Due to the large content of easily degradable N accumulated in the green manure crops, the potential N losses from the green manure herbage are large (Breland 1996 a, b; Askegaard *et al*. 2005). The practice of leaving the herbage as mulch after repeated mowing increases this risk of N losses (Larsson *et al.*, 1998) both through gaseous emissions (NH_3, N_2O and NO), and surface runoff or leaching of NO_3^- and soluble organic N. Such N losses are a hazard for the environment and a reduction of the N input to the system, which is not compatible with a sustainable development of organic farming. Hence, it is important to focus on strategies improving N utilization of whole season green manure in organic spring cereal production.

The aim of the present work was to study to what extent N in mulched green manure herbage contributes to spring barley grain yield the subsequent year.

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Materials and methods

Two field trials were carried out from 2005 to 2006. They were located on organically farmed soil at the Norwegian Institute for Agricultural and Environmental Research at Kvithamar (Field 1) in central Norway (63°29´N, 10°52´E) and Apelsvoll (Field 2) in central south-east Norway (60°42´N,10°51´E). The soil on field 1 is a silty clay loam and on field 2 is a loam. The precipitation during the growing season 2005, the subsequent winter and the growing season 2006 was 473, 546 and 222 mm, respectively, for field 1 and 270, 339 and 222 mm for field 2.

The experiment was designed in blocks with four replicates. The green manure crop consisting of a mixture of common vetch (*Vicia sativa* L., 80 kg ha^{-1}), phacelia (*Phacelia tanacetifolia* Benth. 5 kg ha^{-1}), ryegrass (*Lolium multiflorum var. Italicum* Lam., 10 kg ha^{-1}) and red clover (*Trifolium pratense* L., 5 kg ha^{-1}) was grown in 2005. The green manure was cut with a plot harvester and then either chopped with a stubble cutter and left on stubble (GML) or removed from the plot (GMR). The green manure on field 1 was incorporated into the soil by ploughing (depth of 23 cm on both fields) in the spring the day before barley was sown. Field 2 was ploughed in late autumn 2005. In May 2006, immediately before sowing of spring barley (*Hordeum vulgare* L.), the soil was dragged and harrowed on both sites. No fertilizer was applied.

Grain yield and biomass of green manure was recorded on all plots by harvesting subplots of 9.75 m^2 (Field 1) and 20 m^2 (Field 2). The stubble height of green manure was 5-6 cm. Grain quality parameters; thousand grain weight, hectolitre weight, content of protein and starch were analysed in samples from all plots; the last three parameters by Infratec 1241 Grain Analyzer. Above-ground biomass of barley at early stem elongation (Zadoks 30) was recorded on all plots by harvesting two subplots of 0.25 m^2. Soil mineral N (0-25 cm) was measured in late autumn (Field 1: 7th November, field 2: 19th October); one month after the last green manure cut, and in the spring the day before ploughing. Analyses were done by 1M KCl extraction.

Statistical analyses were carried out by analysis of variance (proc glm; SAS, 2002).

Results

The barley yield in field 1 was 10 % higher for plots with GML compared with GMR (Table 1). The straw yield on the same plots was 15 % higher. No differences between the treatments of green manure herbage were found in amount of N in plants at early stem elongation or in hectolitre weight, thousand grain weight, and amount of protein or starch in grain.

On field 2 no differences in barley yield, straw yield, N content or the quality parameters were found between the treatments.

Tab. 1: Barley grain and straw yields (g dry matter m^{-2}) after whole season green manure with herbage left (GML) or removed (GMR) from the plots. SE in brackets (n = 4)

	Grain			Straw		
	GML	GMR		GML	GMR	
Field 1	240 (14)	217 (11)	*	161 (8)	137 (3)	*
Field 2	237 (16)	225 (22)	n.s.	168 (3)	160 (6)	n.s.

* significant for p<0.05

On field 1 dry matter yield and N yield of the 3rd green manure harvest on plots with GMR were 36% lower than GML ($p<0.05$). There was a tendency to higher amounts of legumes at the 3rd harvest with GMR. On field 2 the dry matter yield of the 3rd harvest was not significant, but there was a tendency to be higher with GMR. On plots with GMR the total N was higher, due to a higher amount of legumes.

The amount of mineral N in soil in autumn on both fields tended to be higher on plots with GML than with GMR. In the spring no difference in mineral N content in soil was found between the treatments. The amount of nitrate in soil in autumn was highest on plots with GML on both fields. Highest amount of nitrate was found in depth 12.5-25 cm on field 1 and in depth 0-12.5 cm on field 2. The difference between treatments in ammonium content was not significant.

On field 1 the amount of N in grain yield with GML was 9% higher than with GMR. This additional N yield of 4 kg ha^{-1} corresponded to 3 % of the N in the above-ground biomass of green manure herbage the year before (Figure 1).

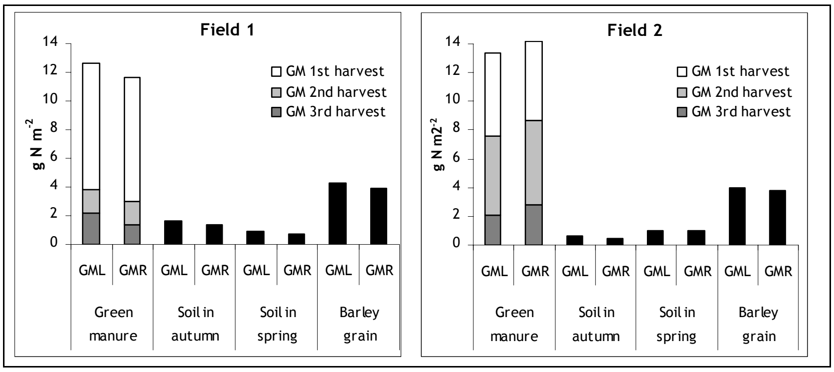

Figure 1: Amount of total N in three harvests of green manure, mineral N in soil (0-25 cm) and total N in barley grain after green manure herbage left (GML) or removed (GMR) from the stubble.

Discussion

Small differences in cereal grain yield succeeding green manure with the herbage left or removed in the field were also observed by Whitbread *et al.* (2000) and Solberg (1995). As no or only a little part of the N from green manure herbage seemed to be recovered by barley the subsequent year, the main N source for the barley was probably soil organic matter (C/N ratio of 11) and the under-ground biomass of the green manure. Autumn incorporation of the green manure on loamy soil (field 2) seemed to remove any difference between the treatments.

How large part of the N that was lost through leaching or gaseous emissions and how large part that was built into soil organic matter was not measured. However, the results indicate that N losses from mowed and mulched green manure may be substantial, as also found by e.g. Janzen & McGinn (1991) and Larsson *et al.* (1998).

Løes *et al.* (2007) found that whole season green manure in one out of four years in cereal crop rotation does not accumulate enough N to compensate for the N removed in cereals. They concluded that additional N sources are needed. Strategies to improve N utilization of whole season green manure in organic spring cereal production should be sought. An alternative strategy could be the conservation of the green manure herbage during the winter as hay, silage, compost, or biogas slurry from anaerobically digestion of green manure herbage, for early incorporation in the spring before sowing the cereal crop. This topic requires further study.

Conclusions

The results from the field experiments showed a 10% lower or no difference in subsequent spring barley grain yield when green manure herbage was removed from the field after each cut compared with green manure herbage left on the stubble after the cuttings. The additional grain N yield of 4 kg ha^{-1} with mulched herbage corresponded to only 3 % of the N in above-ground green manure biomass. This fact, together with the knowledge of high risks of N losses from remaining herbage, implies that alternative ways of handling and storage of green manure herbage should be sought.

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Potentially mineralizable nitrogen is soils green manured with biocidal crops

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Key words: green manure, N mineralization, Brassicaceae, methyl bromide, metam sodium

Abstract

Biofumigant crops used as green manure, in addition to producing a biocidal effect on some soil-borne pathogens and pests, could represent a source of N for crop nutrition. In two laboratory experiments we compared i) the potentially mineralizable N (PMN) of a silty clay soil after incorporation of glucosinolate-containing (GLS+) and non-containing (GLS–) plants, or after incorporation of metam sodium; and ii) the mineralization rate of different types of soils (silty clay, loam and loamy sand) after green manuring with GLS+ crops. After a 3-month incubation, the PMN of the silty clay soil amended with the GLS+ Brassica juncea was significantly higher than the unamended control and the soil amended with Triticum aestivum and Eruca sativa. Metham sodium, while showing a remarkable nitrification inhibition activity, gave rise to amounts of inorganic N (mainly in the ammonium form) of the same level as B. juncea. Mineralization rate was higher in the loamy sand soil than in the loam and in the silty clay soils. Biofumigant crops used as green manure, by increasing N availability in soil, may represent an interesting source of N for the following crops in organic agriculture.

Introduction

Biofumigant crops used as green manure, in addition to having a biocidal effect on some soil-borne pathogens and pests (Brown & Morra, 1997), may represent a source of N for the following crops. Two laboratory experiments were performed with the following objectives: (i) to compare the potentially mineralizable N (PMN) of a silty clay soil green manured with glucosinolate-containing (GLS+) and non-containing (GLS–) crops. Metam sodium, which is a chemical treatment widely used as an alternative to methyl bromide, was also tested for its effect on soil PMN; (ii) to compare the mineralization rate of different kinds of soils after green manuring with GLS+ crops.

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Materials and methods

Experiment I. A silty clay soil was green manured with Indian mustard (*Brassica juncea* L. Czern., GLS+), garden rocket (*Eruca sativa* Mill., GLS+), or winter wheat (*Triticum aestivum* L., GLS–) crop species, in comparison with an untreated soil and with a soil fumigated with metam sodium (methyl isothiocyanate). *Experiment II*. Three soils belonging to contrasting textural classes: silty clay, loam, and loamy sand, were amended with *B. juncea* and *E. sativa, and* compared to an untreated control. Experimental details are reported in Tab. 1. The plant material had been harvested from small field plots at full flowering and finely cut in a grinder mill just before incorporation to soil.

Tab. 1: Selected properties of green manure (GM) and soils used in the two experiments.

GM	Exp.	Added fresh GM (g L^{-1} of wet soil)	Kjeldahl N (g kg^{-1} dry matter)	Plant moisture (% wet weight)
B. juncea	I	71	22.0	77.5
B. juncea	II	71	17.9	80.2
E. sativa	I	36	14.8	75.1
E. sativa	II	36	21.2	80.2
T. aestivum	I	71	13.3	74.8

Soils	Exp.	Bulk density (kg wet soil L^{-1})	Kjeldahl N (g kg^{-1} dry soil)	Initial moisture (% dry weight)	Sand (g kg^{1})	Silt (g kg^{1})	Clay (g kg^{1})
Silty clay	I	0.79	1.58	17.0	116	478	406
Silty clay	II	0.81	1.95	22.7	98	494	408
Loam	II	1.04	0.80	12.3	466	415	119
Loamy sand	II	1.11	0.82	4.3	821	154	25

Amendments were incorporated to a known volume of wet soil in pots kept moist at ambient temperature for a week. In both experiments, PMN was then determined according to Drinkwater et al. (1996): 25 g of wet soil were added to 40-mL scintillation vials, the soil moisture was adjusted at 75% plant available water content and the vials were incubated at 30°C for 3 months (91 days), with 3 replicates for each treatment and date (i.e., at time 0 and after 91 d after the start of the incubation). In the first experiment the PMN was expressed as the net cumulative inorganic N released in soil in the 3-month incubation period. As short-term aerobic incubations quantify a portion of the total PMN (Drinkwater et al., 1996), which, in turn, depends on the total soil organic N content (measured as Kjeldahl N), in the second experiment mineralization rate (MR) was estimated from PMN, as the mean daily amount of net inorganic N released per unit of Kjeldahl N measured at the beginning of the incubation period in both amended and control soils (MR, mg N g^{-1} N d^{-1}= (PMN/91) / soil Kjeldahl N). Statistical analysis was performed using the SAS PROC MIXED (SAS Institute, 1996).

Results

Experiment I. After 3-month incubation the PMN value of the silty clay soil amended with *B. juncea* was significantly higher than the control (Tab. 2; +51 mg N kg^{-1} soil), mainly due to the accumulation of nitrate N. The PMNs of the soil amended with *E. sativa* and *T. aestivum* were not significantly different from the control, even though the former was higher, and the latter lower than the PMN of the control. In soil added with metam sodium, the PMN was significantly higher than the control soil, due to a remarkable increase of ammonium, but not of nitrate N.

Tab. 2: Potentially mineralizable N (PMN) in a silty clay soil 3 months after the incorporation of different amendments. Inorganic N is the sum of net cumulative nitrate (NO_3–N) and ammonium (NH_4–N) N.

Treatment	PMN, total inorganic N and N forms (mg N kg^{-1} soil dry weight)[1]		
	Inorganic N	NO_3-N	NH_4-N
B. juncea	102ab	122a	˜21b
E. sativa	68bc	71b	˜3b
T. aestivum	27d	41c	˜14b
Metam sodium	111a	5d	106a
Control	51cd	51bc	0b
$LSD_{0.01}$	40.8	27.6	22.8

1 For each column, means followed by the same letters are not significantly different for P<0.01.

Tab. 3: Mineralization rate (MR, mean daily amount of net cumulative inorganic N per unit of organic N in soil) of different soils green manured with Brassicaceae plant material.

Treatment	MR (mg net cumulative inorganic N g^{-1} Kjeldahl N day^{-1}) in soil[1]			
	Loam	Loamy sand	Silty clay	Means of Treatment
B. juncea	0.79b	1.11a	0.54cd	0.74A
E. sativa	0.71bc	0.87b	0.46de	0.63B
Control	0.25f	0.33ef	0.30f	0.30C
Means of Soil	0.59B	0.77A	0.43C	

[1] Upper-case letters were used for comparisons of the mean effects, lower-case letters for the comparison of the first-order interaction effects. For each source of variation, means followed by the same letters are not significantly different for P<0.01. $LSD_{0.01}$ for comparisons between soils or treatments = 0.104 mg inorganic N g^{-1} Kjeldahl N day^{-1}. $LSD_{0.01}$ for comparisons between soils and treatments (soil □ treatment effect) = 0.181 mg inorganic N g^{-1} Kjeldahl N day^{-1}.

Experiment II. Green manured soils showed significantly higher MRs than the control soils. The highest MR was observed in the loamy sand (Tab. 3). Not significantly different MRs were observed between control soils.

Discussion

In the first experiment the highest PMN was observed in soil green manured with *B. juncea*, the lowest in soil green manured with *T. aestivum.* Trinsoutrot et al. (2000) reported a net N mineralization in soil amended with *Brassica napus* leaves throughout 168-d incubation, in contrast with net N immobilization for maize straw. The short-term reduction of N availability following the incorporation of winter wheat crop residues, as a result of N immobilisation, is well known, and confirmed by our results. Metam sodium, while showing a remarkable nitrification inhibition activity (in agreement with the findings of Welsh, 1996, in laboratory conditions), greatly stimulated the release of ammonium N from indigenous soil organic matter. In the second experiment, nitrogen mineralization in green manured soil was faster in the loamy sand than in the loam and silty clay soils. This is in agreement with the observations of Pare and Gregorich (1999) for sand soils added with crop residues having a low C:N ratio.

Conclusions

Biofumigant crops used as green manure, by increasing N availability in soil, may represent an interesting source of N for the following crops in organic agriculture.

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Agronomic performance of annual self-reseeding legumes and their self-establishment potential in the Apulia region of Italy

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Key words: annual self-reseeding legumes, *Trifolium* spp*., Medicago* spp*., biological* nitrogen fixation, Mediterranean region.

Abstract

The agronomic performance, biological nitrogen fixation (BNF) ability and self-establishment potential of seven species of annual self-reseeding legumes were investigated in Apulia region, Italy. For the first cropping cycle (2005-2006) preliminary results showed that Trifolium spp. *performed better than* Medicago spp. *Among the seven species, five were more suitable to the site's conditions.* T. angustifolium *and* M. polymorpha *gave the best results.* T. angustifolium *fixed 131.7 kg ha^{-1} year of nitrogen (^{15}N isotope dilution method), produced 1976 kg ha^{-1} of seeds and 8.7 t ha^{-1} of dry matter (DM).* M. radiata *and* M. rigidula *were the less performing. During the second cropping cycle (2006-2007) results showed that* Trifolium spp. *self-established better than* Medigaco spp. *Regenerated species appeared to sustain optimum level of BNF.* Again T. angustifolium *was the best performing species producing the highest DM (7.7 t ha^{-1}) and fixing nitrogen (146.7 kg) N ha^{-1} symbiotically. In contrast,* M. polymorpha, *was the less performing (0.3 t ha^{-1} of DM and 11.5 kg ha^{1} of BNF) while* M. rigidula *and* M. radiata *did not regenerate. Given the overall performance of all species, it was determined that* T. angustifolium *had the greatest potential for further development in this environment.*

Introduction

Successful establishment of annual legumes is achieved only with the use of varieties that have both high persistence and high productivity within the specific environment in which they are used (Rochon *et al*., 2004). In the Mediterranean areas, native ecotypes are more persistent and better adapted than commercial varieties. Self-reseeding annual legumes can play an increasingly important role in Mediterranean organic farming systems. They are flexible components within the whole farm systems, and can be used as cover crop, living mulches, green manure and forage crops to increase economic, environmental and social sustainability (Caporali *et al*., 2004). Nitrogen fixed by legumes is the main nitrogen source in organic farming systems (Loges *et al*., 2000). Moreover, in order to design strategies for optimizing management of biological nitrogen fixation (BNF) for maximal production with minimal nitrogen pollution of water resources, it is essential that nitrogen inputs by legumes and the subsequent fate of this nitrogen be quantitatively assessed (Unkovich and Pate, 2001).Therefore, the agronomic performance, ability of nitrogen fixation and self-establishment potential of seven self-reseeding legumes (four *Trifolium* species *as* well as three *Medicago* spp.) were investigated in comparison with *Trifolium*

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subterraneum cv. Antas *(T.su.)* used as reference crop during the period between autumn 2005 and spring 2007 in South of Italy.

Materials and methods

The experiment was carried out at the experimental field of IAMB located in Apulia region, South of Italy (41°03'16"N, 16°52'45"E, 72 m a.s.l.). Apulia region is characterized by a Mediterranean climate with humid mild winter and hot dry summer. Precipitation varies from 400 to 500 mm/ year and is mainly concentrated between October and April. Annual average temperature ranges from 15 to 16 °C, with a maximum of 35°C recorded in July and a minimum of 0°C in January (IAMB's Agrometerological Station). The soil type was a sandy clay. Soil pH was 8.1, soil organic matter 1.6%, P and K (0-20 cm) were approximately 85 and 514 mg kg^{-1}, respectively at experimental site. Seven accessions of annual self-reseeding legumes (*Trifolium angustifolium (T.a.), T. campestre (T.ca.), T. cherleri (T.ch.), T. stellatum (T.st.), Medigago polymorpha (T.p.), M. rigidula (M.ri.) M. radiata (M. ra.*) and two reference crops *Trifolium subterraneum (T.su)* cv. ANTAS (Crl1) and barley *Hordeum vulgare* (Crl2) (as reference for ^{15}N isotope dilution method) were arranged in a randomised completely block design with four replicates. Each block was composed of 9 plots of 9 m^2.

Legumes were sown in November 2005 at a rate of 28 kg ha^{-1}. The first growth cycle extended over seven months until the end of May 2006. Legumes were left on the field over the summer after seed production. In autumn (October 2006), legumes self-established after the first rain and grew until April 2007. Legumes were then incorporated (no cutting regime) as a green manure for further investigation. During the two growing cycles, plant height and crop ground cover were measured every two weeks. Before full-flowering stage April 2006 and March 2007, BNF was quantified using ^{15}N isotope dilution method (Unkovich and Pate 2001). In each plot, a quadrat of 2.25 m^2 was identified and two grams of ammonium sulphate $(^{15}NH_4)_2SO_4$ diluted in 10 liters of water were sprayed. At the end of each growing cycle a representative sample per plot was used to measure DM, seed yield (only for the first cycle) and ^{15}N (mass spectrophotometer) for BNF quantification. Statistic analysis was performed on each variable by analysis of variance followed by Duncan's test.

Results and brief discussion

Highly significant differences of DM production were obtained between *T.a*, *T.ca*, *M.p.* and *T. su* (Crl1) in which Crl1 showed the lowest DM value. Highly significant differences were also observed between the Crl1 and *M.ri* and *M. ra,* in which Crl1 showed a higher value (Tab.1). The lowest DM production of *M. p.* and *M. ri.* were far inferior to these reported by Walsh *et al*., (2001) in a study for annual medic production, with large differences in experimental design and sites conditions (i.e. soil pH=6.1) in Western Australia. Amount of BNF ranged from 0.7 to 147 kg ha^{-1} (Tab.1 & 2) and this is confirming results of Peoples *et al*., (1998) and Evers (2003). *T. a.* resulted in the highest BNF (146.7 kg ha^{-1} year), *M. p.* and *T. ca*. resulted in the lowest amounts (11.5 and 9.9 kg ha^{-1} year) in the second cropping cycle while (90 and 70 kg ha^{-1} year) in the first, respectively. This is due to the high DM production of *M. p.* and *T. ca*. in the first cropping cycle (5.5 and 5.1 t ha^{-1}) in comparison with only (0.3 and 0.3 t ha^{-1}) in the second cycle, respectively. A clear reduction in BNF was also determined for *T.ch*. and *T. st*. for the second cropping cycle.

Tab. 1: Agronomic performance of annual self-reseeding legumes (at the end of the 1st growth cycle November 2005- May 2006)

Species	Plant height (cm)	Crop ground cover (%)	DM (t ha^{-1})	Seed yield (kg ha^{-1})	BNF (kg ha^{-1} year)
T. angustifolium	43.4 b	100 a	8.7 a	1976 a	131.7 a
T. campestre	33.9 b	100 a	5.1 b	472 cd	66.7 c
T. stellatum	32,6 c	100 a	3.2 c	683 d	35.2 d
T. cherleri	28.5 cd	99 a	3.6 c	1089 b	47.2 d
M. polymorpha	55.6 a	100 a	5.5 b	732 c	89.6 b
M. rigidula	23.6 d	53 b	0.9 d	60 e	1.9 e
M. radiata	6.1 e	8 c	0.2 d	22 e	0.7 e
T. subterraneum cv. Antas (Crl1)	51.4 a	100 a	2.8 c	527 cd	32.6 d

Means with different letters are significantly different (Duncan test, α=0.05)

Highly significant differences were assessed between *T. a.* and *T. su.* (Crl1) for mainly DM and BNF in which the Crl1 showed the lowest value. Highly significant differences were also obtained between the Crl1 and the rest of the tested species in which the Crl1 showed the highest value (Tab. 2).

Tab. 2: Self-establishment of annual self-reseeding legumes (at the end of the 2nd growth cycle September 2006- April 2007)

Species	Plant height (cm)	Crop ground cover (%)	DM (t.ha^{-1})	BNF (kg ha^{-1} year)
T. angustifolium	97.5 a	40.6 a	7.7 a	146.7 a
T. campestre	20.6 b	3.0 c	0.3 c	9.9 d
T. stellatum	63.8 b	6.8 b	1.2 c	39.6 c
T. cherleri	55.0 b	7.0 b	1.7 c	40.8 d
M. ploymorpha	4.6 b	3.8 c	0.3 c	11.5 c
M. rigidula	Not regenerated			
M. radiata				
T. subterraneum cv. Antas (Crl1)	100.0 a	39.8 a	5.4 b	125.2 b

Means with different letters are significantly different (Duncan test , α=0.05)

Generally, the legumes (except *T.a)* did not perform as well during the second cropping cycle compared to the first. This result confirms the results of an experiment conducted by Thorup-Kristensen and Bertelsen (1996) in Denmark, as well as the results of another experiment conducted in Italy at Mediterranean Agronomic Institute of Bari (IAMB) (Al-Bitar, 2005). These results are not only based on the amount of nitrogen fixed, but also on others parameters like legumes plant height, crop ground cover and DM production.

Conclusions

The genus *Trifolium* appeared better adapted to the pedo-climatic conditions of the studied area than the genus *Medicago*. Both *Medicago radiata* and *Medicago rigidula* did not regenerate while *Medicago polymorpha* regenerated very poorly. We conclude that *Trifolium angustifolium* is suitable for Apulian conditions due to its higher BNF and rapid soil covering. After their incorporation, all legumes treatments (except *T. ra.* and *T. ri.*) showed a positive precrop effects on all growth parameters of the subsequent crops (Zucchini and lettuce) compared to controls without legumes preceding. *T.a* induced the best effect on the zucchini and lettuce crop yields (42.66 and 48 t ha^{-1}) respectively. Consequently, *T.a.* may play an important role in managing soil fertility and be considered as a key-element in enhancing field biodiversity. It can further be recommended to integrate *T.a* in Apulian organic cropping systems (i.e. organic vegetable crops) as a winter cover crop for the purpose of green manure under a rotation program.

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Performance of grain legume crops in organic farms of central Italy

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Key words: pea, faba bean, lupin, grain legumes, Mediterranean crop

Abstract

In the 2005-2006 growing season, eight varieties of faba bean, pea and lupin were compared in two organic farms, located in two regions of Central Italy (Tuscany and Marche), to evaluate their adaptation to local environment and agronomic performance in terms of grain yield and competitive ability against weeds. Pea showed a higher grain production than faba bean and lupin, which were negatively effected by the environmental conditions during winter 2005 and spring 2006. Time of seeding seems to be very important for the competitive ability against weed of the different varieties. In Tuscany the lupin Italian variety Multitalia, the only one Italian variety, obtained interesting performance in terms of grain yield and weed competition, although the spring seeding.

Introduction

Grain legumes such as faba bean (*Vicia faba L var. minor*), field pea (*Pisum sativum L.*) and lupin (*Lupinus albus L.*) play a fundamental role in organic agriculture and livestock (Siddique et al, 1999) to improve soil fertility, to close the cycle of nitrogen and as protein sources alternative to soybean which could reduce the risk of GMO contamination in the food chain. Even though field pea and faba bean are mainly diffused in Italy as grain legumes for animal feeding, recently a strong interest has been developed for white lupin (*Lupinus albus L.*) due to its interesting performance in France, Germany and Australia. In Italy only one lupin variety (Multitalia) is enrolled in the national registry; moreover lupin cultivation was reduced from 60.000 hectars in 1931-35, with an average seed production of 0,93 t/ha, to 3.000 hectars in the period 1986-1990, with an average seed production of 1,27 t/ha. At present, due to the need of identifying an alternative to soybean in the organic livestock sector, the cultivation of lupin can gain a renewed interest. The purpose of the research was to evaluate the adaptability to environments of Central Italy and to evaluate the agronomic performance~~s~~ of grain legumes such as field pea, faba bean and lupin in organic cropping system.

Materials and methods

The field experiments were carried out in the growing season 2005/06 in two organic farms of the Central Italy, one (S1) located in province of Florence (Tuscany) and the

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other (S2) in province of Ancona (Marche region). The soil characteristics in the two locations are reported in Table 1.

Tab. 1: Soil characteristic (0-30 cm) in the two experimental fields

Experimental site	Clay content %	organic matter %	pH	N tot ‰	P2O5 avail. mg/kg	K20 exch. mg/kg	Ca exch. mg/kg
S1	65,00	1,67	6,86	1,21	150,60	351	2321
S2	41,40	1,68	8,20	1,10	19,00	228	81000

The eight varieties (2 of faba bean, 3 of field pea, 3 of white lupin) of Italian and French origin used in both field trials are listed in Table 2. Both in Tuscany and in the Marche region sowing was carried out in November. Lupin seeds were inoculated with *Bradyrhizobium lupins* (souche LL13). In the trial carried out in the Marche region also the pea varieties Speleo and Pacific were included.

Tab. 2: Characteristics of the varieties of leguminous used in the experiment

Species	Variety	Constitutor	Seed density (seeds/m^2)	Distance between rows (cm)
Vicia faba L var. minor	Vesuvio	Iscf/SIS	50	18
	Chiaro di Torre Lama	Università di Napoli/ Agroservice	50	18
Pisum sativum L. leafless type	Classic	Cebeco	100	18
	Hardy	Serasem/Florisem	100	18
	Ideal	Serasem/SIS	100	18
Lupinus albus L.	Multitalia	Università di Napoli/ Agroservice	50	36
	Lumen	Inra-AgriObtentions/ Jouffrey Drillaud	50	36
	Luxe	Inra-AgriObtentions/ Jouffrey Drillaud	50	36

In both locations lupin crop has endured strong damages from winter cold and in the S1 trial a spring seeding of lupin was executed. The field trial was laid out in a randomized block design with two and three replicates in the S1 and S2 location, respectively. Plot size was 1020 m^2 (6x170m) in S1 and 420 m^2 (6x70m) in the S2 location. In the S1 site, the presence and density of weeds (number of species and number of individuals for each species) was determined in April 2006 with two samplings of 0,25 m^2 within each plot. In June 2006 average plant height and time of the reached maturity (expressed as number of days after sowing) were assessed. Moreover, at maturity plants were harvested by hand with 3 samplings of 1 m^2 within each plot. Weeds were separated from leguminous crop plants and both were oven dried at 80 °C to constant weight to assess dry matter (DM) production. In both experimental sites, mechanical harvesting was performed when grain reached 13% of relative humidity. Differences between treatments were tested using an analysis of variance (ANOVA) and mean comparisons were evaluated by the Bonferroni test.

Results and Discussion

In the location S1, faba bean and field pea reached maturity with slight differences (tab. 3) while the varieties sown in spring didn't manage to mature properly before the warmth.

Tab. 3: Reached maturity of leguminous crop in Days After Sowing (DAS) in S1

Crop	Variety	Sown period	Maturity DAS (gg)
Faba bean	Vesuvio	autumn	214
Faba bean	Chiaro T.L.	autumn	213
Pea	Classic	autumn	214
Pea	Hardy	autumn	216
Pea	Ideal	autumn	216
Pea	Hardy	spring	88
Lupin	Multitalia	spring	102
Lupin	Luxe	spring	102

At maturity faba bean plant were higher than the other species but both field pea and faba bean sown in autumn accumulated equivalent biomass (tab. 4). However, field pea varieties sown in autumn obtained greater grain yield than faba bean. The performances of lupin Multitalia is interesting as it reached equivalent height and biomass of pea and faba bean varieties sown in autumn and greater grain yield than faba bean.

Tab. 4: Average height (cm) and dry matter of leguminous crop (gr/m^2), dry matter of weed (g/m^2), grain yield at 13% of humidity (t/ha) in S1

Source of variation	n weed plant	n weed species	DM weed		H Leg		DM Leg		Grain Yield	
			(g/m^2)		(cm)		(g/m^2)		(t/ha)	
Species			***		***		***		***	
Faba Vesuv.	95	8,0	45,58	c	98,00	ab	940,63	a	3,16	f
Faba Chiaro	117,5	8,0	56,16	c	107,33	a	1036,60	a	3,49	e
Pea Class.	43,5	8,5	49,66	c	92,83	b	1039,98	a	5,36	b
Pea Hardy	94,5	10,5	43,50	c	95,16	ab	1117,66	a	6,03	a
Pea Ideal	98	8,5	34,33	c	91,00	b	1040,35	a	5,15	c
Pea Hardy	59	8,0	140,00	b	52,16	c	263,33	b	0,00	g
Lupin Multi.	42,5	4,0	36,95	c	91,50	b	874,25	a	4,50	d
Lupin Luxe	9,5	1,5	251,00	a	26,66d	d	170,83	d	0,00	g

* significant for P<0.05; *** significant for P<0.001

The weed DM biomass is inversely proportional to the biomass developed by the cultivated plant. Spring pea Hardy was the less competitive against weed and lupin Multitalia was competitive as the crops sown in autumn. Results concerning grain production obtained in the field trial carried out in the Marche region are summarized in Table 5. Field pea varieties showed significantly higher seed productions than faba bean. In particular, the varieties Speleo and Hardy showed seed yield higher than 4 t/ha, which can be considered of relevant interest for organic farms of Central Italy. Pacific was characterized by the lowest yield among the field pea varieties tested. The low grain yield of faba bean varieties (low vegetative growth, a low density of the faba bean crop in terms of number of plants/m^2 and a low number of legumes per plant) could be a consequence of the environmental conditions of winter and spring in the growing season 2005-2006. This trend was observed also in most of the farms which cultivated faba bean in the area where the field trial was conducted. Lupin cultivation completely failed in the S2 location, probably due to the high pH and $CaCO_3$ concentration values of soil (tab. 1). This result, compared to the success of the lupin crop in the Tuscany trial, support the need of new lupin varieties with an increased tolerance to high soil pH values to extend this crop in wider areas of Central Italy.

Tab. 5: Average grain yield at 13% of humidity (ton/ha) obtained in the field trial carried out in the Marche region. All lupin crops failed

Source of variation	Grain (t ha^{-1}	
Species/Variety	*	
Pea Speleo aut.	4,34	a
Pea Hardy aut.	4,23	ab
Pea Ideal aut.	3,80	ab
Pea Classic aut.	3,51	b
Pea Pacific aut.	2,61	c
Faba bean Chiaro T.L. aut.	2,07	c
Faba bean Vesuvio aut.	1,89	c

* significant for P<0.05; *** significant for P<0.001¨

Conclusions

Pea was shown to have higher grain yield in both sites than faba bean and lupin. The proper choice of variety and right time of seeding are fundamental for the pea cultivation in organic agriculture. Faba bean and lupin were influenced by winter cold and adverse environmental condition. However, lupin Multitalia sown in spring managed to develop a good biomass in order to compete against weeds and to produce grain yield greater than autumnal faba bean.

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Influence of intercropping and irrigation frequencies on leaf development and taro (Cocoyam) productivity under organic management

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Key words: Organic Agriculture, *Colocasia esculenta*, *Crotalaria juncea* und Green Manuring

Abstract

The objective of this work was to evaluate the influence of the intercropping and irrigation frequencies on the leaf development and productivity of taro (Colocasia esculenta) under organic management. The experiment was set up as a randomized complete block design, a factorial 2 x 2, with four replications. Taro was cultivated in monoculture or intercropped with Crotalaria juncea under two irrigation frequencies: every 3.5 days for 30 minutes and every 15 days for 2 hours. The intercropping increased taro petiole length but did not increase leaf area. The same effects were observed for irrigation frequency on the leaf area and petiole, length at the 30th and 60th days after C. juncea cutting. The amount of taro yield and offshoot number of class 1 (category up to 40g) were affected negatively by the intercropping. However the total number, total yield and average weight of the offshoot were not affected by the intercropping. The irrigation frequency promoted positive effects in the number and weight of offshoot (category of 80g weight or higher), as well as in the total taro yield and average offshoot weight. The conclusion was that the short frequency irrigation contributed for the development and productivity of taro offshoots and the intercropping with C. juncea did not decreased the total productivity of taro cropping.

Introduction

The taro (*Colocasia esculenta*) is a food with great potential for exploration, because it has a good rusticity and adaptation capacity to different conditions of soil and climate (Nolasco, 1983) of the tropics and is well suitable for organic production. The cycle of the culture of taro is influenced by several factors, including: temperature, variety, brightness and availability of water and nutrients. In Brazil, the cycle varies between 5 and 9 months in the Central Regions and Southeast of the country (Filgueira, 2003). The initial growth of taro is slow, only reaching maximum development between the fourth and sixth month. That phase is marked by the increase in the leaf area, in the number of leaves and plant height. In the next phase, the leaf development decreases in intensity and the plant growth is reduced. Under irrigation, the cycle is prolonged and the maturation point is more difficultly recognized, and the harvested period can be reduced, because tillering starts faster (Soares, 1991). Some of those factors such as availability of nutrients and plant variety characteristics have been studied, however, the factor water supply and shading still need more information, primarily in planting systems intercropped with legume. The objective of the present work was to

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determine the influence of the intercropping and irrigation frequencies in the leaf development and productivity of taro (*Colocasia esculenta*) under organic management.

Materials and methods

The experiment was conducted in the Experimental Station of Pesagro-Rio (Rio de Janeiro State Agricultural Research Organization) in Avelar, Municipality of Paty do Alferes, State of Rio de Janeiro, Brazil. The Station is located in a mountain area at 575m of altitude with climatic condition of “tropical humid of altitude” according to the Köppen system. The soil of the experimental area is an Oxisol previously cultivated during several years with horticultural crops. Soil was ploughed down once and disked in twice before planting. The experiment was set up as a randomized complete block design, a factorial 2 x 2, with four replications. The treatments were two crop systems, taro in monoculture or intercropped with *Crotalaria juncea*, and two different irrigation frequencies: 30 minutes every 3.5 days (short frequency) and 2 hours every 15 days (long frequency), being four hours/month with the same volume of water for both cases. The taro was planted in the spacing of 1.0 x 0.3 m. At planting time it was applied bovine manure equivalent to 100 kg ha^{-1} of nitrogen. The *C. juncea* was sowing in double lines (spaced 0.5m with 30 seeds/linear meter) between the taro raw 90 days after the taro planting, and cut 60 days after planting. The attributes evaluated in the taro plants, after the legume cutting, consisted in measurements of the leaf area and height of taro plants in a follow up of three months. In the harvesting time it was evaluated the number and yield of the taro offshoots separated in three categories: class 1 - up to 40 g; class 2 - between 40 g and 80 g and class 3 - above 80 g. For statistics interpretation, it was applied the F test and Scott-Knott test ($p<0.05$).

Results

The statistical analysis showed significant effects for factors, but no interaction among them. The leaf area was the same in monoculture or intercropped with *C. juncea* (Figure 1), declining significantly in the end of the cycle, not happening the same with the height of the plants.

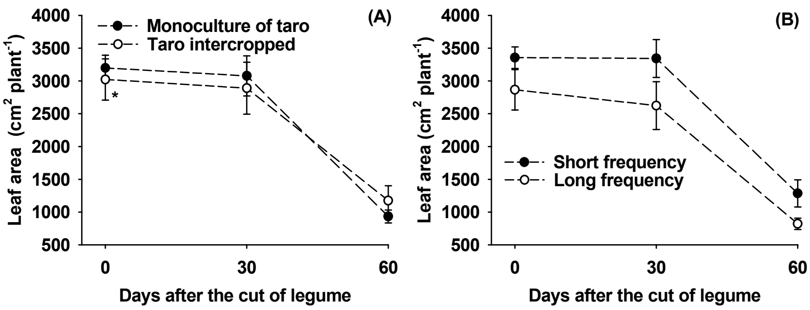

Figure 1: Leaf area of taro plants (A) in monoculture or intercropped with *C. juncea,* and (B) with different irrigation frequency at 0, 30 and 60 days after the cut of the legume. *Vertical bar indicate ± standard error of the mean.

The taro petiole was longer in the intercropping system with a legume cut at 60 days (Figure 2). The same effect was observed for the irrigation frequency, being the larger leaf area and taller plants at 30t and 60 days for the short frequency irrigation.

The taro yield and offshoot number (class 1) was affected negatively by the intercropping system. However, the total number and offshoot yield were not affected by the intercropping, as well as the weight of the taro corms and offshoots (Table 1). The short irrigation frequency promoted effects significantly larger in the number and weight of offshoot of the class 3, as well as in the total productivity and medium weight of offshoot, not affecting the weight of the central taro corm (Table 1).

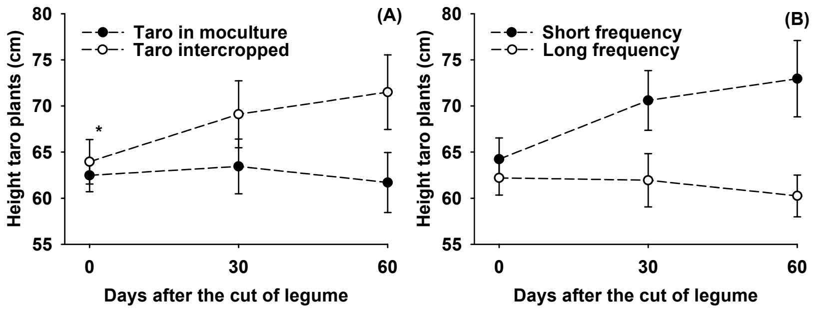

Figure 2: The taro plant height (A) monoculture or intercropping with *C. juncea*, and (B) irrigation frequency at 0, 30 and 60 days after legume cutting. *Bars in vertical indicate ± standard error of the mean.

Tab. 1: Mean values of total number and yield of taro offshoots and corms in monoculture and intercropped with *C. juncea* under different irrigation frequency.

Treatments[1]	ONC[2] ha^{-1} x 10^3			TON ha^{-1} x 10^3	WC (Mg ha^{-1})			TOW Mg ha^{-1}	WCC Mg ha^{-1}	WMS (g)
Irrigation frequency	1	2	3		1	2	3			
Long frequency	102,20 a	70,63 a	37,30 b	210,13 a	1,87 a	3,15 a	2,66 b	7,68b	3,12 a	35,53 b
Short frequency	112,50 a	80,67 a	66,72 a	259,90 a	2,21 a	3,42 a	5,66 a	11,29 a	3,63 a	43,83 a
Crop system										
Monoculture	124,15 a	80,06 a	54,03 a	258,24 a	2,35 a	3,27 a	4,20 a	9,82a	3,19 a	37,65 a
Intercropped	90,55b	71,25 a	50,00 a	211,80 a	1,73 b	3,30 a	4,12 a	9,15a	3,55 a	41,71 a
C.V. (%)	17,52	30,14	45,69	21,02	22,75	28,27	44,20	28,57	24,25	16,87

[1]Means followed by the same letters in the column for the same treatment are not different by Scott-Knott test (p>0.05).
[2]Taro offshoot number per class (ONC), total taro offshoot number (TON), weight per class (WC), total offshoot weight (TOW), weight of central corm (WCC) and mean offshoot weight (WMS).

Discussion

The growth of *C. juncea* caused progressive increases of shading on taro plants. Although the majority of the species of the family Aracea is considered shade-tolerant (Rubatzky & Yamaguchi, 1997) taro intercropped with *C. juncea* showed increasing on petiole length, and in consequence taller plants were produced in comparison to taro cropped alone. This result was different than what could be expected for a shade tolerant specie (Rubatzky & Yamaguchi, 1997). During the taro cycle some leaf blights occurred due to excess of sun shinning, what might have affected the leaf area in monoculture, as well as in the long frequency irrigation for monoculture and intercropping treatments. In a shading condition, the reduction in taro offshoot number (class 1) in the intercropping treatment may be due to decreasing in energy and nutrients availability for the central taro corm and the use of this energy and nutrients for prolongation leaf petiole. Oliveira (2004) also found in an alley cropping of taro with pigeon pea (*Cajanus cajan*) the incidence of leaf blight where legume was pruned.

Conclusions

The intercropping of taro with *C. juncea* stimulates the development of taller taro plant but not altering taro leaf area.

The intercropping affects negatively the number and yield of offshoot of the class 1 but not affecting the total yield and total number of offshoot all classes together.

Short irrigation frequency increases in the taro: the leaf area, the plant height, the mean offshoot weight, and the total offshoot yield.

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Effect of crop management on weeds, pests and diseases

Effects of husked oat varieties, variety mixtures and populations on disease levels, crop cover and their resulting yields

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Key words: husked oats; varieties; variety mixtures; diseases; crop cover

Abstract

Two seasons (2005/06 and 2006/07) of field experiments which aimed to study the suitability of new and established husked oat varieties, variety mixtures and a husked oat population for organic systems were established at two sites in the west and east of the UK. The ground cover and leaf area indices of the varieties had significant effects on final yields in the 2005/06. Mixtures generally yielded similarly to the means of component varieties but the mixtures in 2005/06 and 2006/07 had 25 % and 18 % less disease, respectively, than the average of the component varieties at one site.

Introduction

Oats have many qualities that make them suitable for organic production including high nitrogen use efficiency (Sylvester-Bradley, 1993) and competitiveness against weeds (Seavers & Wright, 1999). The aim of this project was to identify, in existing and novel husked oat varieties, traits that are key for organic farmers. These traits include competitiveness (measured by crop cover and maximum leaf area index (LAI)), pest and disease resistance and good combining ability in variety mixtures that may help to overcome variability caused by biotic and abiotic stresses.

This paper discusses crop cover, LAI and disease results of two years of the husked oats experiments and their influence on final yields. Further details of the trials can be found in Clarke *et al.* (2007) and Jones *et al.* (2006).

Materials and methods

Organic trials examining husked varieties of winter oats were established at both Sheepdrove Organic Farm, Berkshire, UK and Wakelyns Agroforestry, Suffolk, UK in October 2005 and 2006. The experiments tested three varieties (Gerald, Tardis, Brochan) in 2005/06 and four (original three plus Mascani) in 2006/07, plus their three (or four) -way mixture and a selection of lines bulked at F2 ('population') and then grown at only Sheepdrove or Wakelyns. The experiments were carried out as the first cereal in the rotation (after a grass-clover ley) in 2005/06 and the second cereal in the rotation in 2006/07. The experiments were of a replicated split-plot design with 1.45m x 10m split-plots. Variety assessments included numbers of plants emerged and established, early crop cover (percentage of ground covered by crop) at growth stage (GS) 29 (Zadoks *et al.*, 1974), crop height, diseases on the flag leaf (GS 70-75), lodging, maximum canopy cover, and grain yield.

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Results

Trial season 2005/06

The first differences among husked varieties were detected when crop cover was determined early in the season. The significant ($P < 0.001$) differences in early crop cover among varieties were evident at Wakelyns only (Table 1), where Tardis had the highest crop cover, Brochan was slightly, but not significantly lower, and Gerald had a significantly lower level of crop cover than Tardis and Brochan. This trend was seen again, but this time at both sites, later in the season when maximum Leaf Area Index (LAI) was determined (Table 1). For both assessments, and at both sites, the mixture performed better than the mean of the components, although the differences were small at Wakelyns. At Wakelyns the mixture had a 2 % higher leaf area index than the component varieties and at Sheepdrove, this was higher at 10%.

There were generally low levels of the foliar diseases crown rust (*Puccinia coronata*) and powdery mildew (*Erysiphe graminis*) this season. However, at Sheepdrove, there were significant ($P < 0.001$) differences among varieties in terms of disease; Tardis had the lowest levels and Gerald the highest (Table 1). The variety mixture had 25% less foliar disease than would have been expected from the average of the component varieties.

Yields were generally high, with yields at Wakelyns averaging 9.8 t ha^{-1}. At both sites, the significant ($P < 0.05$) differences among varieties showed the same effects (Table 1); Tardis had the highest yield and Gerald the lowest. The mixtures yielded 2 % higher than the mean of the component varieties and the ‘population’ yields were similar to those of the mixture.

Tab. 1: Mean early crop cover, Leaf Area Index (LAI), percentage disease on the flag leaf and yield of husked varieties grown at Sheepdrove, Berkshire and Wakelyns, Suffolk in 2005/06.

Site	Variety	Early crop cover (%)	Maximum LAI	Total Disease (%)	Yield (t/ha at 15% moisture concentration)
Wakelyns	Brochan	46.4	9.96	-	9.55
	Tardis	50.1	9.75	-	10.48
	Gerald	36.3	8.98	-	9.04
	Mixture	45.3	9.80	-	9.90
	Population	46.7	9.89	-	9.96
	l.s.d.	4.34	0.455	-	0.357
Sheepdrove	Brochan	16.0	6.60	11.0	6.98
	Tardis	17.8	6.31	1.7	7.70
	Gerald	17.3	5.97	14.4	6.93
	Mixture	17.8	6.95	6.8	7.35
	Population	18.8	6.48	7.7	7.23
	l.s.d.	4.74	0.632	2.78	0.465

Trial season 2006/07

Differences were detected in early crop cover among the entries only at Sheepdrove. Tardis had a significantly (P = 0.015) higher level of crop cover than the other varieties and mixture (Table 2). However, there were no significant differences in LAI among the varieties, the mixture and populations at either Sheepdrove or Wakelyns.

This season was notable in terms of the large amounts of disease present, especially crown rust (*Puccinia coronata*). There were significant (P < 0.001) differences in total disease levels on the flag leaf among the varieties, mixture and populations (Table 2) at both Sheepdrove and Wakelyns. At Sheepdrove, Gerald had significantly higher levels of disease than the other varieties, with Mascani having slightly, but not significantly, lower levels than Brochan and Tardis. At Wakelyns, Gerald had the lowest level of disease of the varieties, but was still greater than the population. The disease results of both sites are reflected in the yields of the varieties with Gerald having the lowest and Mascani the highest yields at Sheepdrove and Gerald the highest yields at Wakelyns (Table 2). The mixture had 18 % less disease than the average of its component varieties at Sheepdrove (Table 2), but only 3% higher yields. The populations yielded relatively well at both sites.

Tab. 2: Mean early crop cover, Leaf Area Index (LAI), percentage disease on the flag leaf and yield of husked varieties grown at Sheepdrove, Berkshire and Wakelyns, Suffolk in 2006/07.

Site	Variety	Early crop cover (%)	Maximum LAI	Total Disease (%)	Yield (t/ha at 15% moisture concentration)
Wakelyns	Brochan	28.9	2.74	81.6	3.99
	Tardis	25.9	2.91	85.6	4.02
	Gerald	26.7	2.68	65.8	4.75
	Mascani	22.8	3.11	83.8	4.41
	Mixture	27.2	2.76	80.0	4.09
	Population	34.2	2.86	58.2	4.65
	l.s.d.	6.82	0.349	7.20	0.371
Sheepdrove	Brochan	39.4	4.74	11.4	6.23
	Tardis	52.8	4.58	10.3	6.66
	Gerald	37.0	4.26	22.3	6.15
	Mascani	42.5	4.55	8.9	7.05
	Mixture	41.3	4.69	10.8	6.71
	Population	45.1	4.49	14.4	7.20
	l.s.d.	8.85	0.63	5.23	0.590

Discussion

In 2005/06 differences in canopy cover and LAI throughout the season had major effects on final variety yields. This is likely to have been due to the greater level of photosynthesis in the denser crops, but may also have resulted from the better weed smothering ability of the larger plants, a trait especially important early in the season (Bond & Grundy, 2001). Effects were not found to the same extent in 2006/07, but this was related to very unusual weather patterns during the season which may have influenced tillering.

Disease levels were also important in determining final yield, especially in 2006/07 where severity was greater due to a wet summer. The results from both seasons show the effectiveness of mixtures at controlling the spread of disease, with 25% and 18% less disease present on the flag leaves of the mixtures than the average of the component varieties at Sheepdrove in 2005/06 and 2006/07, respectively.

The use of populations gives an extra level of diversity over and above that found in mixtures, leading to complementation of genotypes and the ability to buffer environmental variation (Phillips & Powell, 1984). In 2006/07 this ability may have lead to the populations having the highest and second highest yield at Sheepdrove and Wakelyns, respectively, when unusual weather patterns resulted in lower than average yields.

Conclusions

Tardis and Mascani were the best performing varieties in 2005/06 and 2006/07, respectively. However, mixtures were useful in reducing disease levels, and populations performed consistently well.

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Exploiting weed management benefits of cover crops requires pre-emption of seed rain

Gallandt, E.R.[1], & Molloy, T.[1]

Key words: cropping system; green manure; weed seedbank

Abstract

To manage weeds with reduced reliance on, or without herbicides, cropping systems require intervals during which rapid and significant reductions in the germinable portion of the weed seedbank occur or, if already small, management to maintain a low density. Cover cropping systems and component studies have identified single-season cover cropping practices that will lower the density of the germinable weed seedbank, offering an effective means for managing the weed seedbank while maintaining or improving soil health. Specifically, field experiments demonstrated that soil disturbance events associated with cover cropping encouraged germination and seedling establishment thereby reducing the density of germinable seeds in the weed seedbank. Of notable importance, however, are the disturbance events that preempt weed seed rain. If weeds are permitted to reach reproductive maturity in cash or cover crops, the "debits" to the seedbank resulting from early season disturbance will likely be overwhelmed by the resulting seed rain "credits."

Introduction

Cultivation generally kills a constant proportion of established weed seedlings (Mohler, 2001). High levels of weed control in organically-managed fields thus requires a low density of germinable seeds in the weed seedbank, and consequently a low initial density of weed seedlings. Seedbanks in agricultural systems may be managed by maintaining low densities of weeds, by enhancing the competitive advantage of the crop, by increasing seed mortality, and by manipulation of the soil environment to reduce the probability of weed establishment (Gallandt 2006. Cover cropping practices may be useful in this regard, contributing soil disturbance events that preempt weed growth and stimulate germination of additional weeds, and establishing a competitive environment that can reduce seed production of surviving weeds. Moreover, cover crops often offer flexible management opportunities that can prevent weed seed rain. They also contribute residues that reduce weed establishment in subsequent crops. A further advantage of cover cropping practices is their potential beneficial contribution to soil quality.

We compared single-season cover cropping practices, varying in intensity, for their ability to directly or indirectly reduce the density of germinable seeds in the weed seedbank. We hypothesized that the decline in the weed seedbank would be proportional to the intensity of cover cropping as reflected by the amount of time live cover crop biomass is present in a system, and the frequency of unique disturbance (tillage/mowing) events.

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Materials and methods

To evaluate the contribution of cover cropping practices to the management of the weed seedbank, field experiments were established in the spring of 2004 and repeated in the spring of 2005, in a randomized complete block design with four replications. Treatments included four cover crop systems and a fallow control. We considered the intensity of cover cropping to be based on the length of time a field is kept in a living cover crop, the biomass production of the cover crop, and the number of tillage or mowing events before the next cash crop (Figure 1). Back-to-back cover cropping involves more soil disturbance and was therefore hypothesized to decrease the soil seedbank faster.

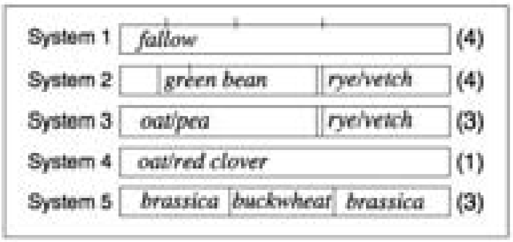

Figure 1: Cover cropping systems established in 2004 and repeated in 2005. Numbers in parentheses indicate major disturbance events that would preempt weed growth.

Synthetic seedbanks were established in the areas to be planted to the cover crop Systems. Weeds were dispersed at 2100 viable seeds m^{-2} in the early spring ("frost-seeded") prior to cover crop establishment. The synthetic seedbanks included a 2 m^{-2} area seeded with an equal number of *Setaria lutescens*, *Chenopodium album*, and *Abutilon theophrasti*. Ceramic beads, similar in size and density to *C. album*, were included to evaluate the efficiency of recovery. Greenhouse germination was used to estimate the readily germinable (non-dormant) fraction of the seedbank. Direct extraction using specialized wet sieving equipment was used on sub-samples to enumerate dormant seeds and ceramic beads.

Results

Greenhouse germination. The initial germinable seedbank densities were unaffected by System (Figure 2). Poor timing of late-season disturbance resulted in considerable *C. album* seed production and an increase in the seedbank in the field pea/oat-rye/vetch system (Figure 2 A). Other treatments responded remarkably similar over time and species, demonstrating that systems with more soil disturbance events result in greater depletion of the seedbank over a single season (Figure 2). Notable is the consistently dramatic single-season reduction in *C. album*, *S. lutescens* and *A. theophrasti* in the systems that included three or more unique disturbance events (Figure 2 A-C).

Direct extraction. Thirty nine percent of the sown "surrogate" seeds (ceramic beads), averaged over years, were recovered in the spring following sowing, and 25% in the following spring. The density of *S. lutescens* seeds remained the greatest in the oat/red clover system (data not shown), consistent with the theory that season-long cover crops may act to preserve the preceding years seedbank compared to systems managed with more frequent disturbance events.

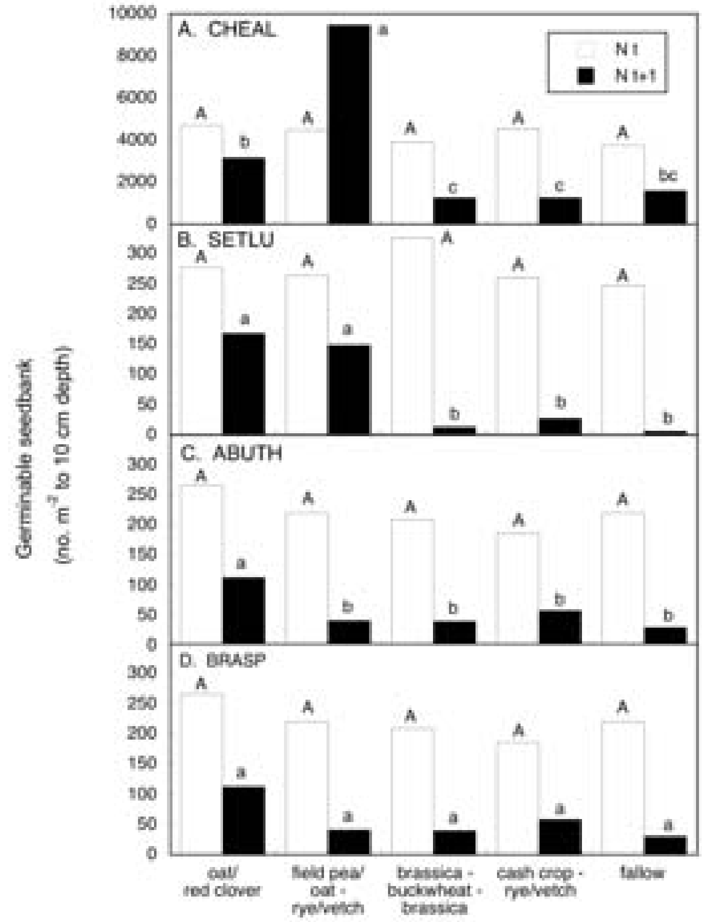

Figure 2: Density of germinable seeds sampled in the spring, prior to implementing cover cropping sytems (N t), and sampled the following spring (N t+1), in Maine, U.S.A. *Oat/red clover* included a single unique disturbance event whereas *fallow* and *cash crop/rye vetch* received four disturbance events; other systems included three disturbance events. Species included *Chenopodium album* (A), *Setaria lutescens*, *Abutilon theophrasti* (C), and several brassica species (D), primarily *Sinapus arvenses*, *Brassica rapa*, and *Raphanus raphanistrum*. Means labeled with common letters within year (N t or N t+1) are not significantly different (P > 0.05).

Discussion

Cover crops may contribute multiple benefits to organic farming systems that aim to function with greater biodiversity, notably linking management to improve soil quality with multiple direct and indirect stresses that may reduce weed problems (Bàrberi 2002; Gallandt 2004). While the beneficial contributions of cover crops are frequently discussed, without strategic implementation, cover cropping may actually exacerbate existing weed problems. A long period of a perennial cover crop will, for example, preserve the seedbank of relatively persistent species. If the growth of a cover crop is not terminated prior to weed reproduction, the cover crop can contribute significant seed rain. Thus, deployment of cover crops should be guided by the timing of unique disturbance events to avoid "crediting" the seed bank while maximizing opportunities for "debiting" the seedbank (Forcella 2003). For example, post-harvest management should aim to keep seeds on the soil surface to encourage predation (Westerman et al., 2006), and timing of tillage events, i.e., summer fallowing, should aim to maximize germination losses.

Conclusions

Single-season cover cropping practices including three or more unique soil disturbance events resulted in a marked reduction in the germinable weed seedbank. Despite their apparent competitive ability, and likely benefits to soil quality, full season cover crops lacking soil disturbance may result in considerable weed seed rain and therefore an increasing weed problem in subsequent years. While we do not discourage growers from considering these full-season cover crops, they must be monitored carefully so that they are terminated prior to production of viable weed seed.

Acknowledgments

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Direct Seeding of Faba Beans in Organic Agriculture

Köpke, U.[1] & Schulte, H.

Key words: weed control, high residue reduced tillage system, mulch, precrop oats, gross margin

Abstract

Field experiments carried out at two experimental sites over two years showed that temporary direct seeding (DS) of faba beans (FAB) is possible in Organic Agriculture (OA) when weed pressure of perennials is low. Weed density of DS treatments was significantly lower when compared with mouldboard plough (MP, control) although no clear effects on annual weeds were given by the precrop oats neither by the amount of crop residues (0, 4, 6 t ha^{-1}) nor the sowing density of autumnal sown oats (0, 600, 1200, 1800 seeds m^{-2}) simulating hail-shattered grains. No significant differences in grain yield but lower costs of labour and fuel were determined for DS compared with MP. Estimated DS gross margins exceeded MP gross margins when DS yield losses remained lower than 0.95 t ha^{-1} as compared with MP yields.

Introduction

The aim of reducing tillage intensity is to prevent soil compaction and erosion, to improve top soil trafficability and to save labour and energy costs. All non-inverting tillage procedures usually show higher microbial activity or microbial biomass in the upper topsoil compared with the lower topsoil. Correspondingly, it is often suggested that tillage procedures in Organic Agriculture (OA) should avoid disturbance and mix of the different soil layers. However, the use of loose soil husbandry (LSH) which is mostly performed with the mouldboard plough (MP) and combined with secondary tillage is still common practice. Only a few organic farmers in Central Europe are using the extreme option of firm soil mulch husbandry (FSMH), i.e. direct seeding (DS), mainly due to two reasons: i. under temperate climate conditions omitting deep loosening and thorough inversion of the topsoil results in cooler and wetter soils in early spring and hence in reduced mineralization and nitrification of soil-borne nitrogen and its transformation into crop yield of non-leguminous crops. ii. tillage, and in particular ploughing, is one of the most effective tools to directly control annual and perennial weeds as well. Synthetic total herbicides that enable mainstream farmers to conduct no-till systems over years are not allowed to be used in OA, and their natural counterparts ('bioherbicides') that are officially certified in other regions of this globe (e.g. natural vinegar, corn gluten, pine wood extracts) are currently not considered as adequate to be used in Europe's OA (Kühne et al. 2005).

In contrast to non-legumes, grain legumes do not depend on soil-borne nitrogen due to their ability to fix nitrogen symbiotically. Competitiveness against weeds is high for faba beans (FAB) which can satisfy their high demand for water to germinate in wetter no-tilled soil.

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Mulch layers of precrops may suppress weeds. For efficient weed suppression Barberi (2002) considers homogeneous distribution of at least 4-6 t ha^{-1} crop residues necessary. Additionally, allelopathic action of some oats genotypes has been assumed (Chou 1986). For the conditions of European temperate climate, competitiveness of yellow oats (*Avena sativa* L.) is considered as relatively high when compared with other cereals (Davies & Welsh 2001). Our own previous experiments have shown that yellow oats performed better, i.e. more residues and higher crop ground cover were produced when compared with black oats (*Avena strigosa* Schreb). Based on the experience in year 2004 when hail-shattered grains and reduced yield of yellow oats by 60%, leaving the field with a thick mulch layer of straw and shattered germinating seeds weed free, we established field trials in order to test the following hypotheses: (i.) Direct seeding of FAB into a mulch layer of precrop oats enables sufficient control of annual weeds. (ii.) Increasing density of autumnal germinating oats can further increase weed suppression. (iii.) Perennial weeds can limit FAB grain yield also in a system that omits tillage only temporarily.

Materials and methods

Two two-factorial field trials with four replicates were carried out in 2006 and 2007 at the organic research farm Wiesengut (WG) of the University of Bonn in Hennef (Germany) on a clayey-silty to sandy-silty floodplain sediment (fluvisol, 50°48´ N, 7°17´ E; 62 m a.s.l.; mean annual temperature 10.2°C; mean annual precipitation 750 mm). The experimental site was homogeneously covered with *Ranunculus sardous*, an endangered 'red list' annual weed species that could develop vigorously in autumn and overwintered with about 15 winter rosettes m^{-2} . Thus, *R. sardous* was considered as realizing early competition comparable to perennial weeds. A further trial was conducted in 2007 under the conditions of low weed pressure on a conventional experimental farm Frankenforst (FF) on a stagnic luvisol derived from loess (50°42' N, 7°12' E; 182 m a.s.l.). Since data of 2007 are still not fully exploited predominantly results of 2006 are presented here. DS-treatments were: (a) straw residue: 0, 4, 6 t ha^{-1}, resp.; (b) autumnal seeding density of oats: 0, 600, 1200, 1800 grains m^{-2}, resp., hand sown broadcasted into oats stubble. MP control consisted of oil radish as winter cover crop, ploughing and seed bed preparation in early spring. FAB (45 grains $m^{-2)}$ were sown in all treatments of WG-2006 trial on March 24, 2006 with a direct seeding machine (John Deere 750 A). Crop establishment was determined. Weed ground cover, weed density and weed dry matter were determined four times over the growing season in 0.5 m^2 subplots. Besides combine harvesting on 11 m^2 $plot^{-1}$ grain yield and yield components were determined also in weedy and manually weeded 1m^2 subplots Soil nitrate and ammonium were determined. ANOVA was performed by using SPSS (version 14) followed by Shapiro-Wilk's test. In a first step factors 'residues' and 'seeding density of oats' were tested omitting the control. In a second step a pairwise comparison of each DS treatment with MP control was performed by using the Dunett's test.

Results and brief discussion

Seeding density and crop establishment of FAB were equal in DS and MP treatments (38 plants m^{-2}). According to our hypothesis, density of annuals apart from *R. sardous* was significantly lower in DS treatments compared with MP control (FIG 1). Pairwise comparison of weed dry matter including *R. sardous* resulted in some DS treatments significantly higher compared with MP control that eliminated *R. sardous* completely. Weed parameters did show neither a significant effect of increasing amount of straw residue nor the seeding density of oats whose seedlings were totally destroyed by frost over winter as expected. Soil nitrate in DS treatments was significantly lower compared with the MP treatment. Retarded early development of FAB in DS treatments was considered as resulting from cooler and wetter soil as well as high competitiveness of *R. sardous*. Significantly higher shoot d. m. production was determined in MP compared with DS until 90 DAS (FIG. 2). FAB did overgrow weeds in DS after *R. sardous* finished flowering. 130 DAS (harvest date) differences of shoot mass of tillage treatments no longer existed.

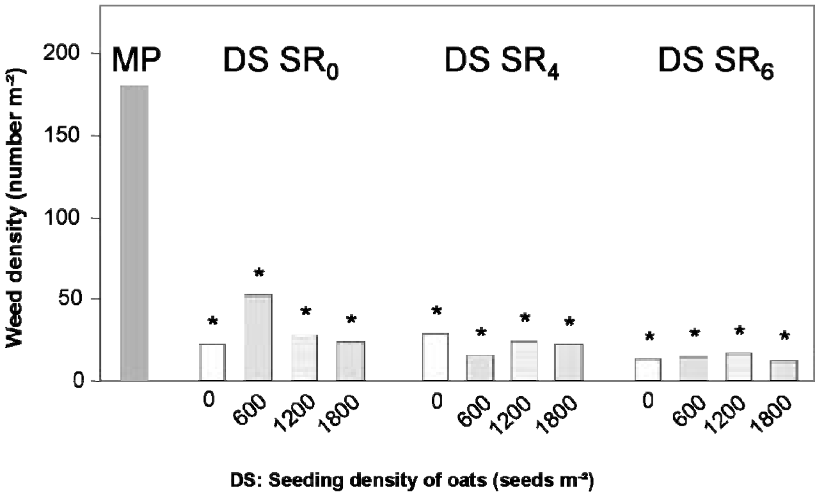
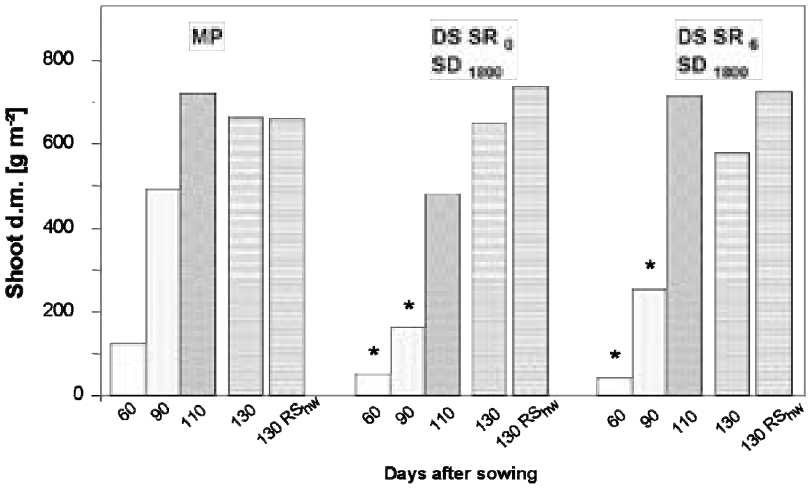


Figure 1: Weed density (*R. sardous* not included) in faba beans (30 DAS), as affected by tillage treatment (mouldboard plough MP, direct seeding DS), amount of straw residues (SR in DS: 0, 4 and 6 t ha^{-1}) and seeding density of oats (sown in autumn). Pairwise comparison of MP with DS treatments: Dunett's test, * significant for P<0.05

The early competition of *R. sardous* in DS plots was indicated by higher pod insertion in DS plots (not shown). Competitiveness of R. *sardous* in DS plots resulted in significantly lower grain yield compared with the hand weeded plots. Nevertheless, retarded FAB development resulted in no significant yield losses in DS treatments. No significant yield differences were determined between MP (3.80 t ha^{-1}) and DS (3.44 t ha^{-1}) treatments which showed no tendency of lower grain yield neither influenced by the amount of straw residues nor the seeding density of oats. Costs for labour and fuel inputs were more than five-fold higher in MP (€ 275 ha^{-1}) compared with DS (€ 48 ha^{-1}) resulting in a 0.95 t ha^{-1} lower grain yield for DS that might be accepted at least to equalize gross margin of the MP treatment when based on a FAB market price of € 240 t^{-1}. Low weed pressure and vigorous growth enabled DS FAB in the 2007-FF-trial to yield 3.83 t ha^{-1} grain compared with 3.40 t ha^{-1} (MP) (not significant).



hw: *Ranunculus sardous* hand weeded

Figure 2: Shoot dry matter of faba beans as affected by tillage treatment (mould-board plough MP, direct seeding DS), amount of straw residues (SR in DS: 0, and 6 t ha^{-1}), seeding density of oats (SD: 1800 seeds m^{-2} sown in autumn) and hand weeding of *R. sardous* and time. Pairwise comparison of MP and SR in DS treatments with Dunett's test, * significant for P<0.05

Conclusions

Temporary use of DS of FAB is considered as a suitable approach to save labour and fuel in those cases where perennial weeds do not play an important role or can be accepted for one season due to sufficient crop competitiveness. Failure of clear effects of weed suppression assumed for the amount of oat crop residues and seeding density of oats in autumn makes further investigations necessary.

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Soil tillage in organic farming: impacts of conservation tillage on soil fertility, weeds and crops

Peigné, J.[1], Aveline, A.[2], Cannavaciuolo, M.[2], Giteau, J.-L.[3] & Gautronneau, Y.[1]

Key words: no tillage, mouldboard ploughing, soil structure, earthworms, weeds

Abstract

Organic farmers are encouraged to adopt conservation tillage to preserve soil quality and fertility and prevent erosion. In the framework of a national study, we compared conservation (no tillage NT and reduced tillage RT) and conventional (mouldboard ploughing MP and shallow mouldboard ploughing SMP) tillage systems in 3 field experiments and 2 on-farm surveys. We measured the impacts of soil tillage on: (1) soil compaction: more compacted soil under NT and RT, (2) earthworm populations: more earthworms under NT, (3) weed infestation: weed level tends to be higher under NT, but it is not a general trend, and (4) crops: crop yields are lower under NT according to weed infestation. Then, independent of soil type and experimental year (2 to 5 years), it seems that soil physical fertility decreases under NT and RT. But, the first reason of a decline of crop yield under NT is the weed infestation.

Introduction

Conservation tillage leaves organic mulch at the soil surface, which reduces runoff, increases the soil organic matter content and improves aggregate stability which limits soil erosion (Franzluebbers 2002). These benefits can improve soil fertility and environmental impact of organic crop production. However, Koepke (2003) reported that organic farmers generally use conventional tillage systems with a mouldboard plough, and occasionally till to a greater depth than in conventional agriculture. In the framework of a French national study, we compared conventional (ploughing) and conservation tillage systems in organic farming for arable and vegetable systems. Fields experiments and on-farm surveys were conducted in several regions of France in order to assess the effects of different tillage systems on soil fertility (physical, chemical, biological) and on weed and crop developments. This paper compares the effects of 4 tillage systems on soil physical and biological fertility and on weed and crop developments in arable systems.

Materials and methods

Three fields' experiments associated with 2 on-farm surveys have been carried out in 3 regions of France: Rhône Alpes (A), Pays de la Loire (B) and Bretagne (C). On each experimental field (table 1), 4 tillage systems were compared on a completely randomised block design with 3 replicates: 1) mouldboard ploughing (MP) (30 cm depth), 2) shallow mouldboard ploughing (SMP) (20 cm depth for A and B, 15 cm for C), 3) reduced tillage (RT) with tine tool (15 cm depth for A and B, 12 cm for C) and 4)

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no tillage (NT). For A and C, NT was managed under a cover crop during the first year of experimentation. Otherwise, mechanical weed control is carried out on each plot.

Tab. 1: Description of the 3 sites

Area	Organic farming conversion	Start of the essay	Soil type	Crop rotation
A	1999	2004	Sandy loam (fluvisol)	Alfalfa (3 years) – Maize – Soybean – **Winter wheat (2007)** – Soybean - Maize
B	2000	2005	Silty (cambisol)	Maize – Field bean – Winter wheat – **Lupin crop (2007)**
C	1996	2003	Silty	Maize – Triticale – Winter wheat – Winter pea - Triticale **(2007)**

The on-farm survey in Rhône-Alpes was composed by 7 farmer-fields where 2 tillage systems were compared: (1) MP, traditional tillage system of the farmer, and (2) RT or SMP (1 farmer). The 7 fields are representatives of the arable systems and soil-climate diversity in Rhône Alpes. Mechanical weed control (harrowing/hoeing) is carried out on each plot. On-farm survey in Site B is not presented.

We used a morphological description of the soil structure. It allowed us to integrate and explain temporal and spatial variation of the soil structure at the field scale. We characterised the spatial arrangement of the peds and clods as well as pore space on a pit (3 m in length, 1 m deep) according to Roger-Estrade et al. (2004). This method quantifies distinct structural zones in the soil profile: % of zones with loose structure noted □ clods and % of compacted zones, noted □ clods. Moreover, bulk density was measured from soil cores of 5 cm diameter (5 replicates / soil layers).

We measured the earthworm abundance (number / m^2) and species diversity (grouped in ecological category) with the formaldehyde method (Bouché et al. 1984). Each sample was taken plumb of the pit used for soil structure description in order to connect soil structure with earthworm characteristics.

Weed diversity and density were measured on 0.25 m^2 areas (4 replicates / plots / blocks in experimental fields, 8 replicates/ tillage management in farmer field). Crop components and yields were measured on the same 0.25 m^2 areas than weeds. Determination of weed biomass was done at the flowering stage on an adjacent area.

Results

Soil structure: For each experimental field MP and SMP develop a more porous structure than under RT and NT soil profiles: the proportion of □ clods (porous) is higher under MP (table 2). These results are confirmed in farmer fields (table 2): after 2 years of treatments differentiation the proportion of □ clods is higher under MP than under RT systems (6/7 cases). No differences are observed between MP and SMP excepting for the 20-30 cm layer where MP exhibited a more porous structure. Thus, independent of the soil type (clay and silty loam), RT and NT tend to degrade soil structure compared to MP. Modification of soil structure is confirmed by measurements of soil bulk density (figure 1). After 5 years of differentiation, bulk density of soils under MP and SMP are significantly lower at 15 cm depth than under RT and NT (site C). However, after 2 years of reduced tillage in farm fields or field experiments, no statistical difference was found (data not shown).

Tab. 2: Comparison of observed spatial arrangement and porosity of clods of soil structure created by MP, SMP, RT and NT in area A, B and C and On-farm survey 2007 (2 years)

Area	Comparison (% □ clod)	
Experimental fields		
A (3 years)	0-20 cm : MP>SMP=RT=NT	20-30* cm :MP>SMP>RT=NT
B (2 years)	0-20 cm: MP>SMP=RT=NT	20-30* cm: MP>SMP=NT>RT
C (5 years)	0-15 cm : MP>SMP=RT=NT	15-30* cm :MP=SMP>RT=NT
Farmer fields (2 years)		
Silty loam	MP>RT (3/4) - MP=SMP (1/4)	
Clay	MP>RT (3/3)	

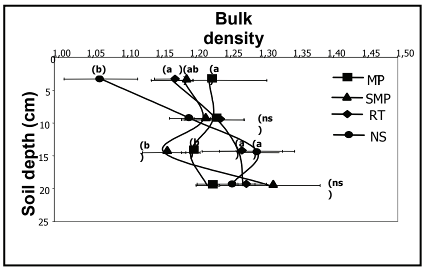

Figure 1: Comparison of bulk densities of MP, SMP, RT and NT for 0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm soil layers - Site C - 2007 (5 years)

Abundance and diversity of earthworms: In area A, B and C, more earthworms were found under NT than MP, SMP and RT (significant difference with Kruskal-Wallis test). NT presents higher epigeic (in crop residues or cover crop at the soil surface) and anecic species (vertical channels). No data are available for on-farm survey.

Weeds and yields: Soybean (site A) and winter pea (site C) yields were lower for NT compared to the other treatments. Weed level was significantly higher under NT (figure 2a and b). The same trend was observed in the on-farm survey (figure 3a and b). Independent of soil type and crop, when NT or RT systems exhibited a high weed development, crop yields tend to decrease significantly compared to MP and SMP.

Discussion and conclusion

A better soil structure is obtained under MP than SMP, RT and above all NT. Soil structure degradation under NT during the first years of transition have been reported by Munkholm et al. (2001). In silty and sandy soils, soils with low shrinking- welling effect, quality of soil structure can decrease in conservation tillage with time. However, in clay soils, we could expect similar soil structure between RT and MP. Nevertheless, we observed a deterioration of soil structure under RT compared to MP as no freezing day occurred during winter 06-07. Moreover, in each field experiments, we found more earthworms under NT compared to SMP and MP. Even if higher earthworms are found under NT, no more earthworm channels are found in depth. At short term, earthworms are not able to improve soil structure in conservation tillage in organic farming.

Whereas soil compaction is higher under NT, weed level plays the main role considering fall of crop yields under NT. Indeed, when weed infestation is controlled under NT and RT, no difference in crop yields is found. According to Kouwenhoven et al. (2002), RT is difficult in organic farming regarding weed infestation. Our first results do not confirm this hypothesis: if weeds are well mechanically managed, no decline of yield is observed under NT and RT compared to MP despite of the degradation of soil structure.

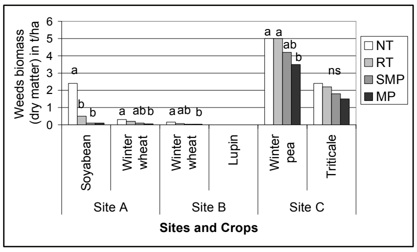

Figure 2a: NT, RT, SMP and MP weed biomass (t/ha) at flowering or harvesting, field experiments Site A – B - C (2005/06 2006/07

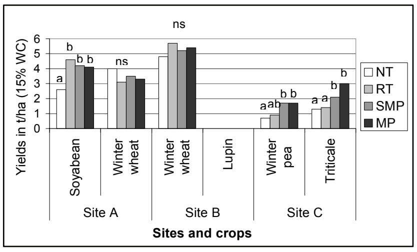

Figure 2b: NT, RT, SMP and MP crop yields (t/ha), field experiments Site A – B - C (2005/06 2006/07)

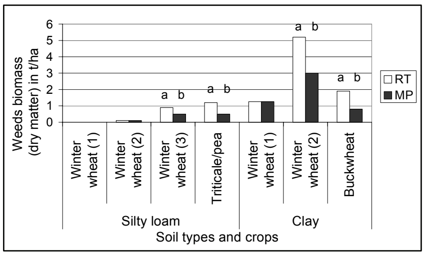

Figure 3a: RT and MP weed biomass (t/ha) at flowering or harvesting, farmers' fields (2006/07)

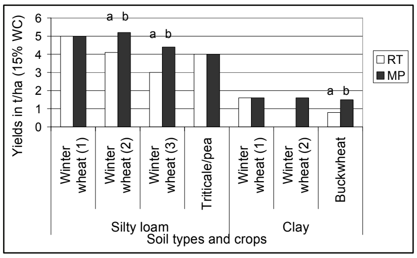

Figure 3b: RT and MP crop yields (t/ha), farmer's fields (2006/07)

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Effects of crop management factors and the environment on pest and disease incidence in vegetables

Cooper, J.M.[1], Schmidt, C.S.[1], Lueck, L.[1], Shotton, P.N.[1], & Leifert, C.[1]

Key words: organic production, pesticides, *Delia radicum*, *Sclerotinium sclerotiorum*, *Phytophthora infestans*

Abstract

The Nafferton Factorial Systems Comparison (NFSC) experiments are part of a long-term field trial that compares organic and conventional systems of crop rotation, crop protection and fertility management, in a factorial design. Pest and disease incidence in vegetables in the 2005, 2006 and 2007 season are reported. Cabbage root fly damage was always reduced under organic crop protection, but there were no consistent trends for the effects of fertility management on this pest. Sclerotinia in lettuce was consistently higher under conventional fertility management. Blight in potatoes was enhanced in the 2007 season by the combination of conventional fertility management and organic crop protection practices. Mechanisms for these effects, including the role of plant nutrition and the environment, are discussed.

Introduction

The Nafferton Factorial Systems Comparison (NFSC) experiments have provided a unique opportunity to study the interactions between crop rotation, soil fertility management, crop protection practices, and the environment, and their effects on the incidence of pests and diseases in a variety of crops. Previous results from these experiments showed that while some diseases were enhanced by organic fertility management, e.g. *Septoria* spp. in wheat (Cooper et al., 2006), other diseases were more prevalent under conventional fertility management, e.g. powdery mildew in barley (Cooper et al., 2007). Proposed mechanisms for these effects include the creation of optimum conditions for biotrophic pathogens when nutrients are provided to the crop in excess, and the weakening of plant defense mechanisms under nutrient-limited conditions. Trends in pest and disease incidence have varied from year to year, indicating the additional effect of environmental conditions on pests and disease. This paper further examines the role that crop management and the environment play in the incidence of pests and diseases in cabbages, lettuce and potatoes

Materials and methods

The incidence of cabbage root fly (*Delia radicum*), *Sclerotinium sclerotiorum* (in lettuce) and potato blight (*Phytophthora infestans*) were studied in the 2005, 2006 and 2007 field seasons in the Nafferton Factorial Systems Comparison (NFSC) experiments, near Stocksfield, Northumberland, in the UK. The experiments are a long-term trial set up in a split-split plot design with crop rotation (pre-crop factor) as the main plot and two levels of both crop protection and fertility management as the subplot and sub-subplot factors respectively. Cabbages under conventional crop

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protection (CP) are sprayed with Chlorpyrifos and Toppel 10 for insects and Bravo and Amistar for fungal infections while CAPATEX netting is used for organic crop protection (OP). Lettuce under conventional crop protection was sprayed as needed with Amistar and RovralFlo fungicides; no fungicides or insecticides were applied to lettuce under organic crop protection. Potatoes under conventional crop protection were grown in soil treated with Temik 10 G for cyst nematodes, and sprayed regularly with Shirlan and Fubol Gold for late blight control. Under organic crop protection, potatoes received regular treatments with Headland Copper for blight control. Crops under conventional fertility management (CF) receive recommended rates of NPK supplied as mineral fertilizer, while under organic fertility management (OF) nutrients are supplied from composted dairy manure. The experimental design allows analysis of both the main effects (pre-crop, crop protection and fertility management), and comparisons among four production systems: organic (OP-OF), 'low input' (OP-CF and CP-OF) and conventional (CP-CF). All of the experiments within the trial are replicated four times.

Results are reported here for cabbage root fly incidence (percentage total plants affected) assessed at GS (growth stage) 43 in 2005, GS43-45 in 2006, and in the harvested crop in 2007. The incidence of *Sclerotinia* in lettuce (percentage total plants affected) is reported for GS49 in 2005, GS49 in 2006, and GS46 in 2007. Potato blight incidence (visual estimate of percentage of plot affected) was assessed in all three years, but only detected in 2007. The area under the disease progress curve (AUDPC) for 2007 was calculated using the blight incidence data from 10 dates between 25 July and 3 August.

The data was analyzed using the linear mixed effects (lme) function in R (Crawley, 2007; R Development Core Team, 2006). The normality of the residuals of all models was tested using QQ-plots and data were cube root transformed when necessary to meet the criteria of normal data distribution. Models were simplified to remove the pre-crop factor where it did not contribute significantly to the variance of the data (Crawley, 2007). Main effect means were compared using the F-statistic from the ANOVA and subplot means were compared using linear contrasts.

Results

In every year crop protection had a significant effect on cabbage root fly incidence, with lower values under organic crop protection, due to the use of CAPATEX netting for protection of cabbages from insect pests ($p<0.01$). In 2005 crop protection was the only significant effect, however in 2006 and 2007; there was also a significant effect due to fertility management. This effect was not consistent over both years: in 2006 organic fertility management increased the incidence of cabbage root fly ($p=0.0143$), while in 2007 conventional fertility management enhanced cabbage root fly incidence ($p<0.0001$).

For *Sclerotinia* in lettuce, fertility management was a significant factor in every year, with consistently higher incidences of this disease where conventional fertility management was used ($p<0.05$). Conventional fungicide treatment (CP) did not have a significant effect. In 2006 the main effect for pre-crop was significant ($p=0.0292$) with higher incidences of *Sclerotinia* when lettuce was grown after a crop of beans. When barley was a pre-crop there was a significant fertility management by crop protection interaction ($p=0.0145$) with significantly higher *Sclerotinia* due to conventional fertility management under organic crop protection, but no fertility management effect under conventional crop protection.

In 2007 potato blight was closely monitored. There was a significant fertility management by crop protection interaction with higher AUDPCs where conventional fertility management was used in combination with organic crop protection (p=0.0003, Figure 1 treatment OP-CF).

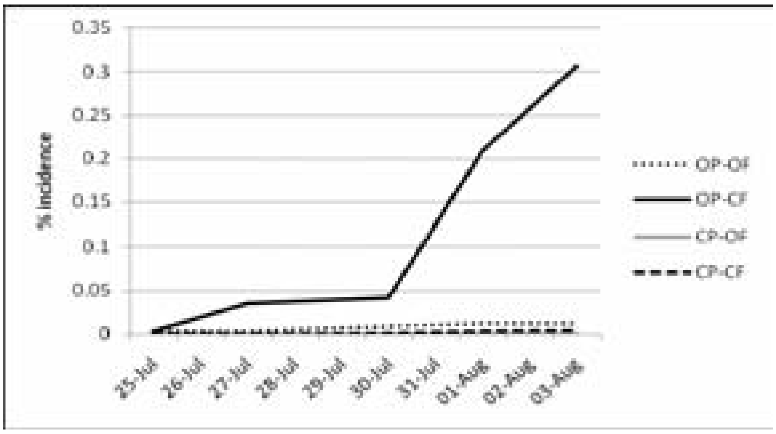

Figure 1: Potato blight incidence during the 2007 cropping season

Discussion

For some of the crops in the NSFC trial the use of conventional fertility management enhances disease and pest problems, regardless of the type of crop protection used. This is clearly the case for *Sclerotinia*, which was not significantly affected by conventional fungicide treatment. For some crops the use of mineral fertilizers may elevate leaf tissue N contents creating conditions more favourable for disease (Daane et al., 1995; Hofmeester, 1992); however, in the NFSC trials mineral fertilizer use did not result in higher tissue N contents in lettuce in 2005 (data not shown). The fertility effect on *Sclerotinia* incidence may be an inhibitory effect on growth of the organism in soils that have received compost additions. This effect has been previously reported in the literature (Asirifi et al., 1994; Nico et al., 2003).

The results for the potato blight incidence are similar to those previously reported for mildew in barley and wheat (Cooper et al., 2007; Cooper et al., 2006) in the same experiment: increased disease incidence under conventional fertility management in the absence of pesticides. For the 2007 potato crop, conventional fertility amendment also resulted in higher leaf greenness readings (by SPAD meter, data not shown) which is indicative of higher leaf N contents. High leaf N contents are favourable for biotrophic pathogens such as mildew, which affected cereals in previous years in the NFSC trials, and blight which affected the potatoes in 2007. There is therefore some evidence to suggest that the use of conventional mineral fertilizers encourages the development diseases caused by biotrophic fungi.

The environment as a driving factor for disease and pest incidence should also be considered. 2007 was a particularly wet year with 273 mm rain falling between May 1 and Aug 31, compared to approximately 180 mm during the same time period in 2005 and 2006. This created optimum conditions for the development of blight.

Environmental factors may also help explain the varying effects of fertility management on cabbage root fly incidence. In 2006, a relatively dry year, the survival of the larvae may have been improved in the soils of the organically fertilized crops, which would have higher moisture contents due to their higher soil organic matter contents (unpublished data). In 2007, it is not likely that soil moisture limited larval survival. Other factors, possibly related to plant nutrition, may have enhanced the incidence of cabbage root fly in the conventionally fertilized plots.

Conclusions

The long-term NFSC trials have allowed detailed studies into the effects of crop management and the environment on the incidence of pests and disease. Fertility management is frequently a significant factor contributing to the development of pest and disease problems although the mechanism for this effect is not likely the same in every case. While for *Sclerotinia* in lettuce organic fertility management may result in the inhibition of the pathogen within the soil, for biotrophic pathogens, conventional fertility management may create conditions within the plant that are optimum for infection. The role of the environment in controlling year to year variations in pest and disease incidence is also key. Future research will focus on identifying the mechanisms underlying the effects of crop management on pest and disease incidence.

Acknowledgments

The authors gratefully acknowledge funding from the European Community financial participation under the Sixth Framework Programme for Research, Technological Development and Demonstration Activities, for the Integrated Project QUALITYLOWINPUTFOOD,FP6-FOOD-CT-2003- 506358.

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Effects of Conservation Tillage on Canada Thistle (*Cirsium arvense*) in Organic Farming

Gruber, S.[1] & Claupein, W.[1]

Key words: Soil tillage, weed management, crop rotation

Abstract

A long-term experiment was established to examine the crop yield and the weed infestation, focussed on Canada thistle (Cirsium arvense), as effect of different intensity of primary tillage (mouldboard plough deep or shallow, double-layer plough, chisel plough) in combination with or without stubble tillage. The most effective ways to keep the infestation of C. arvense *at a low level were deep mouldboard ploughing and the use of a double-layer plough. After the experiment had run seven years, the thistle biomass was < 2 g DM m^{-2} in these treatments, compared to 23–26 g DM m^{-2} in the treatments with chisel ploughing or shallow ploughing. In all treatments, stubble tillage in addition to primary tillage significantly reduced the thistle biomass by 30–80 %. A high density of lucerne/grass re-growth occurred in the chisel plough treatment. The soil seed bank of thistles ranged between 220 (deep plough) and 6,400 seeds m^{-2} (chisel plough) in the sixth year of the experiment. Stubble tillage is essential if the chisel plough or shallow ploughing is used for conservation tillage in organic farming. The double-layer plough can control* C. arvense *comparable to deep ploughing.*

Introduction

Conservation tillage practices have been adopted by conventional farmers in many regions throughout the world (Derpsch 2005). The idea of conservation tillage subsumes a wide range of tillage practices which all have in common that a deep soil inversion by a mouldboard plough is abandoned. Many ecological benefits are associated with conservation tillage due to less intensive soil disturbance. Microbial life and soil organic matter increase (De Souza Andrade *et al*. 2003), infiltrability and trafficability of the soils is improved, and the soil is better protected against wind and water erosion (Ehlers & Claupein 1994). Conservation tillage also means a reduction in labour, time and costs. All these benefits correspond well with the objectives of organic farming. On the other hand, reduced tillage intensity in conventional farming is accompanied with the use of herbicides. Traditionally, weed control is achieved by the use of a mouldboard plough which shifts weeds and their seeds to deeper soil horizons from where germination and emergence is reduced (El Titi 2003; Pekrun *et al*. 2003). Therefore, organic farmers usually adhere to ploughing to ensure weed control. Particularly a higher infestation with perennial weeds, accompanied by lower yields, is expected by farmers in the absence of the mouldboard plough (Peigné *et al*. 2007). A lower N-net mineralisation (Pekrun *et al.* 2003) with conservation tillage may additionally lead to a reduction in yield. The question emerges whether there are tillage practices which combine the ecological benefits of conservation tillage with the capacity for weed control. Aim of this study was to examine the development of the

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Canada thistle *(Cirsium arvense)* population in a long-term experiment over one organic crop rotation under different levels of conventional and conservation tillage. Furthermore, the effect of stubble tillage in addition to primary tillage should be analysed in one experimental year.

Materials and methods

A long-term experiment was established in a split plot design with four replicates in the year 1999 on the Experimental Station Kleinhohenheim, University of Hohenheim, south-west Germany. The crop rotation was spelt (2000) – potatoes (2001) – triticale (2002) – lucerne/grass (2003, 2004) – winter wheat (2005) – oats (2006). The experiment had four main treatments of primary tillage as a main factor and stubble tillage as a secondary factor (levels: with or without stubble tillage). The main factor primary tillage had following levels: deep (25 cm) or shallow (15 cm) mouldboard ploughing, double-layer ploughing (15 cm + 10 cm) or chisel ploughing (15 cm, no soil inversion). The sub-plot size was 10 × 40 m. The double-layer plough combines a shallow inversion of the topsoil with a non-inversive soil loosening of the subsoil by a goosefoot-shaped chisel (operating in 62 % of the field width), thus the natural soil stratification of the subsoil is maintained. For stubble tillage, the "Stoppelhobel", a modified skimmer plough (100 % of the field width undercut), was used one time after each harvest, and was followed by primary tillage usually in the mid of October. Thistle shoots were counted every year after harvest (August/September), i.e. before the first tillage operation; a distinction between seedlings and shoots from roots was not made. The soil seed bank was examined in spring 2005 for the first time. Soil samples were taken in a depth from 0–30 cm using an auger with a core of 1.2 cm. Seeds were washed out from the soil by sieving (mesh width 4.0 and 0.25 mm), and then dried and determined (after Hanf (1990), and in comparison with a seed collection of the institute). The total above-ground biomass production of *C. arvense* was determined on 21.06.2006, when the thistle plants had a height of 80 cm and were shortly before flowering. All shoots were cut on 100 m^2 in the centre of each plot, then dried at 80° C for 48 hrs and weighed. The statistical analysis was performed using the procedure 'MIXED' (for crop yield and thistle biomass) or GLM (seeds) in the statistical programme SAS. If necessary, data were square root-transformed for the statistical analysis to obtain the normal distribution and homogeneity of variance, and then retransformed.

Results

The *C. arvense* infestation was higher in the shallow plough and in the chisel plough treatments in comparison to the deep plough and double-layer plough treatments over a period of seven years (Fig. 1, last five years shown). The period during which lucerne/grass was grown clearly reduced the density of thistle shoots in the year 2004, which increased again as soon as cereals were grown as succeeding crops. Lucerne/grass re-growth occurred in the chisel plough treatment with a mean of 37 plants m^{-2}, compared to one plant m^{-2} in the deep plough treatment in the year 2005 (data not shown). Deep mouldboard ploughing and the use of the double layer plough significantly reduced the thistle biomass compared to shallow ploughing and chisel ploughing (Tab. 1). Stubble tillage in addition to primary tillage significantly reduced the total biomass production of thistles in all treatments by 30–80 %. There was no significant interaction between stubble tillage and primary tillage. *C. arvense* seeds were present in the soil seed bank in spring 2005 in an amount of 6,400 seeds m^{-2} in the chisel plough treatment while all other treatments showed less than 440 *C.*

arvense seeds m^{-2}. The yield of oats did not significantly vary between all treatments in the year 2006.

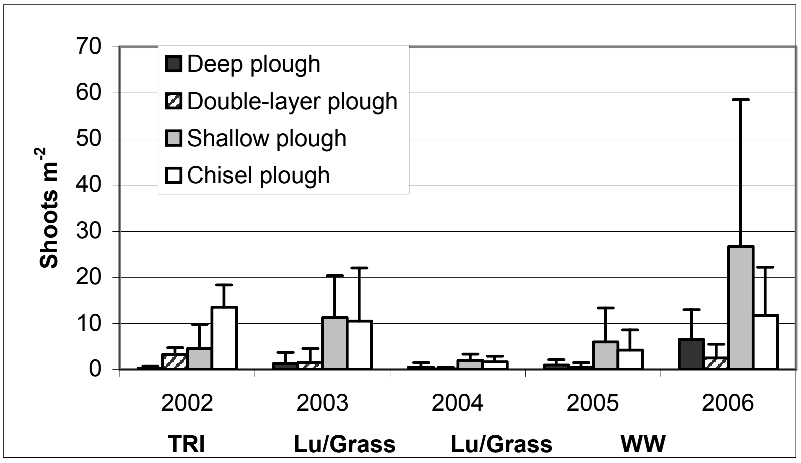

Figure 1: Development of the *C. arvense* population (no. of shoots) in the course of five years with different treatments of primary tillage, without stubble tillage. Error bars: standard deviation. TRI: Triticale, Lu/Grass: lucerne/grass, WW: winter wheat, OA: oats. Data 2002, 2003: after Pekrun & Claupein 2004.

Tab. 1: Soil seed bank (March 2005) and above-ground biomass (June 2006) of *C. arvense*, and grain yield of oats (2006) as effect of tillage. Primary tillage: upper case, stubble tillage: lower case, comparison on the same level of primary tillage only); data "shoots" detransformed; P< 0.05. DM: dry matter

Primary tillage	Deep Plough		DL-Plough		Shallow Plough		Chisel Plough	
Stubble tillage	yes	no	yes	no	yes	no	yes	no
2005								
C. arvense seeds m^{-2}	221 b	n.d.	442 b	n.d.	442 b	n.d.	6411 a	n.d.
2006								
C. arvense shoots g DM m^{-2}	1.1 a	0.8 b	1.6 a	0.2 b	25.6 a	1.9 b	22.5 a	4.8 b
	B		B		A		A	
Grain yield oats t DM ha^{-1}	4.5 n.s.	4.3 n.s.	5.0 n.s.	5.2 n.s.	4.4 n.s.	4.3 n.s.	3.0 n.s.	4.8 n.s.

n.d.: not determined

Discussion

Shallow tillage in a depth of 15 cm, independently from inversion or non-inversion of soil, was not sufficient to keep the population of *C. arvense* on a similar low level as deep ploughing and double-layer ploughing. The extent to which the weed infestation increased shortly after the lucerne/grass period did not match the hypothesis that perennial legumes have a long-term effect in weed control in organic farming. One reason may be the re-growth of lucerne/grass in the chisel plough and shallow plough treatment which affected emergence and growth of the crop and provided an undisturbed habitat for the thistles. Additionally, there was a large soil seed bank of *C. arvense* in the chisel plough treatment which had persisted for two years of lucerne/grass. Though weed surveys were not specifically targeted at distinguishing between thistle seedlings and shoots from roots, germination of new thistle plants might have been occurred. The reason for the effect of stubble tillage on yield in the chisel plough treatment in 2006 is probably not only caused by a reduction of thistles but also by a reduction of lucerne/grass re-growth and other weeds by stubble tillage. A weed-controlling effect of stubble tillage toward perennial weeds in organic farming was clearly shown by Pekrun & Claupein (2006). Though some concerns remain about conservation tillage in organic farming (Peigné *et al.* 2007), *C. arvense,* at least, can be managed by the reduced mechanical intervention of the double-layer plough.

Conclusions

Stubble tillage is essential if the chisel plough is used for conservation tillage in organic farming. The use of a double layer plough had similar effects on the control of the perennial weed *C. arvense* as a deep soil inversion by a mouldboard plough. Therefore, presuming that a better preservation of the natural resource soil and other benefits of conservation tillage are achieved, the double-layer plough can be recommended to replace the traditional mouldboard plough.

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Monitoring of click beetles (*Agriotes lineatus* and *A. obscurus*) in organically managed farms in Northern Germany

Böhm, H.[1], Koppe, W.[2] & Dreyer, W.[3]

Key words: potato, click beetle, pheromone traps, wireworm

Abstract

Wireworms, the larvae of Agriotes *spp., are an increasing problem on many organically managed farms with potato or vegetable production. The damage caused by wireworms is economically significant. With the use of pheromone traps it is possible to get more information about the habitat requirements of click beetles. In 2005 and 2006 click beetles were monitored at different locations in northern Germany. Because of the warmer springtime in 2005, the first peak of click beetles was about two weeks earlier than in 2006. The second peak was found one month later. The presented data show the highest occurrence of click beetles in ryegrass-clover mixtures in both years. The catches in cereals were much lower than in ryegrass-clover. The reasons for the differences of the trapped click beetles in the different cereal fields cannot been explained so far. In the majority of cases the trapped number of* Agriotes lineatus *was higher than for* A. obscurus.

Introduction

The damage caused by wireworms, the larvae of click beetles (Coleoptera: Elateridae), in potatoes and other vegetables is high and has increased on many organically managed farms in recent years. Knowledge of the ecology and the habitat requirements of wireworms and click beetles is very low (Schepl and Paffrath 2003). With the use of pheromone traps the occurrence of click beetles can be monitored in different regions and crops, with the aim of getting more information about their occurrence and habitat requirements. Blackshaw and Vernon (2006) have used pheromone traps for describing the spatiotemporal stability of click beetles in an agricultural landscape. Based on such data sets it may be possible to figure out new strategies for reducing the populations of click beetles.

Materials and methods

In 2005 and 2006 pheromone traps were installed at different locations on organically managed farms in northern Germany. The traps were installed during the vegetation period in different crops, such as ryegrass-clover mixture, oat, summer barley, summer wheat, and spelt. At every site four traps, two baited with pheromone lures specific for *Agriotes lineatus* and two baited with *Agriotes obscurus*, were installed 30

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m from each other. The pheromone lures and traps were obtained from Plant Research International (PRI), Pherobank, Wageningen (NL). The lures of pheromones were changed after 45 days; the traps were emptied every week.

In 2005 the traps were located on one farm in two different crops (ryegrass-clover mixture and summer wheat) from the end of April until early August. In 2006 the traps were installed from the beginning of May until the middle of July on four different farms in Lower Saxony and Schleswig-Holstein.

Results

From the end of April until the beginning of August 2005, on average 1831 click beetles were caught per trap in a ryegrass-clover mixture and 1631 click beetles per trap in summer wheat. In both crops the number of *A. lineatus* was higher (1448 and. 1047 respectively) than for *A. obscurus* (383 and 585 respectively). Figure 1 shows the number of click beetles during the vegetation period. The first peak of click beetles was early in May, the second nearly one month later at the end of May/beginning of June, and the third around the 20th of June. The time the peaks appeared was similar in ryegrass-clover and summer wheat, but the peaks were more pronounced for *A. lineatus*.

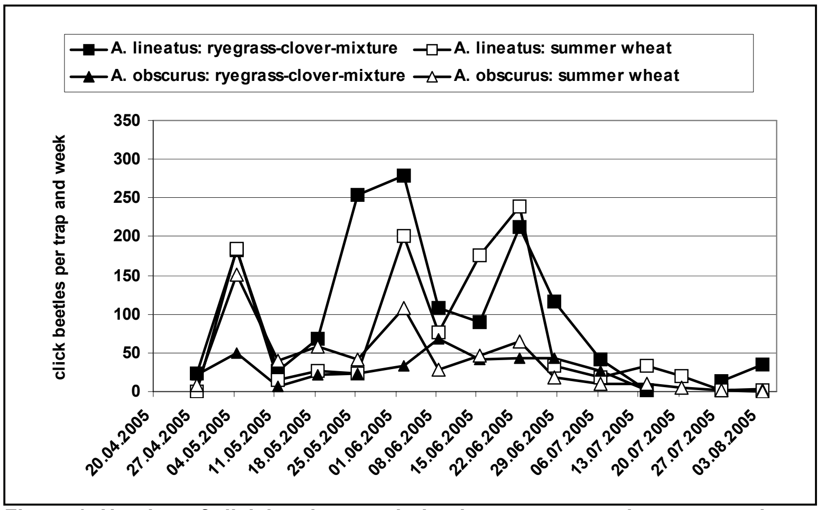

Figure 1: Number of click beetles caught in pheromone traps in ryegrass-clover mixture and summer wheat in 2005

Comparing the same collecting period and the same location, the number of click beetles caught was similar in the two years in the ryegrass-clover mixture (1492 vs. 1502 adults of *Agriotes* spp.). Also, the catches of click beetles were lower in cereals than in ryegrass-clover (Table 1). Obviously the location and the particular cultivated cereal had an influence. For example, at location 2 the number of click beetles was much higher in winter barley than in winter wheat.

Tab. 1: Number of trapped click beetles (*Agriotes lineatus* and *Agriotes obscurus*) during the vegetation period 2006 in different crops and locations in northern Germany

Location	Crop	A. lineatus	A. obscurus	Total
1	Ryegrass-clover-mixture	1250	242	1492
1	Oat	678	326	1004
2	Winter barley	745	84	829
2	Winter wheat	263	35	298
3	Winter barley	190	310	500
4	Spelt	169	176	345

Figure 2 shows the number of click beetles during the course of the catching period in 2006. Compared with 2005, the first peak was about two weeks later in 2006. One month later the second peak was evident. Because of the shorter catching period, no third peak was evident. At location 1, where the period was still going on, a third but low peak was evident. The timing of the peaks differed only a little among the locations.

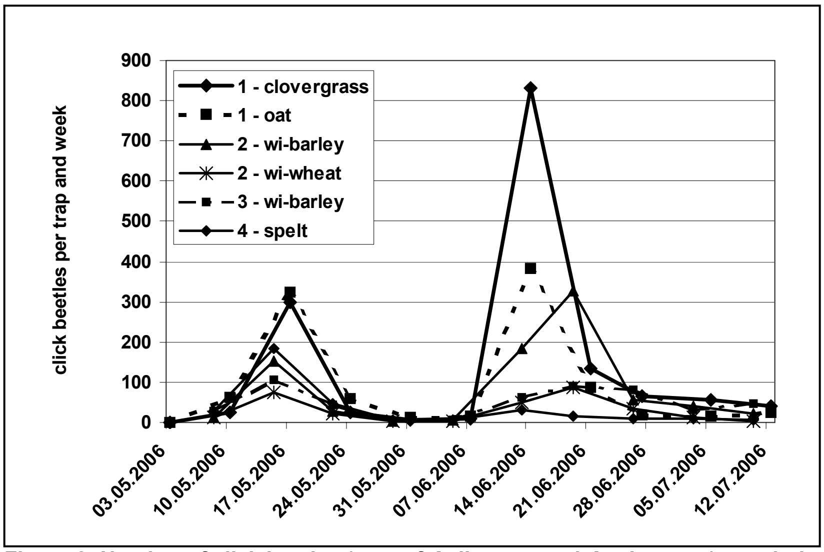

Figure 2: Number of click beetles (sum of *A. lineatus* and *A. obscurus*) caught in pheromone traps in different crops and locations in northern Germany in 2006

Discussion

Other authors reported the occurrence of click beetles in early to mid-May (Böhm and Krause 2005; van Rozen et al. 2007). The first occurrence of click beetle depends on the weather in spring: warmer conditions enable earlier appearance of the click beetles. First calculations showed good correlations between the sum of soil temperature and the appearance of click beetles. The preference for crops with a high plant density also is described in the literature (Parker and Seeney 1997; Schepl and Paffrath 2003). Therefore it is obvious that the number of click beetles in the investigation would be highest in ryegrass-clover mixtures. However, other factors such as plant height or landscape with refuge areas must also determine the occurrence of click beetles.

Conclusions

The results showed the high attractiveness of ryegrass-clover mixtures to click beetles and corroborate that a high percentage of rye-grass in the crop rotation increased the population of wireworms. In Organic Farming, ryegrass-clover mixtures are necessary in the crop rotation for fodder production, N_2-fixation and humification. However, in the case of potato production the ryegrass-clover mixture creates out a risk of wireworms. For direct control, no pesticides are allowed in organic farming. Therefore the wireworm population must be reduced by agronomic practices or by the use of pheromone traps. Both possibilities will be checked in a new project in the coming years.

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Monitoring *Agriotes lineatus* and *A. obscurus* in organic production using pheromone traps

Sufyan, M.[1], Neuhoff, D. & Köpke, U.

Key words: pheromone traps, *Agriotes* spp., range of attractiveness

Abstract

Wireworms, particularly Agriotes lineatus and A. obscurus are becoming a problem in organic crop production causing economically severe damage on potatoes and other arable crops. Since pesticide application for direct control is not allowed in organic farming, reliable methods for quantifying wireworm infestation levels and forecasting damage are urgently needed for any control strategy. In the present work, the assessment of the range of attractiveness of pheromone traps to male A. lineatus and A. obscurus beetles was investigated in 2006 and 2007. The results indicated that the trap recovery rate of released beetles was more dependent on release distance than on time. Recovery rates greater than 40% were only noted for short release distances (up to 10 m), while less than 10% of the beetles released at a distance of 60 m returned to the traps. Recovery rates of click beetles were also negatively affected by cold and wet weather conditions. Most of the beetles were recovered within the first 3 days.

Introduction

Wireworms, the larval stage of click beetles (Coleoptera: Elateridae), have become one of the most serious polyphagous insect threats to many agricultural crops worldwide (Parker and Howard 2001). They live in the soil for 4-5 years where they cause germination failure and injury of underground organs e.g. potato tubers. There are different species of plant damaging click beetles in Europe, but *Agriotes lineatus* and *A. obscurus* are most abundant in Germany (Furlan et al. 1999). Problems are particularly high in Organic Farming, due to favouring crop rotations with leys and the absence of chemical control options. For these reasons, the development of alternative control strategies has become an essential task. A pheromone trapping system (Furlan et al. 2001 and Toth et al. 2003) proved to be a highly sensitive risk assessment tool to complement existing baiting techniques (Parker 1994) and other risk assessment methods (Parker and Seeney 1997). The sex pheromone mixtures give a good indication of presence and flight peaks of the male beetle populations (Ester et al. 2002) and are permitted according to EU regulation 2092/91 on OF. Currently click beetle flight behaviour is monitored by using pheromone traps, but it is still unclear whether apart from monitoring, a control of soil wireworm population is possible by mating disruption. Mating disruption has been tested against some tortricid pests and was successful for controlling the codling moth, *Cydia pomonella* (Moffitt and Westigard 1984) and the European grape moth, *Eupoecilia ambiguella* (Charmillot et al. 1987). Any potential control by mating disruption needs to consider the range of attractiveness of the pheromone. Despite the significance of pheromone traps, information on the range of attractiveness of pheromone traps to *Agriotes* species is

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lacking. The objective of this work was to assess the effectiveness of pheromone traps to attract *A. lineatus* and *A. obscurus* on clover grass field and bare soil for forecasting wireworm damage and for considering their use in mating disruption.

Materials and methods

The experiments were conducted at the experimental farm for organic agriculture ´Wiesengut`, University of Bonn, Germany located in River Sieg Valley/Rhineland (longitude: 7°17' east latitude: 50°48' north). The soil is acid alluvial loam and the climate is comparatively mild with an annual average temperature of 10.2° C. The farm has been under organic management since 1987.

Experimental set up and trap types

Mark release recapture experiments were carried out in 2006 and 2007 in order to determine the average range of attractiveness of pheromone traps. Experiments were carried out on two types of soil coverage (clover grass and bare soil) in natural dispersal peaks i.e. May and June of both years.

Traps were placed at least 100 m distant to each other. Each group of 25 beetles was released both upwind (west) and downwind (east) at distances of 2, 5, 10, 15, 20 and 60 m from a central YATLOR funnel trap baited with fresh lures for both *A. lineatus* and *A. obscurus*. After the release, trap catches were recorded at 1hr, 1d, and every day up until 30d. For every assessment date the absolute (i.e. not cumulative) number of captured beetles was recorded. Data were analysed by ANOVA followed by Tukey's test ($\alpha \leq 0.05$) using SPSS.

Source of beetles

The adults of the male click beetles, *A. lineatus* and *A. obscurus* were collected by putting pheromone traps in different highly infested fields on the farm. Field collections were made as early as possible according to species biology. All captured beetles were sexed, identified and put in aerated boxes filled with moist soil and fed with fresh gramineae leaves until experiments.

Marking of beetles

Different colours (red, green, white and blue) were used to paint the elytrae of beetles. One marking color was used for each of six distances and randomly assigned to the captured beetles. For each treatment (release distance) 25 males were marked by painting the elytrae with non washable pencils resulting in a total of 150 beetles per trial and species. One hour later, marked beetles were released in the field.

Results

Recovery rate of *A. lineatus* and *A. obscurus*

Of total of 1260 beetles released of *A. lineatus* in two years, 517 were recovered (Fig. 1). The moving behaviour of *A. obscurus* followed a similar pattern to *A. lineatus* and of a total of 1260 beetles released in two years, 536 beetles were recovered. High recovery rates were noted only for short release distances (up to 10 m), while less than 10% of the beetles released at 60 m returned to the traps. High recovery rates were only noted for the early assessment dates (up to 3 days). Beyond the third day, beetles were caught in small numbers, and appeared to approach the traps passively. The results further suggest that the recovery rate of released beetles (*A. lineatus* and

A. obscurus) to the traps was more dependent on release distance than on time, while the wind direction had no effect on the recovery rate. Recovery rates of beetles appeared to be reduced by cold and wet weather conditions during both years.

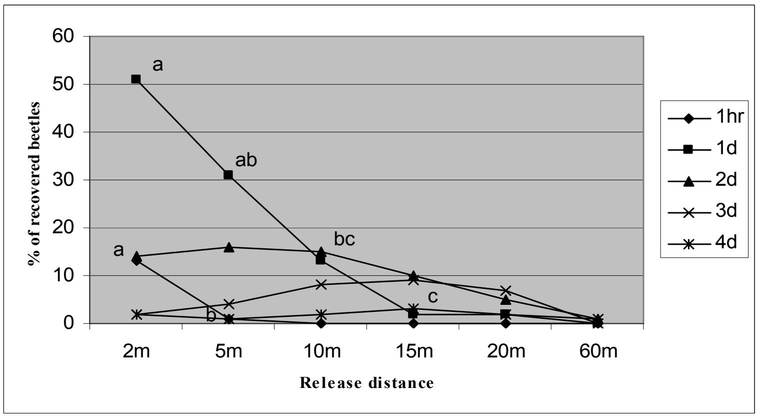

Figure 1: Influence of different release distances and assessment date on the recovery rate of A. lineatus averaged over two years and four trials. Values followed by different letters are significantly different, Tukey's test (α < 0.05).

Discussion

There were two important factors that influenced the range of attractiveness of the pheromone traps: release distance and time. Soil type and wind direction had no effect on the recovery rate. On average, the recovery rate did not exceed 40% for either beetle species, suggesting that on average 60% of the beetles were lost, killed, or were attracted to- and chose to mate female beetles. The high recovery rates for short release distances suggested that painting the beetles was not the main reason for decreasing their recovery. However, the studied parameters were strongly affected by stress and climatic factors, particularly by rainfall. Apparently the range of attractiveness is quite low and is also influenced by the fact that beetles travelling on the soil may encounter the pheromone traps by chance.

Information on the moving behaviour of beetles is still insufficient in the literature. However, current results are supported by Vernon et al. (2001) who observed low flight activities of both *A. lineatus* and *A. obscurus* under the field conditions in Canada. The efficacy of various alternative control methods under consideration (e.g. mass trapping, mating disruption and physical exclusion) would likely be affected by flight activity of beetles. Implications of these findings for practical control of wireworms by mating disruption are part of our ongoing research programme (Sufyan et al. 2007).

Conclusions

The presented experiments suggest that a relatively high number of traps or an extension of the trapping periods need to be considered in order to adult monitoring. The results regarding the range of attractiveness show that the applied technique for male trapping is suitable for limited areas like greenhouses and small areas with high value crops sensitive to wireworms such as asparagus. Whether pheromone traps for click beetles can be used for reducing wireworm populations in the soil is still unclear. Regardless of direct control of click beetles via pheromones, the technique can play an important role in detecting the presence of the beetles, making prevention strategies more efficient. For organic agriculture the pheromone technique is a promising tool to cope with pest problems, which are still a major reason for yield losses in many crops.

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The effect of companion plants on Lygus feeding damage to bean

Szafirowska, A..[1] & Kolosowski, S.[1]

Key words: Lygus, bean seeds, organic farming, companion plants

Abstract

The aim of research was to find out the protective effect of companion plants against lygus bugs (Lygus spp.) in organic production of bean (Phaseolus vulgaris L..). The field experiment was conducted during 2004 and 2005. Bean were sown on three dates: May 10, 25, June 10. As companion plants the following species were applied: red beet (Beta vulgaris L.), dill (Anethum graveolens L.), marigold (Tagetes erecta L.) and sage (Salvia officinalis L.). At harvest the bean seeds were examined for the presence of seed-pitting caused by lygus bugs. The lowest percentage of damaged seeds, demonstrated the samples obtained from plots cultivated in the close proximity of dill and marigold The number of pitted seeds depended on the date of seeds sowing and the year of experiment.

Introduction

Pest occurrence is a severe problem in organic vegetable cultivation, especially in the area of an intensive vegetable production. Less mobile pests and those of a specific host range could be controlled by crop rotation. However, this method is not effective in the control of highly mobile, non specific pests such as aphids and lygus bugs (*Lygus* spp). In Poland the escalation of the occurrence of lygus bugs on many vegetable species had been noticed in recent years (Szwejda 2006). In bean cultivation the pest causes reduction of the yield quality and quantity. Lygus bug's saliva contains the enzymes and amino acids toxic for the plant tissue, thus causing buds and flowers shedding and casting off young pods (Hori 1975). The pests also feed on immature seeds by spitting on the seed surface making shallow hollows (pits) with irregular jagged edges (Szwejda 1978). These pits can be found on the whole seed surface except for the stigma vicinity.

While looking for natural methods of pest control the allelopathy effect of plants can be used. It is known that some plant species stimulates or inhibits other species growth. However, the allopathic relation between plant and insect is not well recognised. Some authors obtained promising results when planting the main crop in the close proximity of species controlling insects occurrence. Kostal & Finch (1994) found a significant reduction in the number of eggs laid by cabbage root fly owing to the companion effect of some plant species. Legutowska and Klepacka (2001) observed a reduction of *Trips tabaci* L. on leek grown in an intercropping with snap bean.

The aim of studies was to examine the effect of several plant species used for companion planting in organic bean cultivation to protect against lygus bugs seed piercing.

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Materials and methods

The experiments were conducted in the experimental organic field in the Research Institute of Vegetable Crops at Skierniewice in Poland during 2004-2005. The field had been subjected to the control-certified system accepted for organic production in the EU (EC Regulation 2092/91). Bean seeds were sown on the 10 m^2 plots with 5 rows on the plot spaced by 45 cm. Two side rows were planted with companion species such as: red beet, dill, marigold and sage. Bean plants used as the companion plant made the control treatment. Bean was sown on three dates: May 10, 25 and June 10. At the same time the companion species were sown. Marigold and sage were used as transplants. The experiment was set by the random block method in four replicates.

Lygus bugs were caught with an entomological net (4x25 catching per plot). The dynamics of lygus bug occurrence was observed at the onset and at full blossoming, the beginning of pod formation and fully formed pods, which means from the second decade of June until the end of August. The number of larvae and imagoes per 1 row meter was counted. The seeding plants were harvested according to the sowing date at September 1, 10 and 20. The total seed yield was examined for the presence of pitted specimens. The seeds with hollows on the seed coat with traces of puncturing on the cotyledons endosperm were recognized as contaminated, following the method of Szwejda (1978). The composition of the *Heteroptera* division was determined down to species following Korcz methods (1977). Results were subjected to the statistical analysis of variance with the significant differences pointed out on the basis of Newman-Keuls test at p=0.05

Results

In both years of research, lygus bugs appeared in a high intensity although more numerously in 2005 (fig.1). The average number of bugs caught on 1 row meter during the whole observation period amounted to 69,5 in the first year and 82,8 in the second one. There were some differences in the occurrence and number of insects in both years of research. In 2005 lygus bugs were noted in the high intensity from the second decade of June until the end of July. In 2004 the pests were less frequent and appeared about two weeks later. This fact, as well as both experimental factors, affected the number of pitted seeds as it is shown in the table 1. Less damaged seeds was observed in 2004 than in 2005. The average percent of pitted seeds was 9,20 and 12,07 respectively as compared to the total yield of bean seeds. The later the sowing date, the more pitted seeds were observed. It was especially visible in the first year, when the seed pods of the earliest sowing were too hard as the lygus started feeding. The most delicate pods of the last sowing date were damaged the worst. The very dynamic occurrence of insects in the second year did not give much chance to the earliest sown bean. The longer feeding period of lygus resulted in a higher level of damage to seeds of all the examined sowing dates. The selected companion plant species significantly influenced the percentage of pitted bean seeds especially in the second an third date of sowing. In the last two cases there were large differences between control and other treatments and in 2005 the differences were significant. The most effective plant species were dill and marigold, which caused a significant decrease in the number of damaged seeds during both years of research. The stage of companion plant development played some role in bean protection. Better developed companion plants in July and August provided the stronger protection against lygus feeding.

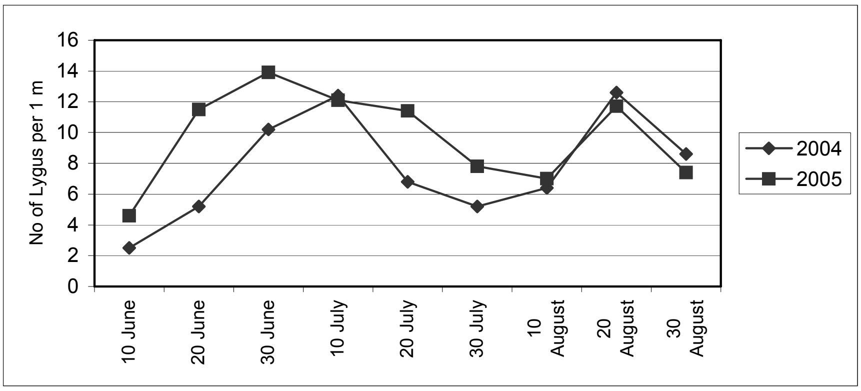

Figure 1: Occurrence intensity of Lygus spp.

Tab. 1: The effect of companion plants on the percentage of pitted seeds in the total bean yield.

Companion species	2004			Mean	2005			Mean
	10 May*	25 May	10 June		10 May	25 May	10 June	
Red beet	3,75	14,11	17,48	11,78	9,70aA	16,83abB	10,59aA	12,37
Dill	1,23	8,70	14,93	8,29	11,60aA	10,72aA	6,55aA	9,62
Marigold	1,85	6,95	10,67	6,49	8,66aA	10,84aA	7,33aA	8,94
Sage	3,23	8,15	11,71	7,69	11,49aA	14,14abA	7,79aA	11,14
Control	3,82	13,54	17,83	11,73	13,10aA	19,35bB	22,43bB	18,29
Average	2,78 a	10,3 b	14,52 c	9,20	10,91	14,38	10,94	12,07

*date of bean sowing; the small letters refer to data in columns, the big ones to data in rows

Discussion

The use of a diversified pest suppressive agro-ecosystem is of growing interest in agriculture. Plant cultivation in a well established ecosystem facilitates pest management and the biodiversity can be used as an important tool in pest control. As Finch and Collier (2000) stated, insects found a host plant faster and easily, when it was clearly visible and not surrounded by weeds or other plants. On the other hand the majority of pests prefer to colonise on a green surface, therefore appropriate companion plants can easily deceive females and invite them to resign from laying eggs on the main crop.

There is scarce literature on the discussed particular subject. The best examined pest in the context of companion plant cultivation are aphids, cabbage root fly or trips. Wiech (1993) received a positive effect in the reduction of aphid occurrence on cabbage by papilionaceous companion planting. Legutowska and Klepacka (2001) found a positive influence of carrot, snap bean and clover on the percentage of strongly damaged leek plants by trips (*Trips tabaci*). In Finch et al. (2003) studies three marigold species (*Tagetes erecta, Tagetes patula* and *Tagetes tenuifolia*), which reduced the number of eggs laid by cabbage root fly females.The obtained results proved that appropriate species used as a companion plant can control the bean seed pitting to some extent. The best protection against lygus feeding provided dill and marigold used as the companion plants in organic bean cultivation.

Conclusion

Bean sown in the first decade of May produced the lowest percentage of pitted seeds. The biggest number of damaged seeds was obtained from the latest sowing date (June 10). The early sowing and right companion species like dill or marigold seems to be useful in protecting against bean seed piercing. It is an important tool, especially in organic farming, because of the lack of effective pesticides allowed to use in this kind of agriculture production.

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Direct and cultural control of pests and diseases

Effects of homeopathic and mineral treatments on dark leaf spot caused by *Alternaria brassicicola* on cauliflower

Trebbi, G.[1], Fantino, M.G.[1], Dinelli, G.[1], Marotti, I.[1], Burgio, G.[1], Nani, D.[2], & Betti, L.[3]

Key words: homeopathic treatments, dark leaf spot, cauliflower, arsenic trioxide, *Alternaria brassicicola*

Abstract

This research aimed at verifying the efficacy of some homeopathic and mineral treatments on Alternaria brassicicola/cauliflower interaction. Growth chamber experiments and a field trial were performed, using Brassica plants artificially inoculated with the fungus. In growth chamber experiments, infection was significantly reduced by arsenic trioxide 35 decimal potency (As_2O_3 35 d) and in field trial by both As_2O_3 35 d and bentonite treatments.

Introduction

The aim of this work is to give a contribution on the effects of homeopathic treatments on dark leaf spot caused by *Alternaria brassicicola* (Schw.) Wiltshire on cauliflower. This disease, very common in *Brassica* crops (Humpherson-Jones, 1983), appears as small dark spots at all growth stages of the plant. In organic agriculture, the control of dark leaf spot, as well as of most fungal diseases, is based on the use of mineral products such as copper, that has a high efficacy and a long-lasting action. Unfortunately, copper use presents some disadvantages: it can be phytotoxic, and it can accumulate in the ground with negative consequences on soil microflora and microfauna. For these reasons, European Union delivered a directive (Commission Regulation EC no. 473/2002) that mandates a reduction in copper use in organic agriculture. In this context, homeopathic preparations, due to their extreme dilutions, could represent suitable treatments, complementary to copper, in organic agricultural protocols. Homeopathic treatments are prepared starting from a mother tincture of different substances, according to a standardized protocol which consists in serial aqueous dilutions (decimal or centesimal, d and c, respectively) coupled with dynamization phases (mechanical agitation of the dilution). An hypothesis of the action mechanism of homeopathic remedies is the following: the manufacturing process employed for the preparation of homeopathic remedies would induce a dynamic ‘ordering’ of water’s constantly switching network of intermolecular hydrogen bonds (Chaplin 2007). This could lead to a long-range molecular ‘coherence’ between trillions of mobile water molecules (Elia et al, 2004; Milgron 2006). The literature on the effects of homeopathy on plants provides several papers on germination and growth tests on different species, some on phytopathological models, whereas very few descriptions concerning field trials are available (Betti *et al*., 2007).

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Materials and methods

Plants of *Brassica oleracea* L. cultivar clx 33247 were used for both growth chamber and field experiments. Plants, at the stage of three true leaves, were artificially inoculated by spraying a fungal suspension ($1x10^7$ conidia ml^{-1}) on the leaves. In the first experiment, arsenic trioxide, As_2O_3 35 d (As) and a bentonite treatment (bent., provided by the company Cosmoonda s.n.c.) at 10 g/l were compared with copper oxiclorure (Cu) at 0.3, 1, and 3 g/l, the control being water. In the second experiment, the treatments with As, bent. and Cu 3 g/l (as positive control) were repeated and compared with As diluted 1:5000 (As dil.) and ß-aminobutyric acid (BABA, 5 mM). As_2O_3 was chosen according to the homeopathic law of similarity (Bellavite *et al.*, 1997): in ponderal concentration it induced on leaves necrotic spots similar to those provoked by *A. brassicicola* infection. Bentonite was chosen because of its inhibiting effect on *in vitro* spore germination and BABA because it is a well-known resistance inducer (Cohen 2002). In the field trial, the same treatments of the first growth chamber experiment were tested. The field was divided in plots consisting of 6 plants/treatment (separated each other by two not-treated healthy plants), each treatment being replicated four times in a randomized complete block design. Treatments were sprayed weekly on the leaves 3 times before and 4 times after artificial fungal inoculation. The evaluation of infection level on leaves (growth chamber experiments) or head (field trial) was carried out blind by two different operators (in order to exclude unconscious influences). A visual assessment of the necrotic area on each plant was performed on the basis of an infection scale, previously defined and then reported in percentage, referred to control. Data were subjected to analysis of variance (ANOVA), followed by Dunnett post-hoc test.

Results

In the preliminary screening of homeopathic treatments, the best disease control was obtained by As, which induced a reduced infection of about 20% (data not shown).

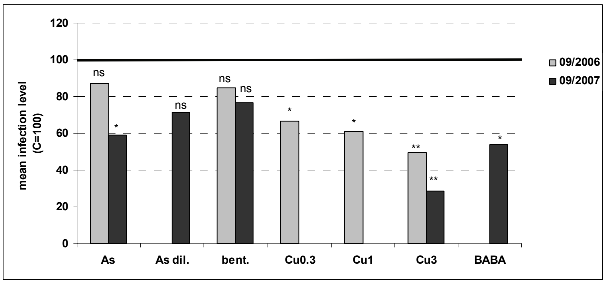

Figure 1: Different treatment effects on mean infection level in growth chamber experiments. Bold line represents control equal to 100.
n = 12 and 18 plants/treatment in 2006 and 2007 experiments, respectively
*** significant for p<0.05; ** significant for p<0.01**

Growth chamber experiment results, shown in Figure 1, confirmed the significant effect in disease control of As in the second experiment (infection level reduction vs. control of about 40%). A reduction of 15-25%, but not significant, was obtained with bent; Cu at all concentrations and BABA significantly reduced disease severity. In the field trial, disease assessments on cauliflower heads, performed in 3 successive times (Figure 2), showed in the last measurement a similar and significant reduction of disease symptoms for As, bent. and Cu 3 g/l, with a relative efficacy vs. control of 46%, 42%, 45%, respectively.

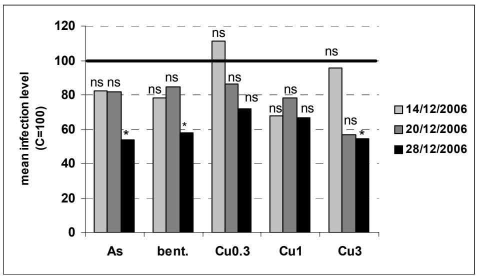

Figure 2: Different treatment effects on mean infection level in field trial. Bold line represents control equal to 100.
n = 4 replicates/treatment ; * significant for $p<0.05$

Discussion

In literature there are some evidences on the efficacy of homeopathic arsenic in the control of plant diseases (Scofield, 1984) and a resistance increase in tobacco plants against tobacco mosaic virus following treatments with As_2O_3 45 d has been already reported (Betti *et al*., 2003). The growth chamber experiment showed that As_2O_3 35 d significantly controlled dark leaf spot disease only in one case, even if a trend towards a symptom reduction can be observed. It is noteworthy that in different plant/pathogen interactions different homeopathic dilutions of the same treatment can have different efficacy. Moreover, since As_2O_3 35 d is diluted above Avogadro's number, there are no arsenic molecules in the treatment and thus it can be used in agricultural practice. Cu treatments confirmed the well known antifungal activity, particularly at 3g/l, and BABA its characteristics of resistance inducer. In particular, BABA was chosen because in a recent work a protection of *Brassica* plants against *Aternaria brassicae* following BABA treatment has been reported (Kamble and Bhargava, 2007). In the field trial, significant positive effects in the last assessment of infection level on corymb have been observed following arsenic, bentonite and copper oxiclorure at 3g/l. Since fungal inoculation was performed on the leaves before flowering, we can hypothesize that arsenic homeopathic treatment and bentonite induced a plant resistance increase to fungal infection. The symptom reduction due to copper oxiclorure, similar in our experimental trial to that induced by arsenic and bentonite, confirms the well known inhibiting effect of Cu^{2+} ions on fungal spore germination (Borkow *et al*., 2005).

Conclusions

The obtained results need further investigations to indicate a real measurable effect of homeopathic treatments, and rather the existence of a significant effect by chance. Our experimentation is still in progress with another field trial. The aim is to check the effects of the above mentioned treatments against a natural infection of *A. brassicicola*. Besides phytopathological analyses, an evaluation of organolectic characteristics and nutraceutical properties of differently treated plants will be performed. In particular, glucosinolates, a class of plant secondary metabolites typical of *Brassicacae*, will be analysed: these organic compounds seem to participate in the plant resistance mechanisms (Ménard *et al*., 1999) and present a potential activity as “plant food protection agents” (Talalay *et al*., 2001). If homeopathic treatments will induce significant effects, an agricultural application of homeopathy (“agrohomeopathy”) could be possible, at least as integrative to conventional agricultural practices. The privileged target of agrohomeopathy could be small farms (and in particular, those of nutraceutical and herbalist sectors) practicing organic farming that strive to be environmentally responsible, economically viable, and socially just.

Acknowledgments

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Late blight in organic potato growing: managing resistance and early tuber growth

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Key words: late blight, organic potatoes, resistance, physiological age, yield formation

Abstract

In organic potato production yields are often reduced by potato late blight (Phytophthora infestans). Two aspects are important in late blight management: a sufficiently high (field) resistance to late blight, and early tuber formation. With early tuber formation the period of tuber growth is extended at the beginning, and with a high resistance level at the end.

In 2006 and 2007 experiments were carried out in which the effects of the physiological age of seed tubers on field resistance to late blight and on tuber yield of potatoes (Solanum tuberosum L.) were tested for early and moderately late varieties. The results indicate that with the use of physiologically older seed tubers (by pre-sprouting) the field resistance to late blight is generally lower than with younger seed tubers. With physiologically older seed tubers, however, yields are generally higher at the time the crop has to be defoliated because of late blight.

It is concluded that especially when the growing period of a potato crop is short, for example as a consequence of an early late blight epidemic, or when a late variety is grown, early tuber growth by the use of older (pre-sprouted) seed tubers is highly important to assure an acceptable yield level at the end of the growing season. Even in years with a long growing season, a late variety like Agria may yield up to 12 t/ha more when physiologically older seed tubers are used.

Introduction

In organic potato growing, late blight, caused by the oömycete *Phytophthora infestans*, is one of the most devastating diseases, shortening the available growth period and thus reducing yields of potato crops (*Solanum tuberosum* L.) (Tamm et al., 2004). Because chemical-synthetical pesticides are not allowed under organic regulations farmers have to achieve a sufficient yield before the potato crop becomes infected with late blight.

The period of tuber growth can be extended at both ends: at the beginning, by using an early variety or physiologically older seed tubers, resulting in early onset of tuber formation, or at the end, by growing a variety or a crop with a high level of field resistance, allowing the crop to continue to grow despite late blight pressure.

Variety choice is generally considered the first and most important step in late blight management, but early varieties are generally too susceptible, and more resistant late varieties may, especially in years with an early late blight epidemic, not yet have

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reached an acceptable yield level when late blight strikes.

The use of physiologically older seed tubers, for example by pre-sprouting, results in earlier crop establishment and earlier onset of tuber growth (Struik & Wiersema, 1999). Pre-sprouting is a generally accepted technology in organic potato growing, but many farmers do not adopt it because of technical problems (work load, required planting equipment, etc.). Moreover, pre-sprouting may give a crop with a lower field resistance (Hospers-Brands et al., 2005).

In 2006 and 2007 we carried out experiments to optimize the balance between early crop establishment by using physiologically older seed tubers on the one hand and enhancing field resistance by using younger seed tubers on the other hand, with four contrasting varieties.

Materials and methods

Variety choice. The varieties were selected to cover a range of early to moderately late maturity type, and a range of late blight resistance levels (Table 1).

Tab. 1: Characteristics of the tested varieties

	Earliness[a]	Late blight resistance foliage[b]
Junior	9	4
Ditta	6	6
Nicola	5.5	4.5
Agria	5	5.5

[a] 1 = very late, 9 = very early, [b] 1 = very susceptible, 9 = resistant

In 2007, the quality of the de-sprouted seed tubers of Junior was too low to allow normal crop growth. Emergence was delayed and after a poor crop development, yields were very low. Results for Junior in 2007 are therefore not presented here.

Seed tuber treatments. We tested young tubers with young sprouts (control) (2006 and 2007), old tubers with old sprouts (pre-sprouted) (only in 2006), and old tubers with young sprouts (de-sprouted) (2006 and 2007). The control tubers were kept in cold storage until one week before planting and then mini-chitted at 16 °C. The pre-sprouted and de-sprouted tubers were kept in cold storage until five weeks before planting, and then pre-sprouted at 16 °C. From the de-sprouted tubers the sprouts were removed two weeks before planting; then the tubers were mini-chitted at 16 °C.

Test sites. The experiment in 2006 was carried out on an organic clay location and in 2007 on an organic sand location in the Netherlands. Crop management was according to the management of the commercial potato crops grown on the farms. The test sites were subjected to natural infection by late blight. The crops were defoliated by burning the foliage as soon as 7% or more of the leaf area in a given plot was infected by late blight, according to Dutch legislation.

Assessments. Emergence rate, soil cover, late blight infection (field assessments and laboratory tests on detached leaves) and fresh tuber yields were recorded. Using the statistical program Genstat (version 7.2) for both years least significant differences (LSD) were calculated, for the interaction variety*seed tuber treatment.

Results

Weather conditions differed between the two experimental years. In 2006, after a cold and wet spring, the summer was warm and dry. As a result, the late blight epidemic started late, at a moment when some organic potato crops were already showing natural senescence. In 2007 the early spring was very warm and dry, but the summer was very wet, and the late blight epidemic extremely early and aggressive.

Crop development. In both years older seed tubers (pre-sprouted or de-sprouted) emerged 1 – 5 days earlier than young seed tubers (control) (differences significant at the 5% level), and canopy development was faster during the first half of the growing season. In 2006, however, when, because of the late onset of the blight epidemic, the growing season was rather long, in the second half of the growing season the canopy from the oldest (pre-sprouted) seed tubers of the earliest varieties already started to senesce, when the canopy from the youngest seed tubers was still expanding. The effects of differences in canopy development were reflected in tuber yields (see below).

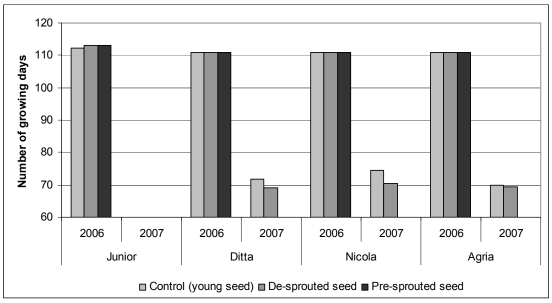

Figure 1: Growing days from planting until defoliation (7% of leaf area infected by late blight). 2006: LSD=0.39; 2007: LSD=4.60 (5% level, variety*seed tuber treatment).

Late blight. Generally, crops from the youngest seed tubers were less infected by late blight than crops from the oldest seed tubers. In 2006, with a late onset of the late blight epidemic, almost no differences in number of growing days were found, but in 2007 crops from the younger seed tubers could grow 1 – 4 days longer than crops from the older seed tubers (Fig. 1) (differences in 2007 not significant). Crops from pre-sprouted seed tubers seemed to be slightly more susceptible to late blight than crops from non-sprouted seed tubers, but crops from the de-sprouted seed tubers were in 2006 as resistant as the non-sprouted crops (results not presented).

Yield. Final yields were dependent on variety, seed tuber treatment and timing of the late blight infection. In 2006, infection by late blight was rather late, and for the earliest variety (Junior), the youngest seed tubers gave a 5.5 t/ha higher yield than the older seed tubers, whereas for the latest variety (Agria) the opposite was true: the older seed tubers gave a 9 – 12 t/ha higher yield than the young seed tubers (differences significant at the 5% level). In 2007, with much lower yield levels in general, yields from the older (de-sprouted) seed tubers were up to 3 t/ha higher than yields from the younger seed tubers (differences not significant) (Fig. 2).

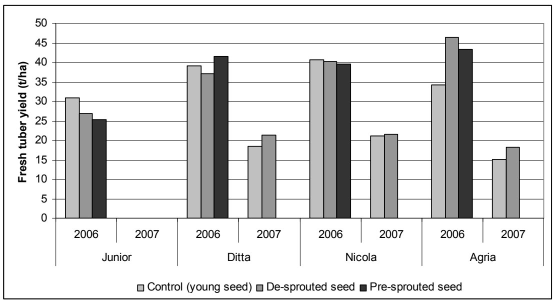

Figure 2: Final fresh tuber yield. 2006: LSD=4.42; 2007: LSD=4.83 (5% level, variety*seed tuber treatment).

Discussion

Especially late varieties seemed to profit from the yield-enhancing effects of physiologically older (pre-sprouted or de-sprouted) seed tubers. The effects, however, depended on the timing of the late blight infection: when the infection was early (2007), all varieties had higher yields with the older seed tubers, but when the infection was late (2006), only the late varieties had higher yields with older seed tubers. In this situation for early varieties the yield was highest for the younger seed tubers, because the canopy of this crop continued to expand when the canopy from the older seed tubers was already senescing. With respect to tuber yields, the yield-enhancing effects of pre-sprouting were more importance than the resistance depressing effects.

Conclusions

Early crop establishment is especially important when a late variety is grown and / or when the crop has only a short growth period because of an early late blight epidemic.

Acknowledgments

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Quassia, an Effective Aphid Control Agent for Organic Hop Growing

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Key words: Hop, *Humulus lupulus*, *Phorodon humuli*, plant protection, quassia

Abstract

In the first three decades of the 20th century, quassia extract was widely used in hop growing as a chemical agent to control Phorodon humuli *and other insect pests. In the first years of the 21st century this compound was rediscovered by German organic hop growers. In several efficacy trials conducted during five field seasons, quassia products proved to be effective control agents for* P. humuli *in organically grown aroma cultivars. A systemic variant developed by painting a suspension of quassia extract to the bines was the best method of application. This method proved not only to be very effective, but was also best from an environmental point of view. The optimal systemic application rate was determined as 24 g/ha of the active ingredient quassin. In order to generate the data necessary for registration of quassin in Annex I of the EU Council Directive 91/414/EEC, further efficacy trials were conducted during 2007. The results emphasize the importance of this compound as currently the only suitable aphid control agent in organic hop growing, especially when applied systemically.*

Introduction

In organic hop growing, the control of diseases and pests is a crucial problem. The most prevalent pests are damson-hop aphid *Phorodon humuli* (Schrank) and two-spotted spider mite *Tetranychus urticae* Koch. Without control measures, both are able to damage the quantity and quality of harvested cones, and in some years they may completely destroy a crop (Neve 1991). The earliest materials used to control *P. humuli* by spraying were nicotine, soft soap and quassia (*e.g.* Theobald 1909). The latter two compounds are still listed today as approved substances for pest control in German organic farming (*e.g.* Bioland 2007). According to these guidelines today's quassia products have to originate exclusively from the wood of the South American tree species, *Quassia amara*, with quassin as active ingredient (a.i.). At the beginning of the 21st century, aphid control by the pyrethrins registered for organic farming proved unsatisfactory, and German organic farmers rediscovered that spraying of quassia solutions, extracted by homebrews from *Q. amara* wood chips was an alternative. This option for aphid control was accompanied with efficacy trials from the first day onwards (Engelhard & Weihrauch 2005), and was advanced in the following five years (Engelhard *et al*. 2007). The best method of application was a systemic variant, developed by painting a suspension of quassia extract to the bines. This was not only very effective, but was also best from an environmental point of view, because sprayed quassia extracts from homebrews had side effects on non-target organisms such as

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leafhoppers (Cicadellidae) (Engelhard & Weihrauch 2005). The optimal systemic application rate was determined to be 24 g/ha quassin.

Therefore, previous results show that organic growers in Germany are dependent currently on quassia products in order to ensure satisfactory control of *P. humuli*. No other effective compounds or control strategies are registered for organic farming in Germany. At the moment no industrial quassia product is registered for aphid control in the EU, and the current modus operandi of organic growers, *i.e*. the use of homemade quassia brews, occupies a legal grey area. Hence, in order to make this compound available within the EU, it is most important to register quassin as an active ingredient for the control of aphids in Annex I of the EU Council Directive 91/414/EEC. The first and most important step towards registration is to generate sufficient data so further efficacy trials were performed with a new industrial quassia extract and these are presented below.

Materials and methods

The study was conducted during 2007 in the Hallertau, Bavaria, Germany. The Hallertau is the world's largest coherent hop-growing region, with almost 30 % of the world's area of this crop. It is situated south of the River Danube in central Bavaria and has an area totalling 1,500 km². Three hop gardens of three farms were chosen as study sites: Haushausen (cv. Hallertauer Tradition), Eichelberg (cv. Perle), and Schweinbach (cv. Hallertauer Magnum). As the experimental procedures and results from all three sites were similar, only Haushausen – the site with the highest aphid infestation level during 2007 - is presented below as that site was representative for all three. Plots of 84 hop plants (six rows with 14 plants each; *c.* 300 m^2) were laid out in three replications, respectively, for the following applications of quassin: 12 g/ha sprayed; 18 g/ha sprayed; 18 g/ha applied systemically; 24 g/ha applied systemically; and untreated control. The experimental dry quassia extract (0.6 % a.i.) was provided by Trifolio-M GmbH, Lahnau, Germany. The date of the single systemic application, a manual painting of quassin in an oily suspension to the bines, was 31 May, when the hop plants were in full extension growth. Quassin was sprayed twice at the above rates a.i., on 14 June, when the aphid migration was finished completely, and on 13 July, when it became obvious that the first spraying was not sufficient. Aphid population development was monitored weekly on 50 leaves sampled from each plot, respectively, for 14 weeks from late May to late August. These counts were compared by repeated measures ANOVA followed by a Bonferroni post hoc test. An experimental harvest was conducted on 29 August, which assessed yield and alpha acids (measuring unit for hop quality) from 10 bines per application in four replications taken from two experimental plots, respectively, and was compared to the grower's own treatment, which included three sprayings of quassia homebrew ('practice' in Fig. 1). Harvest data was compared by ANOVA followed by a Bonferroni post hoc test.

Results

All treatments significantly reduced the aphid population density on the plants throughout the field season (df = 4, F = 2580.402, $P<0.001$). Among all treaments, the 24 g/ha systemic treatment gave significantly the best control of aphid population development ($P<0.001$). The 18 g/ha systemic treatment had significantly fewer aphids than the two sprayed treatments ($P<0.001$), between which there were no significant differences. Compared to the untreated control, on 24 June – the day with the highest recorded aphid numbers - the 12 g/ha spray application reduced aphid numbers by 69.5 % and the 24 g/ha systemic variant by 87.6 %. Table 1 shows the progress of aphid population development in the different plots at that site which, as noted above, had the highest general infestation level during 2007.

Tab. 1: The influence of various quassia applications on the aphid population development in an organic hop garden. Haushausen, Hallertau, 2007, cv. HT. Mean numbers of aphids leaf $^{-1}$ ± s.e. of 50 assessed leaves (n = 3 replications each). Systemic application 31 v 2007, spray applications (full amount) 14 vi and 13 vii 2007.

date / treatment	control untreated	[12 g/ha] sprayed	[18 g/ha] sprayed	[18 g/ha] systemic	[24 g/ha] systemic
30 v	8 ± 5	6 ± 3	8 ± 1	6 ± 1	5 ± 1
06 vi	25 ± 3	23 ± 2	25 ± 4	17 ± 5	13 ± 4
12 vi	70 ± 16	62 ± 16	79 ± 27	20 ± 5	13 ± 2
18 vi	124 ± 7	63 ± 11	88 ± 4	31 ± 8	12 ± 3
25 vi	545 ± 37	228 ± 47	285 ± 37	25 ± 13	12 ± 7
03 vii	415 ± 20	239 ± 28	316 ± 52	44 ± 25	22 ± 15
09 vii	722 ± 145	315 ± 83	337 ± 150	43 ± 23	16 ± 4
17 vii	662 ± 168	170 ± 35	122 ± 13	131 ± 127	39 ± 21
24 vii	1229 ± 280	375 ± 214	305 ±180	343 ± 271	153 ± 97
30 vii	1138 ± 170	288 ± 81	240 ± 180	228 ± 216	64 ± 40
07 viii	325 ± 109	82 ± 33	70 ± 44	75 ± 51	28 ± 12
14 viii	43 ± 11	47 ± 19	34 ± 17	10 ± 4	14 ± 4
20 viii	8 ± 3	8 ± 2	9 ± 1	6 ± 3	7 ± 1

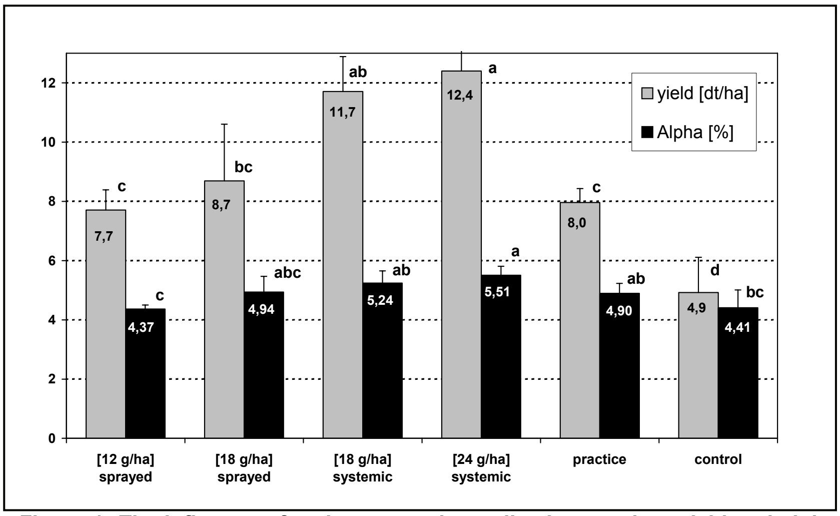

Figure 1: The influence of various quassin applications on hop yield and alpha acids in an organic hop garden. Haushausen, Hallertau, 29 viii 2007, cv. HT

Bars with the same letters are not significantly different by ANOVA, at P<0.05.

The aphid infestation records were mirrored by the results from the experimental harvest. The systemic treatments were significantly the best, and the control plot was significantly lower in yield than any quassin treatment (Fig. 1).

Discussion and Conclusions

The results achieved during the 2007 quassia efficacy trials confirm the conclusions of Engelhard *et al*. (2007). The 24 g/ha quassin systemic treatment proved to be the best and most reliable treatment. Although we tried to reduce the amount of a.i. to 18 g/ha, as a consideration to the costs of this compound, the higher quassin application rate was needed to ensure satisfactory aphid control. As we detected some heterogeneity in the aphid infestation of single plants in the systemic plots, especially in the 18 g/ha treatment, we think that probably those plants with increased infestation did not receive sufficient a.i. during the application. The amount of a.i. painted to each bine is intended to be only 4.5 mg in the 18 g/ha variant, and if the oily suspension prepared for the application is not absolutely homogeneous, some bines will get more and some probably too little quassin. This problem seems to occur less frequently with the higher dosage, which additionally may help to postpone the probable development of aphid resistance to this compound.

The spray applications were generally less effective than bine painting and led to only an approximate reduction of 70 % of aphids. This efficiency, however, may be unsatisfactory when the general infestation level is very high, as was the case at Haushausen during 2007. Furthermore, the painting of bines in the systemic application is not dependent on the calm weather conditions required for spraying, and a tractor with power sprayer is not needed, which will lead to less soil compaction in the fields. In conclusion, the systemic application of 24 g/ha quassin has to be regarded currently as the method of choice for aphid control in organic hop growing.

Acknowledgments

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The two-spotted spider mite can be controlled by water

Conte, L.[1] *& Chiarini, F.*[2]

Key words: *Tetranychus urticae*, *Phytoseiulus persimilis*, biological control, water

Abstract

The effects of a fogging system on the control of the two-spotted spider mite (Tetranychus urticae) were studied in greenhouse cultivation of eggplant, cucumber and strawberry during the period 1999-2006. At the beginning the pest and the phytoseiid predator Phytoseiulus persimilis were released on the crops and then observations were made on the development of the populations of both mites. Fogging system effects were found in terms of lowering the T. urticae population and hindering the growth of powdery mildew fungus. Furthermore there was a yield increase in the cases of strawberry and cucumber in 2001 but no negative impact on pest management was ever detected, particularly on the biological control of the melon aphid (Aphis gossypii) achieved using multiple releases of parasitoids.

Introduction

The two-spotted spider mite *Tetranychus urticae* (Acari, Tetranychidae) is one of the most dangerous greenhouses pests: when the climate is hot and dry, its populations increase rapidly (Crooker, 1985); while in presence of high air humidity (e.g. more than 70%) and, above all, direct contact with water (e.g. rain) the rate of increase of its populations is considerably reduced (Tulisalo, 1974; Holtzer *et al.*, 1988).

At present, in organic farming there are no acaricides effective on this pest and so biological control is necessary: in this case the most common technique relies upon multiple releases of the predator *Phytoseiulus persimilis* (Acari, Phytoseiidae). Unfortunately the rate of increase of the populations of this beneficial is restrained by a hot and dry climate: in fact, when air temperature is between 20°C and 30°C and air humidity is lower than 60% most of its eggs do not hatch and die. When temperature rises, the critical threshold of air humidity rises too (Stenseth, 1979): for this reason, in the Mediterranean regions during the summer, populations of *T. urticae* grow faster than those of *P. persimilis*.

In greenhouses we could get over this limit using an air moisturizing system (Fogging System) which releases tiny droplets of water to hinder the growth of *T. urticae* populations and to favour the growth of those of *P. persimilis*: in order to verify this hypothesis, during the period 1999-2006, experimental trials were done at the Experimental Center 'Po di Tramontana' of Veneto Agricoltura (in Rosolina, 60 km south from Venice).

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Materials and methods

The trials were made on different crops grown inside greenhouses of 340 m^2, in different years: in 1999 on eggplant (April-September), in 2000 and 2001 on cucumber (April-July), in 2006 on strawberry (April-September).

In each trial the greenhouse was divided in two halves by a plastic screen, giving 2 sectors of 170 m^2: "fog" and "no fog". In each sector the same species, varieties and number of plants were cultivated. In the "fog" sector only, a fogging system was assembled. The fogging system consisted of several sprinklers arranged under the roof of the greenhouse at the density of $1/m^2$. It was programmed to work every day from 9 a.m. until 6 p.m. only when the air humidity inside the greenhouse fell under 65%: in this case, droplets of water were sprayed upon the plant canopy for 2 seconds. The frequency of the sprinkles was regulated in order to avoid the persistence of a layer of water on the leaves and to prevent the development of fungal and bacterial diseases; in other words an alternation of wet and dry phases was accomplished on the leaf surface.

If there was not an equal, natural presence of *T. urticae* in the two sectors, the plants were artificially infested so that the trial could begin with equal populations of the pest. The fogging system started sprinkling from May until the end of the cultivation in 1999, 2000, 2001 and from April in 2006. During these periods the releases criteria of the predator *P. persimilis* changed (tab. 1).

Tab. 1: Releases of *P. persimilis* in the different trials (n° of phytoseiids/m^2)

eggplant 1999			cucumber 2000			cucumber 2001			strawberry 2006		
	fog	no fog		fog	no fog		fog	no fog		fog	no fog
27 May	10.3	10.3	8 Jun	0	13.2	6 Jun	6	6	27 Apr	23.8	23.8
17Jun	0	23.5	22 Jun	0	6.6	13 Jun	6	6	29 Aug	11.9	11.9
24 Jun	0	23.5									
1Jul	0	20.6									
8 Jul	0	17.6									
15 Jul	2.3	11.8									
total	12.6	107.3	total	0	19.8	total	12	12	total	35.7	35.7

In 1999, on eggplant, multiple releases of *P. persimilis* were done in order to restrict the growth of *T. urticae* below the economic damage threshold: this strategy allowed us to compare the costs of pest control in the presence or absence of the fogging system.

In 2000, on cucumber, no releases of *P. persimilis* were done in the "fog" sector in order to assess if *T. urticae* could be controlled by water alone; in the "no fog" sector two releases of *P. persimilis* were done.

In 2001 on cucumber and in 2006 on strawberry, two releases of *P. persimilis* were done in order to estimate the population dynamics of both the pest and the beneficial in the two sectors.

The populations dynamics were estimated counting young and adult instars of *T. urticae* and *P. persimilis* on leaves chosen from the upper, median and lower part of the plants of cucumber and on the young and old leaves of strawberry. On eggplant, instead, only the number of leaves occupied by the pest and the predator were recorded; even in this case the leaves were chosen from the upper, median and lower part of the plants. The computation was made weekly, monitoring 20% of the plants on eggplant, 40% on cucumber, 10% on strawberry.

The control of insect pests was made by multiple releases of beneficials: particularly *Aphidius colemani* and *Lysiphlebus testaceipes* (Hymenoptera, Aphidiidae) against the melon aphid *Aphis gossypii* (Hemiptera, Aphididae); furthermore their activity on pest control was monitored. Every year the yields were recorded and observations were made on the occurrence of fungal and bacterial diseases. In 2000 and 2001 trials Proc GLM, Repeated Measure Analysis of Variance was done. In 1999 and 2006 trials Analysis of variance with Tukey test was done.

Results and discussion

The results of the different trials are expressed in the figures 1, 2, 3, 4, where *T. urticae* population dynamics can bee seen.

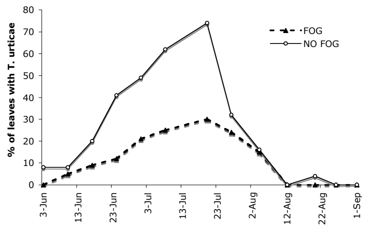

Fig. 1: population dynamics of *T. urticae* on eggplant in 1999

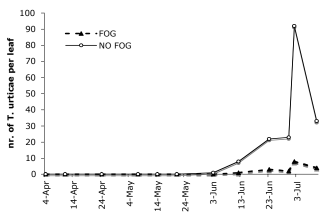

Fig. 2: population dynamics of *T. urticae* on cucumber in 2000

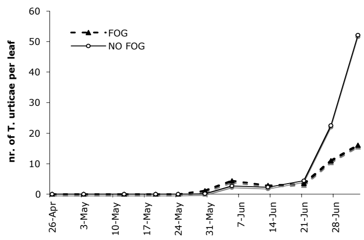

Fig. 3: population dynamics of *T. urticae* on cucumber in 2001

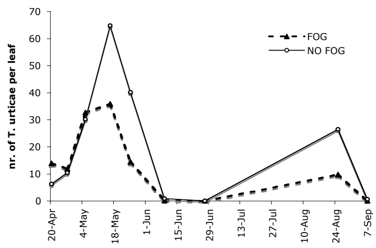

Fig. 4: population dynamics of *T. urticae* on strawberry in 2006

In all the trials the development of *T. urticae* populations in the "fog" sector was significantly lower than the level recorded in the "no fog" sector and it was always under the economic damage threshold. The development of *P. persimilis* populations always followed the one of *T. urticae* in both sectors (data not shown in this paper); as a matter of fact, the fogging system did not affect positively the growth of predator's populations as expected.

In both the sectors the yields were similar, except for the cucumber in 2001 when a higher yield was obtained in the 'fog' sector (Chiarini et al., 2002) and for the strawberry in 2006, which had 467a and 425b g/plant yield, respectively in the 'fog' and ‘no fog’ sectors (p=0.04). The fogging system did not promote the spread and development of fungal and bacterial diseases on the crops; furthermore no negative effects were also recorded on biological control of insect pests.

Conclusions

1. The use of a fogging system in greenhouses, during the summer, is an effective tool to hinder the growth of *T. urticae* populations.

2. The repeated sprinkling of water done in the hottest hours of the day, lowers the leaf temperature below a critic threshold and so rendering the net photosynthesis value positive: this means that during the summer, the crops grow better even inside the greenhouses and give either comparable or even higher yields.

3. The repeated sprinkling of water on the plant canopy does not promote the development of fungal and bacterial diseases and does not affect negatively the biological control of insect pests.

4. In the 1999 trial we estimated that the annual amortization share of the fogging system is lower than the cost of an adequate amount of *P. persimilis* to keep *T. urticae* populations under the economic damage threshold (Conte et al., 2000).

Finally, repeated observations on pest management in small farms suggest that water can be used to control *T. urticae* in greenhouses even without a fogging system: in fact a cheaper system, which consists of a web of micro-sprinklers producing water droplets on the plant canopy, can be used. The farmer should then regulate the frequency and the duration of the sprinkling. The same rule used for the fogging system can be applied: the frequency of the spraying has to be regulated in order to prevent the persistence of a layer of water on the leaves; therefore an alternation of wet and dry phases is needed on the leaf surface. This system is cheaper than the fogging system but has been tested reliable enough to be used on small farms.

Acknowledgments

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Effects of *Trichoderma* applications on vines grown in organic nursery

Di Marco, S.[1] & Osti, F.[1]

Key words: *Trichoderma*, root development, disease, organic nursery

Abstract

A two-year trial was conducted to evaluate the effects of applications of commercial formulations of the fungus Trichoderma on graftlings of grapevine (Vitis vinifera L.) in a commercial nursery where plants were grown under organic management. Treatments were carried out at callusing, rooting and callusing+rooting. Effects on the host-plant morpho-physiological characteristics were observed and depended on the type and timing of Trichoderma application. Treatment at rooting was the most effective whilst application at callusing and combination of treatments gave controversial results. The most noticeable effect of application of Trichoderma was an increase of quantitative-qualitative characteristics of the root system, with a consistent development of root hairs. Compared to untreated plants the percentage of certifiable plants treated at rooting was higher.

Introduction

Studies on the fungus *Trichoderma* demonstrated that this microorganism is able to control several fungal pathogens and can be used as biocontrol agent. The mechanism of activity of *Trichoderma* applied to the soil as inductor of plant defence responses towards pathogens far from the site of application has been recently discussed. An enhancement of crop productivity as well as beneficial effects on plant morphology and physiology were also emphasized (Harman *et al.,* 2004). The potential of nursery applications of *Trichoderma* to prevent or reduce infections of *Phaeomoniella chlamydospora* and *Phaeoacremonium* spp., fungi associated with esca, a complex wood disease of grapevine, was recently investigated. Formulations based on *T. harzianum*, applied at various nursery stages, showed a slight reduction of levels of esca pathogens, assessed on uprooted vines deriving from field nursery, and of leaf necroses due to *Botrytis cinerea* inoculated on vine leaves (Di Marco *et al*., 2004; Di Marco and Osti, 2007; Fourie and Halleen, 2006). This paper reports on results obtained in a two-years study carried out in an organic nursery on morpho-physiological effects on vines treated with *Trichoderma* formulations at various nursery vine-growth stages.

Materials and methods

Field trials were carried out in 2005-2006 growing seasons in a commercial organic nursery at Faenza, Emilia Romagna, north–central Italy. Grapevine plants cv. Trebbiano romagnolo (TR3T) grafted on K5BB or 1103P were treated with commercial formulations Rootshield® granules or Remedier® (in 2006), containing *Trichoderma harzianum* T 22 or *T. harzianum* ICC012 + *Trichoderma viride* ICC080 respectively.

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The bio-products were applied as follows: (i) "callusing": graftlings were completely drenched for 30 min in a water suspension at 15 g l^{-1} (Rootshield) and at 50 g l^{-1} (Remedier) in PVC boxes containing 750-800 plants each, then stored for 3 weeks in boxes with wet sawdust at about 30°C and 70-80% relative humidity; (ii) "rooting": the bottom ends of graftlings were placed for 30 min in PVC buckets with a suspension of the *Trichoderma* formulations at the same concentrations mentioned above; four or five weeks after planting, graftlings were treated by soil drenching with *Trichoderma* suspensions at 0.5 g l^{-1}(Rootshield) and at 5 g l^{-1} (Remedier); (iii) "callusing+rooting": graftlings were submitted to the combinations of the treatments above described. For each treatment, control plants were treated with water instead of *Trichoderma.* For each year of trial, differences in the quality and development of callus around the grafting junction were visually assessed. The graftlings showing a successful callus were recorded as plantable. Two hundred cuttings per treatment with 4 replicates (each consisting of 50 cuttings) were planted in a field nursery and left in the soil for 28-29 weeks. In autumn dormant graftlings were mechanically uprooted. After uprooting, certifiable plants were selected according to the EU directive 2005/43, and recorded. Some plants were uprooted by hand taking care to preserve the entire root system. For each treatment 4 replicates each consisting of one plant were set up. The root system of plants uprooted by hand was washed and root diameter measured with a caliper in the laboratory. Roots were then collected and grouped into 3 categories: hairs (< 0.05 mm diameter); secondary (0.05–0.2 mm); primary (> 0.2 mm). For each category the projected root area (cm^2) was evaluated by video-image analysis as described in Di Marco *et al*. (2004). The root development was examined only in the TR3T/K5BB scion/rootstock combination. In 2005, the examination was carried out with Rootshield both on potted plants and on plants collected from the nursery field; in 2006, trials were conducted only in the nursery field with both Rootshield and Remedier. Results were subjected to statistical analysis using Duncan's multiple range test, P=0.05.

Results

At the end of the callusing period, treatment with Trichodex provided a percentage of plantable plants 5% lower than untreated, only in 2005 trial and for the TR3T/K5BB scion-rootstock combination. No significant differences in the formation of grafting callus between treated and untreated graftlings were observed. At the end of the growing season, effects of *Trichoderma* treatments on the percentage of uprooted plants was not assessed, except for, in a few cases, a certain decrease in plants treated at callusing or at callusing+rooting (Tab. 1).

Tab. 1: Percentage of plants uprooted at the end of the growing season.

Treatment	2005		2006			
	Rootshield		Rootshield		Remedier	
	K5BB*	1103P*	K5BB	1103P	K5BB	1103P
Callusing	42.0a	51.5b	46.5a	58.5a	30.0b	59.5a
Rooting	46.8a	57.0a	52.0a	73.0a	54.0a	67.3a
Callusing + rooting	47.2a	60.3a	13.0b	72.0a	39.0b	56.6a
Untreated control	47.8a	67.3a	53.6a	64.0a	53.6a	64,0a

* Type of rootstock.

A significantly higher percentage of certifiable plants was noticed for plants treated at rooting with Remedier compared to the other treatments. Rootshield applied at rooting showed a significant increase of certifiable plants compared to callusing and, in some cases, to the control or to the callusing+rooting (Tab. 2).

Tab. 2: Percentage of certifiable plants after uprooting selected according to the EU directive 2005/43.

Treatment	2005		2006			
	Rootshield		Rootshield		Remedier	
	K5BB*	1103P*	K5BB	1103P	K5BB	1103P
Callusing	25.8b**	30.0c	22.0b	22.5c	6.8d	27.3b
Rooting	32.8a	42.0a	29.8a	37.3a	31.3a	35.0a
Callusing + rooting	29.8ab	37.0ab	6.5c	32.0ab	15.8c	25.3b
Untreated control	28.0ab	35.3b	25.0ab	28.5b	25.0b	28.5b

* See table 1.

** See table 1.

An enhancement of root hairs development on vines treated with *Trichoderma* was observed (Tab. 3).

Tab. 3: Development of the root type (cm2) of potted plants and plants grown in nursery field assessed by Video Image Analysis.

2005 trials

Treatment	Root system					
	Potted plants			Field nursery plants		
	Hairs*	Secondary	Primary	Hairs	Secondary	Primary
Untreated control	62.4a**	32.3a	15.4a	34.5a	38.5a	26.0a
Callusing	106.5b	32.7a	16.5a	-	-	-
Rooting	125.7b	33.9a	15.2a	107.4b	53.8a	24.0a
Callusing + Rooting	116.5b	32.0a	16.8a	-	-	-

2006 trials

Treatment at the rooting in field nursery trial

Treatment	Root system		
	Hairs*	Secondary	Primary
Untreated control	34.5a**	38.5a	26.0a
Rootshield	107.4b	53.8a	24.0a
Remedier	135.0b	55.1a	23.5a

* Root diameter: hairy (< 0.05 mm); secondary (0.05–0.2 mm); primary (> 0.2 mm).

** See Table 1.

Discussion

Results obtained in this study on the morpho-physiological characteristics of the host-plant after the application of *Trichoderma* at different nursery vine-growth stages, confirmed the complexity of the mechanism of action of the bio-control agent and its potential in enhancing crop productivity and quality. Treatments can affect the percentage of growing graftlings, suggesting the possibility of a kind of selection caused by the action of *Trichoderma*. Callusing, rooting or callusing+rooting treatments gave different results. On the whole, the two *Trichoderma* applications scheduled in the "rooting" treatment showed the most interesting activity reducing as well the variability of results obtained. Beneficial effects may be related with the choice of nursery stage and the localization of the application. In this trial Remedier was used at high dosage; ongoing studies showed that a reduction of dosage does not lead to a decrease of its activity. So, the activity seems not strictly associated with the amount of *Trichoderma* used. Generally all types of *Trichoderma* applications caused a proliferation of root system, consistent for root hairs. So, vines are better equipped to withstand stress conditions, including stress-related pathogens like those associated with esca.

Conclusions

The application of *Trichoderma* formulations in the nursery generally caused beneficial effects on plants which showed an enhancement of quality characteristics, especially for root development and, in some cases, percentage of certifiable plants. The type and timing of application demonstrated to be important for the activity of *Trichoderma*.

Acknowledgments

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Efficacy evaluation of copper formulations for the control of lettuce downy mildew (*Bremia lactucae*)

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Key words: Copper; Downy mildew (*Bremia lactucae*); Lettuce (*Lactuca sativa*)

Abstract

*A four-year field trial was run to determine the effectiveness of copper fungicides and foliar fertilizers in controlling lettuce downy mildew (*Bremia lactucae *Regel) in Italy's Emilia-Romagna Region. The experimental design was randomized blocks with 4 replicates using the highly susceptible Camaro cultivar. Eleven different fungicide formulae and foliar fertilizers with low copper concentration were compared. Tribasic copper sulphate (Cuproxat S.D.I.), copper sulphate (Poltiglia Caffaro 20) and copper oxychloride (Pasta Caffaro Nc) exhibited the best control; the effects of pentahydrate sulphate (Kay Tee) and hydroxyde (Kocide 2000) were less consistent. Hydroxide sulphate (Poltiglia disperses), tribasic sulphate (Cuproxat liquido) and the Special Kopper were less effective. The action of the foliar dressings Kendal TE, Fertileader rame and Labicuper showed the most promising results. The only non-copper-based alternative product, grapefruit seed extract, or DF 100 V, proved to be ineffective. Some of the tested foliar sprays were thus as effective as some copper-based fungicides and released less copper into the environment.*

Introduction

Downy mildew, caused by *Bremia lactucae* Regel, is one of the major lettuce (*Lactuca sativa* L.) diseases worldwide because the fungus attacks the leaves and leads to high crop losses. The control of downy mildew in organic lettuce farming is based on both, the use of resistant varieties and preventive copper-based sprays (Crute, 1992; Malezieux *et al*., 1993). The use of resistant varieties is not sufficient *per se* to prevent *B. lactucae* infections because of the pathogen's ability to breach genetic barriers, hence the need for copper-based compounds (Gengotti, 2003). The alternative fungicides allowed under EU protocols for organic agriculture are less effective in controlling downy mildew, especially when disease pressure is high (Pertot *et al*., 2002). However, since the long-term inputs of copper may have health and environmental consequences due to soil accumulation, Commission Regulation (EC) No. 473/2002 limits the amount of copper used to 6 kg ha^{-1} $year^{-1}$. Given that further studies of low-copper fungicides are needed, our aim was to test the effectiveness of several copper-based compounds at low dressing rates, including foliar fertilizers widely used in Italy.

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Materials and methods

Tab. 1: Main trial data

	Trial 1	Trial 2	Trial 3	Trial 4
Year	2003	2004	2005	2006
Transplant date	15-Sep	22-Sep	16-Sep	15-Sep
Plot size (m^2)	12	12	14	14
No. of sprayings	7	5	7	6
Application date	25-Sept, 3, 10, 18, 25, 31-Oct, 10-Nov	6, 13, 20, 22, 26-Oct	26-Sept, 6, 12, 18, 24, 31-Oct, 9-Nov	19, 27-Sept, 4, 11, 17, 23-Oct
Spray volume (l ha^{-1})	600-1000	800-1000	1000	1000
Harvest date	20-Nov	15-Nov	16-Nov	30-Oct

Tab. 2: Tested compounds and application rates

Product	Type of copper	Copper content (g l^{-1})	Rate	
			Product (g or ml hl^{-1})	Copper (g hl^{-1})
Cuproxat S.D.I.	tribasic sulphate	195.0	350	68.25
Kay Tee	pentahydrate sulphate	60.0	150	9.00
Kocide 2000	hydroxide	35.0 %	150	52.50
Pasta Caffaro Nc	oxychloride	377.5	375	141.56
Poltiglia Caffaro 20	sulphate	20.2 %	700	141.40
Special Kopper (1)	unlisted	42.8	225	9.63
Cuproxat liquido	tribasic sulphate	195	400	78
Poltiglia disperss	hydroxide sulphate	20 %	400	80
Fertileader rame (1)	sulphate	72.0	150	10.8
Labicuper (1)	gluconate	67.8	400	27.12
Kendal TE (1)	oxychloride	23.0 %	300	69

(1) foliar dressing

The highly susceptible cv. Camaro lettuce was tested in four randomized blocks with 4 replicates at plots in Cesena, Italy, from 2003-2006; the main trial features are reported in Table 1. Table 2 shows the products tested and their formulae. Trials 3 and 4 tested also an alternative natural product based on 2% grapefruit seed extract (DF 100 V, marketed by Agritalia Ltd) at the rate of 200 ml hl^{-1}. The sprayer was a power Fox F320 knapsack with Teejet TX 8002 VS nozzles. Whenever possible, sprays were preventively applied 4-14 days after transplants at intervals of 3-10 days depending on weather conditions. The commercial crop and the percentage of infected leaves were assessed at harvest on 10-20 plants/plot and 10-15 leaves/plant. Data were transformed and processed by one-way ANOVA followed by LSD test ($p \leq 0.05$).

Results

Tab. 3: Trials 1 and 2

Treatment	Infected leaves (%)				Commercial yield (g/plant)				Cu^{++} amount (g ha^{-1})*
	Trial 1		Trial 2		Trial 1		Trial 2		
Untreated control	52.8	a	87.8	a	147.3	c	146.1	c	0
Cuproxat S.D.I.	12.0	cd	79.3	b	210.3	a	203.8	a	3554
Kay Tee	23.0	bc	77.5	b	200.1	ab	182.6	ab	469
Kocide 2000	36.5	ab	80.3	b	176.3	bc	190.0	ab	2734
Pasta Caffaro Nc	16.8	cd	77.5	b	197.8	ab	192.0	ab	7371
Poltiglia Caffaro 20	3.6	d	79.0	b	218.1	a	202.5	a	7363
Special Kopper	-	-	79.3	b	-	-	165.6	bc	430

Different letters in the same column indicate statistical differences (LSD test, $p < 0.05$).
*Amount of Cu^{++} distributed (means of Trials 1 and 2)

Tab. 4: Trials 3 and 4

Treatment	Infected leaves (%)				Commercial yield (g/plant)				Cu^{++} amount (g ha^{-1}) *
	Trial 3		Trial 4		Trial 3		Trial 4		
Untreated control	52.4	ab	79.9	ab	112.4	d	344.8	b	0
Cuproxat liquido	48.9	abc	68.3	d	117.9	cd	471.0	a	5070
Poltiglia disperss	44.7	bc	75.9	bc	136.8	ab	454.4	a	5200
Fertileader rame	45.4	abc	71.3	cd	137.2	ab	442.1	a	702
Labicuper	49.2	abc	68.1	d	131.0	abc	446.5	a	1763
Kendal TE	42.5	c	68.1	d	149.4	a	453.3	a	4485
DF 100 V	54.5	a	83.8	a	119.3	bcd	354.8	b	0

Different letters in the same column indicate statistical differences (LSD test, $p < 0.05$).
*Amount of Cu^{++} distributed (means of Trials 3 and 4)

Trial 1. While weather conditions were not conducive to pathogen outbreak, end-of-season rains made it possible to evaluate the efficacy of the products. Except for

Kocide 2000, all the compounds differed from untreated control. Poltiglia Caffaro 20, Pasta Caffaro Nc and Cuproxat S.D.I. were the most effective (Table 3).

Trial 2. The weather was very favourable for the disease. The first symptoms were observed 10 days after transplant (before the first spraying). The early outbreak may explain the generally poor effectiveness registered in this trial. All the fungicides reduced the disease to some extent compared to the control; Special Kopper was the least effective (Table 3).

Trial 3. Weather conditions were disease-favourable. The first symptoms appeared early in the season, soon after the transplant. Kendal TE provided the best protection and, along with Poltiglia disperss, Fertileader rame and Labicuper, resulted in the highest yields (Table 4).

Trial 4. Weather conditions were conducive to mildew. The overall results showed relatively poor disease control; Kendal TE, Labicuper, Cuproxat liquido and Fertileader rame proved the most effective (Table 4).

Conclusions

The tested products adequately controlled the disease in 2003, when mildew incidence was low, but proved unsatisfactory from 2004-2006 despite the high number of sprayings. These results show that pronounced disease pressure makes it extremely hard to control downy mildew infections on lettuce using only copper-based sprays, although the latter proved to be the most effective among the fungicides allowed in organic farming (Pertot *et al*., 2002). The best mildew control was provided by the fungicides Cuproxat S.D.I., Poltiglia Caffaro 20 and Pasta Caffaro Nc; effectiveness of Kocide 2000 and Kay Tee was inconsistent. The foliar dressings Kendal TE, Fertileader rame and Labicuper protected the crop as effectively as, and sometimes better than, the best copper fungicides. Except Special Kopper, the amounts of copper released by the foliar dressings were lower than those from the most effective copper-based products, *i.e*. 2317 g ha^{-1} compared to 6096 g ha^{-1} (average of all trials) (Tables 3, 4). DF 100 V, the only natural compound tested, proved to be ineffective against *B. lactucae*. Thus, the foliar sprays Kendal TE, Fertileader rame and Labicuper effectively controlled the disease with low environmental impact because of their limited copper input.

Acknowledgements

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Evaluation of natural active ingredients and agronomical techniques against flea beetle (*Phyllotreta* spp.) on open field organic garden rocket (*Eruca sativa*)

Gengotti, S.[1] & Tommasini, M.G. [2]

Key words: Crop cover, Flea beetle (*Phyllotreta* spp.), Garden rocket, Rotenone

Abstract

*Natural pesticides and crop covering proved to be effective in containing flea beetle (*Phyllotreta *spp.) in a three-year trial of open-field organic garden rocket (*Eruca sativa *Miller) in Italy's Emilia-Romagna Region. Although rotenone proved to be more effective than pyrethrins, it was still unsatisfactory. Crop cover with non-woven polypropylene sheets produced encouraging results in pest control.*

Introduction

Flea beetles of the genus *Phyllotreta* (Coleoptera: Chrysomelidae) are a serious pest of many crops in the *Brassicaceae* family, including cabbage and garden rocket (Subedi and Vaidya, 2003; Andersen et al., 2006). This plant family's variability in susceptibility to attack by the flea beetle has often made chemical pesticides the only solution (Hiiesaar *et al*., 2003; 2006). While conventional farming uses systematic or contact insecticides, the organic farmer has had little to fall back on. Garden rocket (*Eruca sativa* Miller), also known as arugula or rocket salad, is a good case in point. Its short natural growing cycle and the demand for a high-quality and residue-free crop have made it difficult to treat with chemical deterrents alone (Subedi and Vaidya, 2003). The aim of our study was to determine the effectiveness of different natural active ingredients and crop covering in controlling flea beetle in garden rocket.

Materials and methods

A three-year (2005-2007) trial was set up in randomized blocks at an organic farm at Sala di Cesenatico, Forli'-Cesena Province, Emilia-Romagna Region. The main trial features are shown in Table 1, and Table 2 displays the types and amounts of pesticides used. Besides comparing the results of natural active ingredients, Trials 1 and 2 also tested whether certain management techniques could be used for pest control instead of repeated chemical treatment. In these trials, the garden rocket was covered immediately after transplant with non-woven polypropylene sheets stretched over hoops to form tunnels. Trial 3 compared two cover techniques using non-woven polypropylene sheets: one laid the sheeting directly on top of the plants and the other stretched it over hoops to form a tunnel. A third treatment contained plants that were sprayed with Tanacide 5 times, a standard organic pesticide. *Diplotaxis tenuifolia* (L.) DC, a widely grown species commonly called wild rocket, was included as untreated random control, to compare its susceptibility to that of the untreated garden rocket.

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Each trial was carried out when field plants were 2 cm in height. Given the small size of the plants and the early onset of flea beetle in many of the trials, all plots were treated with pyrethrins (Piresan Plus) pre-trial, *i.e.* one treatment was applied before Trials 1 and 3 and three before Trial 2. The plots with non-woven polypropylene sheets were covered immediately after the last pre-trial treatment to ensure no flea beetles would be inside; samples were taken two days after removal of the sheeting. At harvest, a sample of 50-100 leaves was taken from each plot to measure the extent (% of damaged leaves) and severity (% eaten leaf or number of holes/leaf) of damage. The data were processed by analysis of variance (ANOVA) and LSD test (P<0.05).

Tab. 1: Main trial features

	Trial 1	Trial 2	Trial 3
Year	2005	2006	2007
Transplant date	4-Aug	4-Aug	12-Jun
Plot size (m^2)	12	12	12
Crop cover date	6-Aug	13-Aug	14-Aug
Application equipment	power knapsack sprayer ECHO SHR 150 SI		
Spray volume ($l\ ha^{-1}$)	600-1000		
Number of applications	7	5	5
Application dates	8-10-12-14-16 18-20-Aug	16-18-19 22-23-Aug	15-18-20 22-25-Jun

Tab. 2: Compound details

Compound	Active ingredient (A.i.)	A.i. content (% or $g\ l^{-1}$)	Dose		Applied in trial
			compound (g or $ml\ hl^{-1}$)	A.i. ($g\ hl^{-1}$)	
Diractin	azadirachtin	32	112.5	3.60	1
Piresan Plus	pyrethrins + piperonyl butoxide	150 120	100	12 + 9.6	1 and 2
Rotena 43	rotenone	43	450	193.5	2
Rotena	rotenone	62.4	275	17.16	1
Show	pyrethrins + rotenone	5 + 20	700	35 + 140	2
Tanacid	pyrethrins	36.6	100	36.3	3

Results

Trial 1. The results are shown in Table 3. The leaves of the untreated control were completely riddled by the pest, the eaten leaf area being high. The leaves of plants treated with Diractin did not differ significantly from those of the control, and the protection afforded by Piresan Plus and Rotena, though reducing leaf damage, was not very effective. Plant cover proved to be the most effective measure with slight damage being found on 54% leaves.

Trial 2. The results are shown in Table 4. As in Trial 1, control leaves showed the most, but not very severe, damage. Piresan Plus reduced hole number per leaf but not the number of damaged leaves. Rotena 43 and Show proved to be more effective than Piresan Plus. Crop cover showed significantly lower damage than all the other treatments.

Trial 3. The results are shown in Table 5. The leaves of all the non-treated controls, whether garden or wild rocket, were similarly and heavily damaged. Tanacid spraying reduced the number of holes per leaf but not the percentage of damaged leaves. Crop cover, whether in direct contact or stretched over hoops, proved the most effective means of controlling the pest.

Tab. 3: Average results of trial 1 (22 August 2005)

Treatment		Damaged leaves (%)		Eroded leaf area (%)	
1	untreated control	100	a	63.2	a
2	Diractin	100	a	62.8	a
3	Piresan Plus	98.0	a	25.5	b
4	Rotena	100	a	19.4	b
5	Cover	54.0	b	0.6	c

Different letters in the same column show statistical differences (LSD test, P<0.05)

Tab. 4: Average results of Trial 2 (25 August 2006)

Treatment		Damaged leaves (%)		Number of holes/leaf	
1	untreated control	96.8	a	6.4	a
2	Piresan Plus	71.8	ab	2.3	b
3	Rotena 43	52.0	bc	0.7	c
4	Show	37.8	c	0.4	c
5	Cover	8.8	d	0.0	c

Different letters in the same column show statistical differences (LSD test, P<0.05)

Tab. 5: Average results of Trial 3 (29 June 2007)

Treatment		Damaged leaves (%)		Number of holes/leaf	
1	untreated control (wild rocket)	100	a	144.0	a
2	untreated control (garden rocket)	100	a	131.5	a
3	cover on hoops (garden rocket)	29.0	b	0.2	c
4	cover directly on crop (garden rocket)	30.0	b	0.5	c
5	Tanacid (garden rocket)	100	a	63.0	b

Different letters in the same column show statistical differences (LSD test, P<0.05)

Discussion

Despite the high number of sprayings and the short interval between them the chemicals never provided adequate protection over the three trial years. While our findings appear to be in contrast with those reported by Hiiesaar *et al*. (2003), who tested synthetic, not natural compounds, they are in line with those reported by Andersen *et al*. (2006), who tested the natural azadirachtin on *Brassica rapa* L. It is worth reiterating that Piresan Plus, Rotena, Rotena 43 and Show did reduce, albeit slightly, damage severity, the latter three showing the best results. By contrast, the most effective pest control agent proved to be the row cover, whether laid directly on or stretched over the crop, as also reported by Andersen *et al*. (2006). It is worth noting that the poor scores registered by the natural pesticides may in part be attributed to the small size of the test plots and the pronounced mobility of the flea beetle. Further tests are needed to clarify this point. Note too that both rocket species used in the trials are highly susceptible to flea beetle attack.

Conclusions

No natural pesticide tested proved as effective in controlling flea beetle as non-woven sheeting. Placing the sheeting directly on the crop is obviously more practical than stretching it on hoops to form a tunnel. While removing the cover a couple of days before harvest prevented mechanical damage to leaves, questions remain with regard to both cover-induced alterations in crop flavour traits and economics. Further tests are thus required to address these questions so as to upgrade cover use in organic farming.

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The use of copper seed treatments to control potato late blight in organic farming

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Key words: *Phytophthora infestans*, primary infections, stem blight, Öko-Simphyt

Abstract

In organic farming, potato late blight still is an unsolved problem. Up to now copper fungicides have been the most effective way to control this disease. In order to postpone the beginning of the blight epidemic, as well as the start of spraying, primary stem infections (stem blight) should be reduced by copper seed treatment. In field trials, copper fungicide treatments not only reduced stem blight and the spreading of the pathogen from infected seed tubers, but also decreased the number of infected daughter tubers.

Introduction

Potato late blight caused by the oomycete *Phytophthora infestans* is one of the most important yield-limiting factors in organic potato farming. In most countries the pathogen is controlled by the protective application of copper fungicides. However, the use of copper in Germany is limited to 3kg/ha throughout a growing season. While secondary infections of the leaves can be prevented by the protective application of copper, primary infections (stem blight) can not be prevented. Secondary infections are caused by sporangia blown in from inoculum sources outside the field. Possible sources, especially after a mild winter, are volunteers and/or infected cull piles (HOFFMANN and SCHMUTTERER, 1999). However, the main inoculum source is latent infected tubers in storage (ANDRIVON, 1997). Favourable conditions during storage prevent these tubers from showing symptoms or rotting (ADLER, 2000). The infection remains undetected, and the infected tubers are used as seed tubers, bringing the inoculum direct into the field. The resulting primary infections from this latent infected seed tubers cause an early start of an epidemic. Under favourable conditions (20 mm rain, high soil moisture) the pathogen is able to extend its growth to the stem of the infected tuber, causing stem blight (ZELLNER, 2006). This takes place either by direct intercellular growth from the tuber into the stem (ADLER, 2000; APPEL et al., 2001), or by reinfection of the stem after sporulation on the surface of the tuber. The produced sporangia are also spread via soil water to neighbouring plants (BAIN and MÖLLER, 1998), causing stem blight on them as well. This way of infection cannot be prevented by the foliar application of copper. As a new approach, seed treatments with low volumes of copper should prevent healthy tubers from being infected by inoculum in the soil and also directly inhibit latent infected tubers from producing sporangia (BENKER et al., 2006). In conventional farming the use of fungicide seed treatments can postpone primary infections for 8-20 days and slow down the course of the blight epidemic (BÄßLER et al., 2002). In this project these promising findings will be transferred to organic farming by the application of copper seed treatments within the project Öko-Simphyt.

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Materials and methods

Field trials where conducted in 2005 –2007 at two sites in Bavaria on heavy and light soils. To ensure the appearance of primary stem infections (stem blight), seed tubers were artificially inoculated by injection of zoospores of *P. infestans*. In accordance with the aim of the experiments, the tubers were treated with copper fungicides (copper hydroxide, trade name: Cuprozin flüssig; 120g Cu/ha) before planting.

In one approach the transmission of infections from seed tubers to their daughter tubers was tested with artificially infected (50 zoospores) tubers of the variety Agria. A copper seed treatment should reduce the number of infected daughter tubers by preventing the pathogen from spreading from the infected seed tuber. A sample of more than 45 daughter tubers per approach was analysed for tuber blight by PCR (JUDELSON and TOOLEY, 2000).

In the second approach two seed tubers were planted close to each other. One of them (variety Quarta) was inoculated with 200 zoospores and the other one (variety Agria) remained healthy. Copper seed treatment was applied either to the infected tuber or the healthy one. For control both tubers remained untreated. After emergence the frequency of stem blight was measured weekly and confirmed by PCR detection. In this way the effect of the copper seed treatment on the spreading of inoculum from diseased to healthy plants was tested.

Results

When a copper seed treatment was applied, less than 5% of the corresponding daughter tubers were infected. That is a significant difference ($p<0.05$) compared with untreated seed tubers, which had an average of 72% infected daughter tubers.

In the second approach infected seed tubers of the variety Quarta were able to infect the neighbouring plants (Agria) with a frequency of 45%, if neither of the tubers was treated with copper. A copper seed treatment of the latent infected tubers slightly prevented the pathogen from spreading, reducing the frequency of stem blight to 35% on the adjacent plants. The best effect was achieved by a treatment of the healthy Agria seed tubers with copper. This significantly protected them from being infected by released sporangia (25% frequency of stem blight).

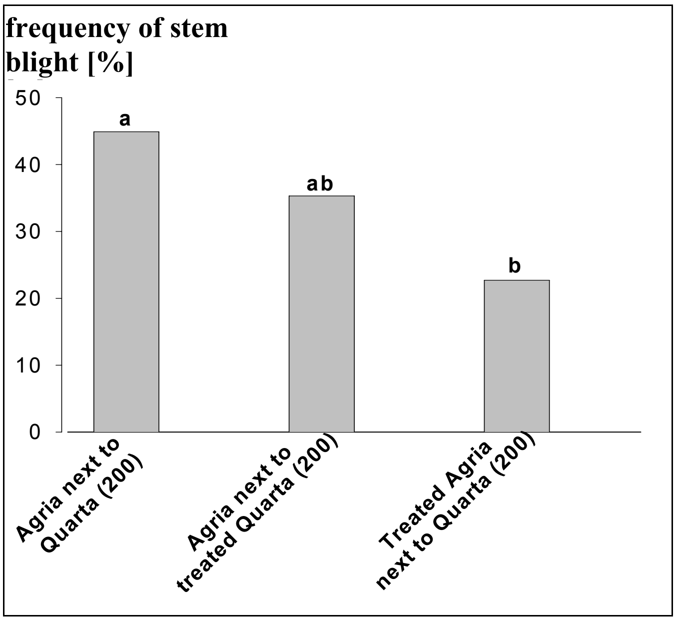

Figure 1: Effect of copper seed treatment (120g Cu/ha) on stem blight; different letters indicate significant ($p<0.05$) differences; variety Quarta was artificially inoculated with 200 zoospores.

Discussion

Primary infections caused by latent infected seed tubers cannot be prevented by crop rotation, since the inoculum is brought into the field by the farmer. The findings show that copper seed treatments are a promising way of reducing stem blight and the spread of the disease. Since the dosage of the copper used to cover the seed tubers is as low as 48g/t (120g/ha), this way of protecting the plants can be deployed in addition to the normal sprayings without exceeding the maximum allowed amount of copper.

Conclusions

Copper seed treatments reduce primary stem infections (stem blight) and decrease the spread of inoculum to neighbouring plants. Thus an early outbreak of the epidemic can be prevented. Also the number of infected daughter tubers is reduced.

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Efficacy of biological insecticides to control the Colorado potato beetle (*Leptinotasara decemlineata*) in organic farming

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Key words: Plant protection, insecticides, Colorado potato beetle, forecast model

Abstract

The Colorado potato beetle (Leptinotasara decemlineata Say) is one of the most important pests on potatoes (Solanum tuberosum). In the present study, we compared the efficacy of three biological insecticides – Neem (NeemAzal-T/S), pyrethrum/rapeseed oil (Spruzit Neu) and Bacillus thuringiensis var. tenebrionis (Novodor FC) – against this pest in field trials conducted from 2005 to 2007. The combined and temporarily shifted application of neem and B.t.t. reduced significantly the number of beetle larvae and the percentage of defoliation due to larval feeding, and increased the potato yield considerably. The SIMLEP3 forecasting model is useful for determining the optimal timing of the treatment. Pyrethrum/rapeseed oil did not lead to a significant reduction of Colorado potato beetle larvae.

Introduction

The Colorado potato beetle (*Leptinotarsa decemlineata* Say) is one of the most important pests on potatoes. In organic agriculture, the application of insecticides of biological and mineral origin is accepted as a last option to control pests only after all other preventive methods have failed. The selection of early-maturing varieties and creating conditions to make them emerge quickly ensure the yield development to occur earlier than the infestation by the beetle. Other preventive steps to be taken are both avoiding volunteers to emerge and selecting fields, neighbouring areas of which had seen potato cropping in the previous year, as the pest always spreads from there. (Kühne et al. 2006). Considering crop rotation, the cultivation of potato in immediately neighbouring fields may be regarded as a monoculture for the Colorado potato beetle. In many areas, preventive measures do not appear to be sufficient to avoid damage caused by the Colorado potato beetle.

Materials and Methods

The insecticides approved for potato beetle control in organic farming were comparatively tested from 2005 to 2007 on a test site of the Federal Biological Research Centre for Agriculture and Forestry (BBA) in Dahnsdorf (Brandenburg), Germany. The test site was certified for organic farming according to EU guidelines (control no.: D-BB-043-4143 A; soil type: sandy loess sL, mean annual precipitation: 526 mm). Relevant experience data were available for the neem-based product "NeemAzal-T/S" and for the *Bacillus thuringiensis* var. *tenebrionis* (*B.t.t.*)-based

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product “Novodor FC” (Zehnder et. al. 2007); however, this was the first time that the efficacy of the pyrethrum/rapeseed oil-based product "Spruzit Neu” was investigated in the context of an organic potato farming comparative study. These efficacy studies were performed in accordance with the specifications in EPPO guideline PP 1/12 (3) (see also www.bba.de/eppo/i_12.pdf). The trials were conducted as a randomised, single-factor experiment with block design and four repetitions. Seven treatments were investigated in 2006 (plot size: 6 m x 17 m per treatment), and three treatments in 2005 and 2007 (plot size: 6 m x 34 m per treatment) (Table 1). They were compared with an untreated control every year. Both the number of potato beetles and the percentage of defoliation due to feeding damage (defoliaton index, Boiteau 1994) were determined at weekly intervals on the same ten randomly-selected and marked potato plants per treatment variant. Since the larvae may be counted on the plants for a comparatively long period of time following the application of Neem, the calculation of its efficacy was performed according to the defoliation index by the Abbott-formula: degree of effectiveness = (X – Y) / X x 100 with X = value of the control and Y = value of the test item. For timing the treatment, the SIMLEP3 forecast model was used in 2006 and 2007 to determine the maximum number of young larvae, thus finding the optimum time of pesticide application. The SIMLEP3 model uses a temperature-sum method to calculate the population dynamics of the potato beetle (Roßberg 1999). The date of first egg-laying in the field and weather data from the nearest weather station were used as input parameters for the model calculations. The respective insecticide treatments were conducted under optimal weather conditions, i.e. with no direct sunlight, wind speed < 1 m/s, and temperature < 20 °C. Pyrethrum was applied with 1000 l/ha of water. Neem and *B.t.t.* were mixed with 400 l/ha and 500 l/ha of water. In 2006, the potato blight (*Phytophthora infestans*) was controlled by a five-time application of copper-products (CUPROZIN flüssig, 750 g copper per application) throughout all treatments.

Results

The results of the field counts made on the respective scoring days were in harmony with the forecast model calculations; the insecticide treatments were therefore performed within the predicted time frame.

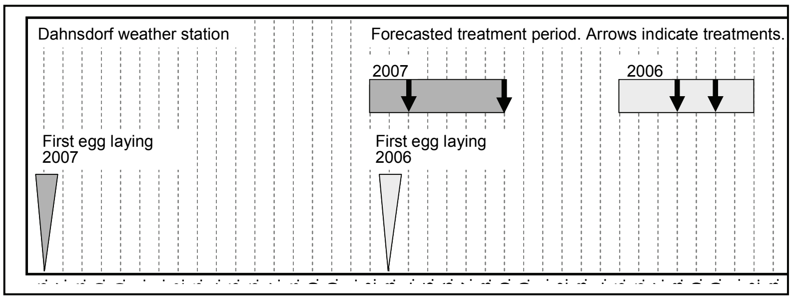

Figure 1: Results achieved with the SIMLEP3 forecast model in terms of predicting the optimal time of treatment for the two years of the trial.

In 2007, treatment was necessary two weeks earlier than in 2006 and 2005. The average number of larvae per plant before treatment were 49 in 2005, 17 in 2006, and 38 in 2007 (n=160). Table 1 shows the treatments for the applications of the plant protection products used to control potato beetles between 2005 and 2007. In addition to that, the degree of effectiveness related to the reduction of leaf consumption (24 days after treatment) and the increase in yield in dt/ha compared with the untreated control are stated.

Tab. 1: Treatments for application of the plant protection products used to control potato beetles between 2005 to 2007, degree of effectiveness in % regarding defoliation 25 days after treatment and increment (dt/ha) in comparison to untreated control. * Significant relates to untreated control (Tukey's test; P<0.05)

year of exp.	First trt	Product (L)/ha	Second trt	Product (L)/ha	Timing of second trt	Degree of effectiv-eness %	increment to untreated control dt/ha
2005	Pyreth.	8	None	None	None	9	16
2006	Pyreth.	8	Pyreth.	8	+12dd	16	17
2005	B.t.t.	5	None	None	None	30	25
2006	B.t.t.	5	None	None	None	45	17
2006	B.t.t.	5	Pyreth.	8	+2dd	43	9
2005	Neem	2.5	None	None	None	44*	54*
2006	Neem	2.5	None	None	None	57*	19
2006	Neem	2.5	Pyreth.	8	+2dd	71	0
2006	Neem	1.5	B.t.t.	5	+2dd	80*	42*
2007	Neem	2.5	B.t.t.	5	+5dd	87*	62*
2007	Neem	2.5	B.t.t.	3	+5dd	82*	70*
2006	Neem	2.5	B.t.t.	1,7	Tank mix with first trt	77*	18
2007	Neem	2.5	B.t.t.	1,7	Tank mix with first trt	68*	16*

The control results with Pyrethrum were unsatisfactory throughout the entire period. Feeding damage rates were high, and even a second insecticide treatment in 2006 could not improve the result essentially. A single *B.t.t.*-treatment was also unsatisfactory and could not increase the yield significantly in terms of statistics. Only one single neem treatment could increase both the degree of effectiveness and the yield significantly. The best potato beetle control results were achieved when using the combination of Neem + *B.t.t.*. In 2007, the degree of effectiveness was increased to 87 % by raising the dose of *B.t.t.* and prolonging the time between treatments in comparison to the tank mix.

Discussion

The explanation for the advantageous effects of neem and *B.t.t.* when combined to control the potato beetle lies in the different mechanisms of action of the two substances. Neem must be consumed by the potato beetle larvae over a long period of time in order to develop its inhibitory effect on moulting whereas *B.t.t. (Bacillus thuringiensis var. tenebrionis*) is a bacteriotoxin that rapidly leads to the cessation of feeding following ingestion. It is also much cheaper than neem. For this reason, the two insecticides should be applied at different times using a temporal displacement strategy with neem always being applied first. When applied 5 days apart, neem has time to weaken the larvae so that the bacteriotoxin *B.t.t.* can kill them faster with the effect that larvae that hatch later will also be killed. Since these biological insecticides remain active for only a few days after application, optimal timing of their application is of utmost importance. The SIMLEP3 forecast model proved to be suitable for this task as the scoring data collecting in the field showed excellent correlation with the forecasts calculated according to the simulation model. The pyrethrum-rapeseed oil-based product (Spruzit Neu) did not exhibit potato beetle control satisfactorily, not even after repeated application. In light of the reports of resistance development to pyrethroid insecticides, the limited efficacy of this plant protection product can presumably be attributed to reduced sensitivity of the Colorado potato beetle population (Nauen 2005).

Conclusions

In many areas, preventive strategies do not suffice to prevent potato beetle damage (Reelfs et al. 2007). In this event, insecticides may and should be used to prevent economic losses—even in organic farming. The SIMLEP3 forecasting model can be used to determine the optimal timing of treatment. The combination of neem (NeemAzal-T/S) + *B.t.t.* (Novodor FC) achieved good control of young larvae. The two insecticides should ideally be applied in a temporally displaced manner; neem should be applied first, followed by *B.t.t.*. At the same time, this dual strategy minimises the risk of the development of resistance to the insecticides.

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Effects of *Trichoderma harzianum* applications on fresh pruning wounds in *Actinidia deliciosa* for the protection against pathogens associated with the "wood decay" of kiwifruit

Neri, L., Baraldi, R., Osti, F. & Di Marco, S.[1]

Key words: kiwifruit, "wood decay", pruning, *Trichoderma harzianum*

Abstract

A chronic wood wasting disease of kiwifruit (Actinidia deliciosa) has recently been identified in Italian kiwifruit vineyards. This disease is principally caused by Phaeoacremonium aleophilum and Fomitiporia mediterranea. The "wood decay" causes a reduced productivity and longevity in the vineyards and influences the quality of the final product. "Wood decay" has a high incidence throughout the vineyards, and is difficult to eradicate once present, leaving prevention as the best defence strategy. The different pathogens causing the disease infect the plant mainly through pruning wounds. We studied a commercial formulation of Trichoderma harzianum T22 for the protection of pruning wounds, and thus for the prevention and reduction of the infection. The studies were carried out on potted plants, on shoots of the year that were cut, simulating a summer pruning, and treated with a T. harzianum commercial suspension. A different morphologic reaction was observed on treated and control shoots; physiological processes connected to the reaction, such as the variation in the levels of a growth-promoting hormone (auxin) and the content of total phenols were investigated through biochemical and histological analyses. The higher levels of auxin and phenols recorded in treated shoots suggested a stimulation of T. harzianum on the wound healing processes.

Introduction

A chronic wood wasting disease of kiwifruit (*Actinidia deliciosa*) has recently been identified in Italian kiwifruit vineyards. Principally caused by *Phaeoacremonium aleophilum* and *Fomitiporia mediterranea,* it has been named "wood decay" (Di Marco *et al*., 2000). The disease was also described in different forms in Greece and France, and affects the quality of the final product, as well as reducing the productivity and longevity of the vineyards. Wood decay is a form of wood deterioration similar to "esca" as found in grapevines, identifiable on the trunks and cordons of infected plants by wide decayed areas with a spongy texture, together with dark and hard necrotic streaks. The disease is caused by different fungi, particularly *Phaeoacremonium aleophilum* and *Fomitiporia mediterranea*, pathogens already associated with grapevine esca (Crous *et al.*,1996; Di Marco *et al.*, 2004; Di Marco and Osti, 2008). The decay starts from pruning wounds, the main portal for pathogens infection (Di Marco *et al.*, 2004). Spores deposit on the wound surface and can diffuse through the open vascular system; wounds remain susceptible to infection for several time, up to 4 months in grapevine (Eskalen *et al.*, 2007), and susceptibility varies according to the pathogen involved and the pruning season (Van Niekerk *et al.*, 2007; Serra *et al.*,

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2007); spraying pruning wounds with products providing long-term protection of xylem and pith tissue is thus recommended as a preventive control measure.

Trichoderma spp. is a well known biocontrol fungal agent. The aim of this study was to test the effect of commercial *Trichoderma harzianum* on the healing process of summer pruning wounds in kiwifruit plants (*Actinidia deliciosa*), by applications to the foliar apparatus. We also investigated the influence of *T. harzianum* on different physiological processes such as the concentration of the auxin indole-3-acetic acid (IAA), a plant growth regulator that enhanced callus formation, and the production of total phenols, compounds involved in plant defence against pathogens.

Materials and methods

The analyses were carried out on kiwifruit potted plants, grown in an open frame. Shoots of the year were pruned during the month of July, and the wounds were immediately treated by nebulization either with a commercial formulate of *T. harzianum* T22 (Rootshield®) at 0.5 g l^{-1} or with water alone (control). The wound closing process was observed on plant, on treated and control shoots, for up to 3 months after pruning. Additionally, the wound closing process was monitored at different times after pruning (6 hours, 2, 4, 8 and 11 days) by sectioning the shoots longitudinally and observing them under a stereo microscope. The quantification of total phenols and starch was carried out through histological analyses on shoot sections pruned and treated with *T. harzianum* and on control shoots. The sections were included in GMA resin (O'Brien and McCully, 1981), stained with PAS and toluidine blue, and analysed under a light microscope. Identification and quantification of indole-3-acetic acid were performed on the shoot sections adjacent to the wound collected at different times after pruning (0, 6, 24, 48 and 192 hours). The IAA concentrations in the tissues were analysed by GC-MS according to Baraldi *et al.* (1988). Re-isolations of *T. harzianum* were carried out placing pruned shoot fragments on PDA, 9 months after inoculation. All the investigations were carried out on 3 plants for each treatment. Means and standard errors are presented.

Results

From in vivo observations, the healing callus on the treated shoots was more developed and organized than in the control ones, on which callus was either not present or not well developed up to 3 months after pruning. Microscope observations on control shoots showed the formation of a lignified layer of closure 11 days after pruning, while in treated shoots lignification was already visible 8 days after pruning and was preceded by the formation of a wide necrotic area and of a lateral callus, both of which were absent in the control.

The histological analyses highlighted a higher accumulation of phenols in treated shoots than in control shoots. This phenomenon was particularly prevalent in the phloem, where it was usually accompanied by the presence of an organized closing callus. Conversely, the presence of starch was higher in the phloem of control than treated shoots (data not shown).

The variation of auxin levels in the tissues adjacent to the wound was followed in treated and control shoots (Table 1). While in treated shoots free IAA concentrations remained substantially unchanged, ranging from 47.5 to 35.8 ng g^{-1} FW, in control shoots a decrease in hormone levels occurred from the first day after pruning. In fact, at 24 and 48 hours IAA concentrations were 26.3 and 25.5 ng g^{-1} FW, respectively, while at 192 hours the concentration raised again, reaching a value similar to the initial one (31.1 ng g^{-1} FW).

Re-isolation of *T. harzianum* from the cortex of treated plants 9 months after treatment was successful.

Tab. 1: IAA concentration (ng^{-1} fresh weight) in control and pruned shoots treated with *T. harzianum* at different times after pruning.

	Time of collection (hours)				
	0	6	24	48	192
Control	47.5 ± 9.0	33.8±13.4	26.3± 0.6	25.5	31.1±7.9
Treated	47.5 ± 9.0	35.8±13.0	42.1±13.6	43.6±3.6	43.9±17.0

Values are means ± standard error (SE)

Discussion

The treatment with *Trichoderma harzianum* accelerated the closing processes of summer pruning wounds by speeding up the formation of a lignified layer of closure; moreover, the presence of a wide necrotic area, a possible obstruction to the entrance of the pathogens, suggested a more pronounced reaction by the treated plants. The hypothesis of an effect of *T. harzianum* on plant defence mechanisms was also supported by the stimulation of an extended closing callus.

The hypothesis of a stimulation of the plant defence reactions by *T. harzianum* was also reinforced by the observed fast and high accumulation of total phenols in the phloem tissue adjacent to the wound, together with a more organized callus and reduced starch levels. It is well known that wound-related defence responses include synthesis and accumulation of phenols to reinforce the cell wall and act as anti-microbic compounds (Moriondo, 1999). The energy required for defence responses is usually obtained by the degradation of carbohydrate reserves such as starch. In the present study, the treated shoots were subjected to stresses caused both by wounding and by interaction with *Trichoderma*. The faster defence reaction recorded on treated shoots could be interpreted as a response to this “double stimulus”. In other studies, *T. harzianum* T22 was reported to act as an elicitor on the plant, through the production of proteins such as Hytra1 (Ruocco *et al.*, 2007).

The pattern of auxin evolution suggested the hypothesis of an involvement of *Trichoderma* in the signalling pathway that finally lead to wound closing and cicatrisation; the constant levels of free IAA measured in treated shoots in fact indicated a possible way of behaviour on the part of the fungus, which protected the biological active form of this hormone from the oxidative degradation normally occurring in wounded tissues. The persisting activity of this hormone could lead to a faster wound closing and to the production, via cell division and elongation, of the more developed callus that was visible on treated shoots.

Finally, *T. harzianum* survived for up to 9 months on treated plants. The prolonged activity of *T. harzianum* on the plant is very important because wounds remain susceptible to pathogens attack for several months (Eskalen *et al.*, 2007). Further trials are underway in order to assess the viability and persistence of this biocontrol agent at lower temperatures than the ones recorded during the winter season 2006-2007.

Conclusions

Trichoderma harzianum, sprayed on summer pruning wounds, appeared to contribute to the physiological processes of wound healing, by accelerating callus formation and influencing the accumulation of total defence phenols, with a concurrent decrease in starch content. This role was supported by the concentrations of auxin, a plant growth regulator involved in the formation of closing callus, whose levels remained higher in treated shoots compared to the control. Further studies focused on the activity of *Trichoderma* towards wood decay associated pathogens, both under greenhouse and field conditions, are ongoing at the moment.

Acknowledgments

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Weed Control in Organic Onion

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Key words: onion, weed control, flaming, transplanting.

Abstract

Weed control is a major management concern in extensive plantings of organic vegetables. We tested organic onion under conventional sowing with mechanical and flaming weed control against transplants. The parameters logged included weed number and species and bulb yield, size and storability. We found fewer weeds and higher yields in the transplanted than in the sown treatments.

Introduction

Weeding is a chief management priority in extensive plots of organically grown vegetables, and the results are seldom comparable to chemical sprays (Casini P, 1994). In effect, it is often the case that field practices like rotation and planting date are more effective than direct control techniques (Barberi P. Frondoni U., 1999). Complicating matters is the fact onion has a low market profile and even relatively effective approaches like flaming can often be too expensive for small-to-mid-sized farms and are not always as selective as possible (Dal Re L., Innocenti A., 2001). We thus tested the viability of two organic approaches by comparing a traditionally sown crop managed under both mechanical control and flaming and a transplant crop (Leskovar D. et al, 2004; Koller M. et al, 2005).

Materials and methods

The trials were run from 2002-2005 at an organic farm in Parma Province of northern Italy's Emilia Romagna Region. The experimental layout consisted of randomised blocks with four replicates. The collected data were processed by analysis of variance and the means separated by Scott-Knott test. Three treatments were tested in 2002: (I) T1 - 76 plants/m² sown under flaming and mechanical control; (II) T2 - 76 p/m ² sown under mechanical control; and (III) T3 - 3 plants/plot, or 57 p/m², under mechanical control. Over the next three years (2003-2005), in addition to the above trial, a new one tested plant density per bulb bed to determine if overhead costs could be reduced and yield increased. The treatments consisted of: (I) T1 - 76 p/m² sown under flaming and mechanical control; (II) T2 - 76 p/m² sown under mechanical control; (III) T3 - 3 plants/plot, or 57 p/m², transplanted under mechanical control; (IV) T4 – 2 p/plot, or 38 p/m², transplanted under mechanical control; and (V) T5 - 4 p/plot, or 76 p/m², under mechanical control. The onion crop in all four trial years followed a wheat crop of cvs. Density in 2002 and Densidor in the subsequent years in rotation. Just prior to sowing and transplant the soil was always thoroughly turned over and tilled to eliminate clods and debris. The units employed for machine weeding were an inter-row adjustable Kress cultivator, which can be fitted with hoe blades or used as

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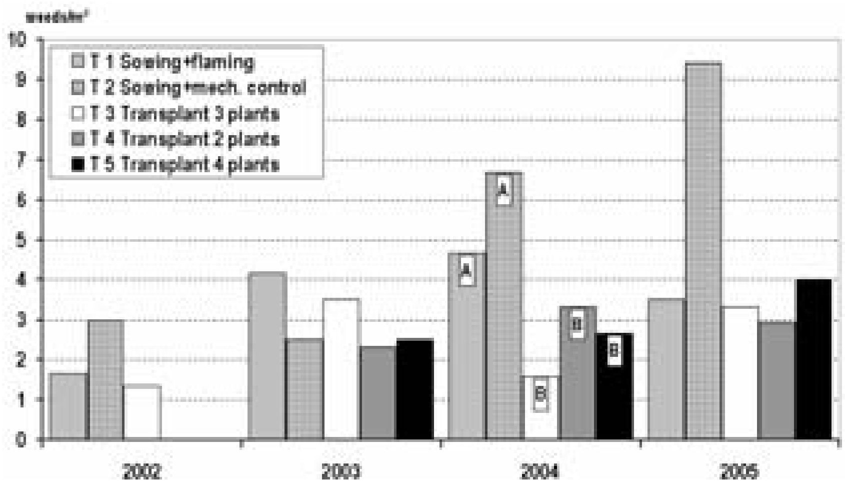
ridger or weeder with rotating tines depending on need, a tool-bar-mounted PTR 1600 flamer made by the Rovigo-based Tecnoecologica company and a tool-bar-mounted Lely harrower with 7-mm tines; the tool-bar-mounted Ferrari transplanter was manufactured by the Guidizzolo firm based in Mantua Province. Inter-row spacing in all treatments was 33 cm so as to be compatible with the cultivator units; intra-row spacing varied depending on unit since the transplanter could not go below 16-17 cm between plants. Treatments T1 and T2 were directly sown in week three-four of March with enough seed for 76 plants/m², or an intra-row spacing of 4 cm, which is the norm in conventional onion plots. Treatments T3, T4 and T5 were seeded at the same time in trays for subsequent transplanting, which took place about a month after direct sowing except in 2003, when the date was 9 May. Flaming of treatment T2 was carried out just before bolting so as to kill most of the emerging and germinating weeds without damaging the crop. Cultivator weeding and hoeing began at the 2-leaf stage for the sown and at leaf 4-5 for the transplant treatments. The cultivator was also used at leaf 2-3 in 2002. The average number of weeding runs was 4-5 for the sown plots and 2-3 for the transplanted ones. The parameters logged were the number and type of weed and bulb yield, size and storability.

Figure 1: Residual weeds at harvest (no./m²). Significant at P<0.05. The same class is marked by the same letter.



Results and discussion

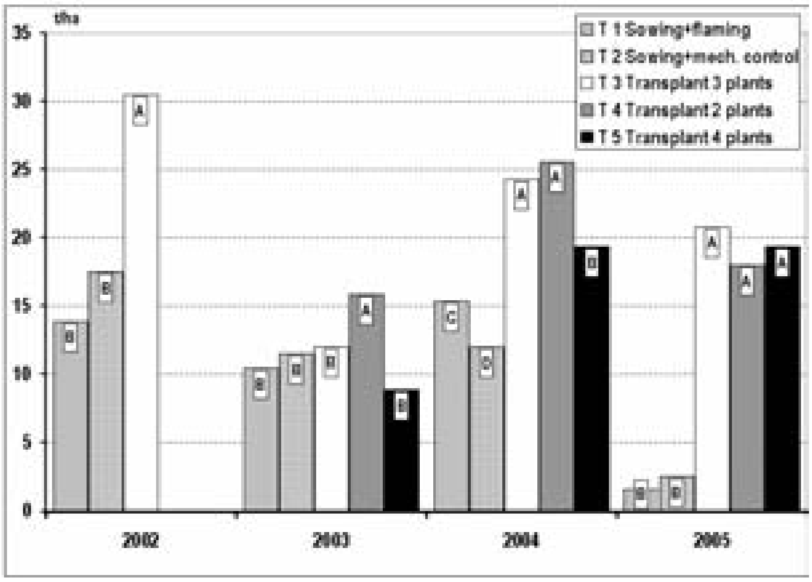
Only a limited number of weeds were found at the beginning of post-emergence operations in all trial years except 2003. The most frequently occurring species were *Amaranthus spp., Capsella bursa pastoris, Fallopia convolvolus, Polygonum aviculare, Polygonum persicaria, Portulaca oleracea, Solanum nigrum* and *Veronica persica*. Flaming proved particularly effective against all weeds except *Alopecurus myusuroides*. Indeed, the number detected in these plots just prior to initial weeding was comparable to that in the transplants and noticeably lower than that in the as yet unweeded sown treatment T1.

The mechanical units effectively controlled inter-row weeds in post-emergence, the only exception being 2003 when high temperatures and drought conditions compacted the soil to such an extent that weeder tines and blades broke and removal operations were severely hampered. By contrast, the effectiveness of cultivator units on intra-row weeds was all but nil.

Figure 2: Marketable crop (MT/ha). Significant at P<0.05. The same yield class is marked by the same letter

Almost all the weeds left at the end of the crop cycle were in the intrarow area and, though not numerous, were of notably large size. The transplant treatments had fewer and smaller weeds than the sown ones, although the difference was significant only in 2004 (Fig. 1). Neither mechanical weeding nor flaming caused crop damage. There was, though, a particularly evident drop in post-bolting bulb number in the sown treatments in 2002 and 2005 because of *Pythium spp*. infections.

Yields were lower on average than the usual 30 MT/ha for onion grown under conventional or integrated management regimes. Treatments with 2-3 transplants per bed registered the highest marketable yields, i.e. bigger than 40 mm, over the four trial



years and, in some case, even higher than under conventional management (Fig. 2). The sown treatments, by contrast, always had lower marketable yields and the T5 treatments with 4-5 transplants per bed had uneven yields. Bulb size in the plots of T5 and in those of the treatments with 2-3 transplants per bed were respectively 30% and 16% smaller. No differences were found in rot affected crop, very little, and post-harvest storability.

Conclusions

Our overall findings show that while cultivator units provided satisfactory inter-row weed control, their intra-row control was decidedly poor even with very small weeds, thus underscoring yet again how difficult weed control is in onion using only mechanical means. Weeds of notable size exerted a marked competitive effect even when their number was relatively low. The treatment with 2/3 transplants per bed showed the best results: (i) it allows more time for pre-planting soil tilling and the use of dummy-seed beds if needed; (ii) its later planting date with respect to direct sowing means weeds have less time to sprout and grow; (iii) it makes possible mechanical control shortly after transplant when weeds are smaller, thus resulting in better removal rates; (iv) it enables a plant number comparable to that planned under direct sowing, where the use of chemically uncoated seed, which is obligatory for organic growers, often falls short of the objective; and (v) it delivers yields very close to those of conventionally grown crop in terms of bulb number, size and storability.

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The use of organic certified compost to control soilborne diseases caused by *Phytophthora* spp.

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Key words: wastes, suppressiveness, soil biodiversity, *Phytophthora nicotianae, Trichoderma* spp.

Abstract

Soilborne pathogens can cause serious damages to economically important crops. Control of these diseases has traditionally depended upon rotations and soil quality improvement strategies. Compost has shown a suppressive activity against soilborne pathogens, and its use may decrease the severity of root rot diseases, optimize waste recycling and increase yields in organic farming. An organic certified compost produced from biowaste, green and yard wastes in a composting plant in the North-West of Italy, has been analysed for its suppressiveness against Phytophthora disease. The organic certified compost has been compared with a conventional compost produced in the same composting plant and with a peat substrate. In the first group of trials, composts maturity and quality have been estimated using Wood's End Lab's "Solvita" Compost Maturity Test Kit, and germination and plant grown bioassays. In a second group of trials, the organic certified compost, has been assessed for its suppressive activity in greenhouse against Phytophthora nicotianae on tomato and Phytophthora capsici on zucchini. In a third group of trials, compost was used alone or enriched with microorganism of the fungal genus Trichoderma and the suppressiveness in open field towards Phytophthora capsici on pepper has been evaluated. Organic certified compost quality was comparable to peat quality. Organic certified compost showed to have a disease suppressive activity in greenhouse, compared to peat amendment, against Phytophthora spp.. The disease suppresiveness of certified compost reached 76% in the case of tomato. The results were not confirmed in open field, even when compost was enriched with Trichoderma spp.

Introduction

Organic farmers use on-farm resources whenever possible to increase organic matter in soil and to manage soil fertility, through the use of compost, cover crops and crop rotations. Some composts have been found to be suppressive against several soil-borne pathogens in various cropping systems (Noble and Coventry, 2005). The use of compost as a peat substitute to control root pathogens in Italy was first suggested in 1988 (Garibaldi, 1988). An increase of some diseases due to compost usage has also been demonstrated, since compost is a product that varies considerably in chemical, physical and biotic composition, and, consequently, also in ability to suppress soilborne diseases (Termorshuizen *et al.,* 2006). The level and reproducibility of

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[2] As Above

[3] As Above

suppressive properties of compost can be increased upon antagonist enrichment (Postma *et al.,* 2006).

In the present study, a certified organic compost has been analysed for its suppressive activity against soil-borne diseases and compared to a not certified compost and to peat.

Materials and methods

The composting plant "ACEA Pinerolese S.p.A." located in Pinerolo, near Torino (Italy), was selected, according to previous trials (Pugliese *et al.,* 2007), for producing high suppressive compost. One organic certified compost and one not certified compost produced by the composting plant in three different periods (autumn, spring and summer) were selected for experiments. Organic certified compost was produced according to EC Reg. 2092/91 from biowaste, green and yard wastes, while non certified compost was produced from sludge obtained from urban waste water treatment, organic domestic waste and green waste.

Compost maturity was estimated using Wood's End Lab's "Solvita" Compost Maturity Test Kit, which estimates maturity based on respiration rate. Germination and plant growth bioassays were used to test the quality of composts, according to Warman, 1999. The germination index (Gi) was calculated according to the formula Gi = G/G0 x L/L0 x 100, where G0 and L0 are respectively the germination percentage and radicle growth of the 100% H2O control. For the plant growth assays, compost was mixed with sphagnum peat at 20, 40 and 100% v/v. Sphagnum peat was also used as control medium and the potting mixes were sowed with 100 seeds of *Lepidium sativum.* The plant growth index (Pi) was calculated according to the formula Pi = (PSc/PSp) x 100, where PSc is the average dry weight of plants grown on compost-amended potting mixes, while PSp is the average dry weight of plants grown on peat. The global plant growth index (Pi) was the Pi average of the 20, 40 and 100% mixes treatments.

A second run of trials was carried out in greenhouse to test the suppressiveness of composts. A randomized block design was used. All assays were repeated at least twice. Five pots of 1 l of volume were prepared for each treatment and 7 seeds of tomato were sown in each pot. Seven days before sowing, pots were inoculated with *Phytophthora nicotianae*, previously propagated in flasks on wheat plus hemp and added to the pots at 2 g/l of mycelium plus substrate. Other pots were also prepared and 5 seeds of zucchini (*Cucurbita pepo*) were sown in each. Seven days before sowing, pots were inoculated with *Phytophthora capsici* at 2 g/l dosage. A sphagnum peat amendment was used as control mean. The disease levels were related to that of the peat control in order to be able to compare suppression levels among the different trials, based on percentage of disease suppression (according to Termorshuizen *et al.,* 2006).

A third run of trials was carried out on an open field of bell pepper (*Capsicum annuum*) strongly infested in the previous years by *Phytophthora capsici*. Compost was inoculated 7 day before rototilling with several biological control agents at 4g/l dosages: *Trichoderma harzianum* T-22 (Rootshield®, 108 CFU/g, Intrachem Bio Italia), *Trichoderma viride* TV1 (TV1®, 108 CFU/g, Agribiotec) and *T. harzianum* (strain ICC012) in mixture with *T. viride* (strain ICC080) (Remedier®, 108 CFU/g, Isagro). Pepper plants were transplanted 2 days after organic certified compost (enriched or not with *Trichoderma* spp.) was rototilled into soil at 2 kg/m^2 dosage. After transplanting diseased plants affected by *P. capsici* were counted every 7-10 days. The effect of micro-organisms added to compost on percentage of disease suppression (according to Termorshuizen et al., 2006) was assessed compared to control.

Analyses of variance (ANOVA) were carried out with the statistical programme SPSS 12.0 (SPSS Inc., Chicago, IL). Tukey's HSD test was applied when one-way ANOVA revealed significant differences ($P<0.05$).

Results

Regarding compost maturity test, organic certified compost showed an higher level of CO_2 in the compost maturity test, that means a lower maturity (Tab. 1). The germination assay showed that organic certified compost has a lower germinability compared to conventional compost (Tab. 1). *L. sativum* growth was not statistically different compared to peat control (Tab. 1).

Tab. 1: Compost maturity and quality

Amendment	Maturity*	Germination index (Gi)**	Plant Growth index (Pi)
Organic certified compost	6	124.9 b	102.3 a
Conventional compost	7	211.5 a	111.8 a
Peat	-	179.7 ab	100.0 a

* 7= very mature; 6 = mature; <6 = not mature.

** Gi lower than 71 indicates low germinability and high phytotoxicity

°significant for $P<0.05$

In greenhouse trials, composts showed a good disease suppressive activity against *P. nicotianae* on tomato (Tab. 2). No differences in disease suppression were showed between organic certified compost and conventional compost.

In open field trial no statistical differences were showed by the use of compost on the disease suppressiveness of *P. capsici* on bell pepper, even when enriched with *Trichoderma* spp.

Discussion

Quality and disease suppressiveness of organic certified compost was assessed. Compost quality showed to be comparable to peat, but with a lower germinability than conventional compost. This difference could be due to an higher nutrient content of the conventional compost. Composts showed to be suppressive against some soilborne pathogens (*Phytophthora* spp.), as already suggested by Noble and Coventry (2005). The suppressive activity was not statistically significant when compost was used in open field, even when enriched with biological control agents like *Trichoderma* spp.

Tab. 2: Effect of compost on disease suppressiveness on *Phytophthora capsici* of zucchino (courgette) and *Phytophthora nicotianae* of tomato in greenhouse.

Treatment	% disease suppressiveness	
	Phytophthora capsici / zucchini	Phytophthora nicotianae / tomato
Organic certified compost	40 b*	76 b
Conventional compost	55 ab	79 b
Peat (inoculated)	5 c	0 c
Peat (not inoculated)	100 a	100 a

* significant for P<0.05

Conclusions

In conclusion, our results indicate that organic certified compost can be used as a mean to control some soilborne diseases at least in greenhouse conditions. Organic certified compost quality is comparable to peat and its adoption is foreseen as a peat substitute. The combination of biological control agents with compost could lead to a more stable suppressive substrate, but *Trichoderma* spp. didn't showed to increase compost suppressiveness against *Phytophthora* spp. This study represents an initial step toward the development of a new substrate able to control a wide range of soil-borne pathogens.

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Investigations on the efficacy of different products for the control of *Stephanitis pyri* in an organic pear orchard during the two-year period 2004-'05

Vergnani, S.[1] & Caruso, S.[2]

Key words: *Stephanitis pyri*, organic pear orchard, control.

Abstract

The results of two trials, carried out respectively in 2004 and 2005, against Stephanitis pyri in an organic pear orchard are reported. Different formulations of the following active substances were tested: pyrethrum + PPBO, rotenone, rotenone + pyrethrum + PPBO, azadirachtin, Beauveria bassiana strain ATCC 74040, Marsiglia and potassium soap; and quassia wood. The pyrethrum + PPBO- and rotenone-based formulated products showed good efficacy, when applied against neonate larvae. A good efficacy was also observed with the azadirachtin-based formulation, but the product may have phytotoxic effects on pear, and therefore its use is not recommended. The B. bassiana-based product showed partial efficacy in controlling the target pest, while the efficacy of the formulations based on Marsiglia soap, Potassium soap and Quassia wood was not satisfactory.

Introduction

The pear lace bug (*Stephanitis pyri*) is an insect that can cause extensive damage in organic pear (*Pyrus communis*) orchards. Widespread infestations, affecting entire plots, can occur in orchards where this pest is not adequately treated (Protic, 1994; Forti, 1992). The major effects of *S. pyri* on pear plants and production are decolorisation of leaves, reduction in photosynthetic activity, early leaf-drop, decrease in fruit size and, finally, loss of production (sometimes on a drastic scale), either in the current year or in successive years. Due to the lack of information available in literature on the use and positioning of insecticides against this pest and the rather limited persistence of the insecticides allowed in organic farming and listed in Annex IIB of Reg. EEC 2092/91, we decided to evaluate the efficacy and application strategies of different formulated products. The results of two trials, carried out in 2004 and 2005 in the province of Modena, are reported.

Materials and methods

The trials were carried out in an organic pear cv. Abate Fetel orchard in Ravarino (Modena, Italy). The tested products are reported in table 1. The different products were tested on large, not replicated plots of 40-48 plants each. We decided to use a large-plot design to avoid biasing of data due to non-homogeneous distribution of the target pest which is very likely to occur on small plots. All treatments were applied during evening hours in order to optimise the efficiency of the products, and directed

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against neonate *S. pyri* larvae. Treatments were applied with a motorized barrow sprayer, equipped with a manual Comet MC 20/20 pump nozzle using normal spray volumes (1500 l/ha). Treatments were applied at regular time intervals according to the presence of living immature stages of the target pest. Due to operational difficulties and the heterogeneity of the infestation, in 2004 the treatments were applied against neonates of the second generation (in July and August), while in 2005 they were directed against neonates of the first generation (in June). To assess for leaf damage caused by *S. pyri*, in each trial and for each treatment, the number of leaves showing symptoms of *S. pyri* damage was counted on a total of 300 leaves (upper 10 leaves of 30 randomly selected shoots) per plot/treatment. Three classes of evaluation were identified: no symptoms (class 0); up to 50% of leaf surface showing symptoms (class 1); syptoms occupying more than 50% of leaf surface (class 2). Furthermore, for each treatment, we evaluated the presence of both living and dead insects on the leaves following the sprays.

Tab. 1: Products tested in 2004 and 2005

Active substance	Formulation	Applied rate (g-ml/hl)	No. applications 2004	No. applications 2005
Pyrethrum+PPBO	Piresan Plus	100	3	2
Rotenone	Rotena 43	600	3	2
Beauveria bassiana strain ATCC 74040	Boveral OF	200	3	2
Soap	Marsiglia soap	600	3	-
Soap of potassium	SBS 200 K PLUS	600	-	2
Rotenone +Pyrethrum+PPBO	Show	700	3	-
quassia wood	quassia wood	500	3	-
Azadirachtin	Oikos	150	3	-

Results and discussion

Year 2004

The year 2004 was characterised by a limited initial development of the lace bug population. The risk that assessments on the first generation would not provide conclusive results due to low pest pressure existed, and therefore the treatments were directed against the second generation. On the final assessment date (11 August) clear differences among the tested products in reducing leaf damage caused by *S. pyri* emerged (figure 1). Leaf damage was considerably reduced only in the plots treated with the products containing pyrethrum+PPBO, rotenone and azadirachtin as active ingredients. We furthermore observed that in these plots, the neonates were all dead and no living adults were present, while in the plots exposed to the other treatments and in the untreated control plot both living adults and neonate larvae were present. The azadirachtin-based product, when applied in July and August, did not show symptoms of phytotoxicity. Azadirachtin-based products are generally indicated as being phytotoxic to most varieties of pears. Since phytotoxicity of a product the a crop is related the phenological phase, we can deduce that the risk of adverse effects of azadirachtin on pear decreases in the summer months. The *B. bassiana*-based product, Quassia wood, and marsiglia soap did not provide satisfactory control.

Year 2005

In the second study year, a heavy infestation occurred already during the first generation of the target pest, thus treatments were applied against the first generation. On the final assessment (16 June), the pyrethrum+PPBO- and rotenone-based treatments again showed highest efficacy in reducing leaf damage caused by *S. pyri*, while the efficacy of potassium soap and *B. bassiana* was only partial and considerably lower than that of the other products (Figure 2). Our observations on the percentage of living individuals confirm the results on leaf damage (table 4): survival was lowest for the pyrethrum+PPBO- and rotenone-based treatments.

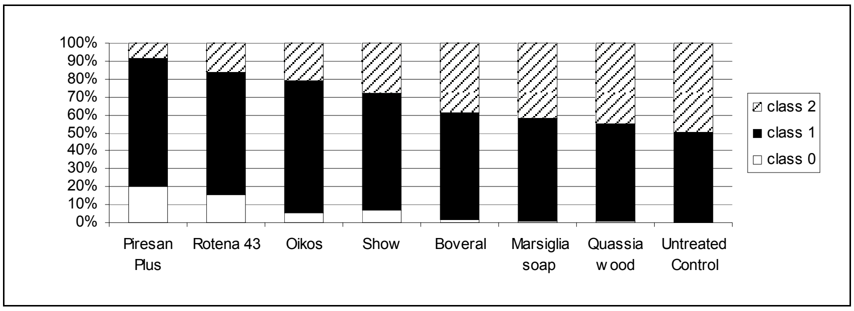

Figure 1: 2004: percentage of leaves in the three leaf damage classes recorded for the different treatments on the final assessment date (11 August 2004).

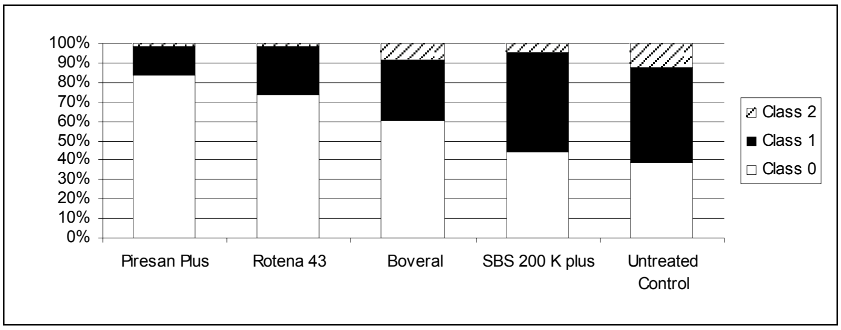

Figure 2: 2005: percentage of leaves in the three leaf damage classes recorded for the different treatments on the final assessment date (16 June 2005).

Tab. 4: 2005: percentage of leaves with living *S. pyri* individuals in the different treatments.

Treatment	% of leaves with living *S. pyri* individuals	Efficacy (Abbott)
Untreated Control	70	-
Pyrethrum + PPBO	5	93
Rotenone	5	93
Beauveria bassiana strain ATCC 74040	40	43
Potassium soap	25	64

Conclusions

Among the products tested in our trials, the pyrethrum+PPBO- and rotenone-based products always showed highest efficacy in controlling lace bug infestations on pear. Products with these two substances as active ingredients may therefore be considered valuable tools for the control of this pest, provided that they are applied against neonate individuals as in our trials. In fact, in additional trials we observed that the efficacy of both insecticides is unsatisfactory when they are applied against adults (data not reported). Also the azadirachtin-based product, tested only in 2004, showed good efficacy in reducing *S. pyri* leaf damage without showing any phytotoxic effect. It is well-known that the phytotoxicity of a product to a certain crop can vary both according to the formulation and the phenological stage of the crop during spraying. Therefore, special care should be taken, when azadirachtin-based products are used on pear, and preliminary testing of possible negative side effects is recommended. Under our trial conditions, the *B. bassiana*- based product showed poor efficacy in 2004 and only partial efficacy in 2005, even though the application instructions reported on the label were followed and application rates were almost doubled. Unacceptable efficacy values were recorded for Marsiglia soap, the quassia wood-based product (not yet included in Annex I), and Potassium soap, the former two tested in 2004 and the latter in 2005. However, the results of one single trial can not be considered conclusive, and further research is needed. In conclusion, given the results of our trials, pyrethrum+PPBO- and rotenone-based products seem to be the best options for an efficient control of lace bugs in organic farming.

Acknowledgements

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Efficacy of *Cydia Pomonella* granulosis virus (cpgv) in controlling codling moth in the Emilia-Romagna region

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Key words: Apple orchard, Pear orchard, *Cydia pomonella*, Granulosis virus, Efficacy

Abstract

During the period 1999 to 2007, numerous field trials were carried out in the Emilia Romagna region in order to test the efficacy of Cydia pomonella *Granulosis Virus-based (CpGV) products in controlling codling moth, Cydia pomonella (L.). The trial results demonstrate that CpGV-based products can be considered among the best larvicides currently available on the market. Good results were achieved against I generation larvae, while applications against successive generations did not always provide satisfactory control.*

Introduction

The introduction of *Cydia pomonella* Granulosis Virus-based (CpGV) products in the Emilia Romagna region, often complemented by the method of mating disruption, has favoured the development of organic apple (*Malus* communis) and pear *(Pyrus communis*) orchards, even in areas with high codling moth, C*ydia pomonella* L. (henceforth CM), pressure, and has suppressed CM damage to fruit. CM control is becoming increasingly challenging not only in organic farming, but also in integrated and conventional production due to ecotoxicological, residue, and resistance issues (Riedl and Zelger, 1994; Sauphanor et al., 1998; Ioriatti et al., 2000). CpGV-based products could be valuable tools to be included in resistance management strategies, could help to avoid the presence of undesired residues in the final production, and to meet the requirements of the most stringent production regulations.

Materials and methods

During the study period (1999-2007), the efficacy of different CpGV-based products in comparison to chemical reference insecticides and an untreated control was tested in a total of 14 trials conducted in both organic and integrated pear orchards. Ten trials (henceforth Trial Group 1) aimed at evaluating the efficacy of a CpGV-based product (formulated product: Carpovirusine; applied rate: 100 ml/100 l; no. applications: 3 at 7-10-day time intervals) in comparison to that of chemical insecticides and an untreated control. Out of these 10 trials, 7 were targeted against I generation CM larvae, while other 3 trials were directed against II generation CM larvae. Four additional trials (henceforth Trial Group 2), instead, aimed at comparing the efficacy of different

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CpGV-based products (tested products: Madex, Virgo/Carpostop, Carpovirusine), and an untreated control against I generation CM larvae.
In each trial, a randomised block design with four replicates per treatment, and with a mean number of 5 trees per plot was used. Since we decided to assess fruit damage on 100 fruits per plot (see below), the number of trees per plot differed among trials according to the number of fruitlets present on the trees. In all trials, treatments were applied according to label instructions with a motorised barrow sprayer (spray volume: 1200-1500 l/ha, depending on vegetative growth and tree height). Indications provided by climate/insect development models (MRV- codling moth) of the Emilia-Romagna region and by CM monitoring traps (threshold: 2 adults per trap per week) were used to choose the correct timing of the applications. In each trial, fruit damage was assessed by counting the number of fruits damaged by CM larvae (fruits with deep entries) on 100 randomly selected fruits per plot at the end of the CM target generation, and percent fruit damage was calculated.

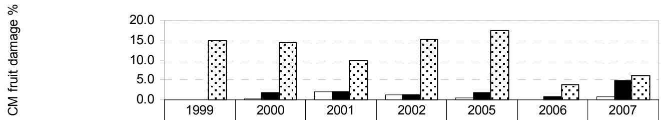
Results

In several trials of Trial Group 1, the CpGV-based product was compared to more than one chemical reference insecticide. In order to provide a clear and concise description of the results concerning CpGV efficacy, for each trial, we decided to report observed percent fruit damage values only for the CpGV-based treatment, the chemical reference treatment that showed highest efficacy (see Table 1 for details), and the untreated control, and to omit the results obtained with the other chemical treatments tested within the same trial that showed intermediate efficacy.
In the 7 trials of Trial Group 1 carried out against I generation CM larvae, percent CM fruit damage in the CpGV-based treatment was always comparable to or lower than that recorded for the chemical reference treatment, and considerably lower than in the untreated control (Figure 1). In the 3 trials of Trial Group 1, conducted against II generation CM larvae, percent CM fruit damage recorded for the CpGV-based treatment was again always lower than in the untreated control, but comparable to that registered for the chemical reference treatment in one trial, and higher in the other two trials (Figure 2). No significant differences among the different CpGV-based products emerged in the trials of Trial Group 2: all products considerably reduced percent fruit damage compared to the untreated control, with efficacy values being comparable among products (Figure 3).

Tab. 1: Active substance, applied rate and number of applications of the chemical reference insecticides in the different trials of Trial Group 1.

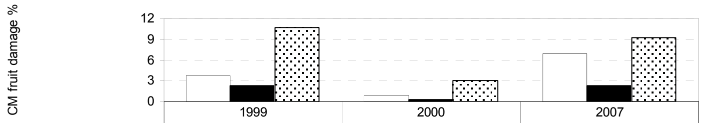
Year	Active substance	Conc. a.s. (%)	Applied rate (g or ml/hl)	No. Applic.
Trials against I generation CM larvae				
1999	Chlorpyriphos	75,0	70	3
2000	Azinphos methyl	19,0	200	3
2001	Chlorpyriphos	75,0	70	3
2002	Chlorpyriphos	75,0	70	3
2005	Azinphos methyl	19,0	200	3
2006	Azinphos methyl	19,0	200	3
2007	Chlorpyriphos	75,0	70	3

Year	Active substance	Conc. a.s. (%)	Applied rate (g or ml/hl)	No. Applic.
Trials against II generation CM larvae				
1999	Chlorpyriphos	75,0	70	3
2000	Methoxifenozide	22,5	40	2
2007	Spinosad	44,2	30	3



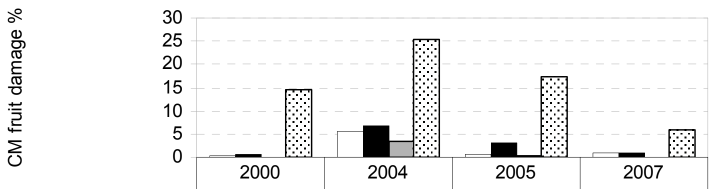
	1999	2000	2001	2002	2005	2006	2007
□ CpGV	0.0	0.3	2.0	1.3	0.5	0.0	0.8
■ chemical insecticide	0.0	1.8	1.9	1.3	1.7	0.8	4.8
⊡ Untreated Control	15.0	14.5	10.0	15.3	17.4	3.8	6.0

Figure 1: percentage of fruits damaged by I generation CM larvae in the different treatments and trials.



	1999	2000	2007
□ CpGV	3.75	0.8	7
■ chemical insecticide	2.25	0.3	2.3
⊡ Untreated Control	10.75	3	9.3

Figure 2: percentage of fruits damaged by II generation CM larvae in the different treatments and trials.



	2000	2004	2005	2007
□ Carpovirusine	0.3	5.7	0.5	0.8
■ Madex	0.5	6.7	3.1	1.0
▨ Virgo/Carpostop		3.5	0.3	
⊡ Control	14.5	25.5	17.4	6.0

Figure 3: Percentage of fruits damaged by CM larvae in the different CpGV-based treatments and in the untreated control in four trials.

Conclusions

The results of our trials are evidence of the excellent larvicidal activity of CpGV-based products: irrespective of the formulation tested, CpGV-based products were able to considerably reduce percent CM fruit damage, with efficacy values being comparable to those of the chemical reference insecticides, especially when the treatments were

applied against I generation larvae (Boselli *et. al.*, 2001). CpGV-based products can therefore be considered valuable tools for the control of *C. pomonella* not only in organic farming but also in any other plant protection strategy.
However, there are also some negative aspects related to CpGV-based products: they may show reduced efficacy against II and III generation CM larvae; they have short shelf life at room temperature (CpGV-based products should be stored in the refrigerator or in the freezer; because of the mode of action of CpGV, superficial damage, depreciating the commercial value of fruit especially on apple, is more likely to occur in CpGV-treated orchards than in orchards treated with chemical insecticides. In organic farming, where CM populations are repeatedly exposed to CpGV treatments over years, because at the moment CpGV is the only efficient active substance available for the control of CM, resistance to the microbial control agent may develop. In fact, cases of CM populations resistant to the Mexican isolate, the active ingredient of the CpGV-products currently available on the market, have already been reported in several European countries (Fritsch *et. al.*, 2004). Different new CpGV isolates are now being studied to overcome resistance (Jehle, 2008). In our opinion, the inclusion of additional natural plant protection substances, such as Ryania and Spinosad into Annex II B of Reg. EEC 2092/91, could be useful for the development of efficient resistance management programs also in organic farming.

Acknowledgements

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Yielding and Selected Leaf Diseases of Old Winter Wheat Cultivars in the Organic System

Stalenga, J. & Jończyk, K.

Key Words: winter wheat, old cultivars, cultivar selection, leaf diseases

Abstract

Intensity of leaf infestation by selected fungal pathogens and yielding of old winter wheat cultivars (Ostka Kazimierska, Kujawianka Więcławicka, Wysokolitewka Sztywnosłoma) against a background of modern winter wheat cultivars (Kobra, Roma, Korweta, Sukces, Zyta, Mewa) in conditions of organic farming was assessed. The research was based on a special field experiment established in 1994 year on a grey-brown podzolic soil in which different crop production systems are compared. The research was conducted in 2005 and 2006. Average for 2 years grain yield of winter wheat for all cultivars amounted to 3.0 t/ha. In both years the largest yields were noted for modern winter wheat cultivars. Old cultivars of wheat reacted better on water deficiency than modern ones. The yield decrease for all cultivars was mainly affected by low level of resistance on fungal pathogens responsible for leaf diseases. Only in 2005 leaves of old cultivars were more than modern cultivars infested by fungal diseases.

Introduction

It is not clear whether old cultivars of cereals may be more appropriate than modern ones for Organic Farming. Some authors indicate that modern rather than old cultivars are the best choice presently when choosing small-grain cultivars for production in environments managed organically (Poutala et al. 1993; Kitchen et al. 2003; Carr at al. 2006). Other authors point out that old cultivars of cereals may be more appropriate for organic farming because they have a better ability to form AMF (arbuscular mycorrhizal fungi) symbiosis (Hetrick et al. 1992) and have higher grain protein concentration (Gooding et al. 1999). Eisele and Köpke (1997) point out that cultivars best adapted to Organic Farming should combine an early covering of the soil surface with long and large leaves, with long leaf area duration due to low susceptibility to fungal diseases. Specific conditions of the organic system (no chemical crop protection and quick-acting synthetic fertilizers) makes a selection of appropriate cultivars a crucial task. Assessment of leaf infestation by selected fungal pathogens and yielding of old winter wheat cultivars against a background of modern winter wheat cultivars in conditions of organic farming was aim of our research.

Materials and methods

The research was based on a special field experiment established in 1994 at the Experimental Station in Osiny (Lublin province, Poland) on a grey-brown podzolic soil in which different crop production systems (organic, integrated and conventional) are compared. The research was conducted in 2005 and 2006 on the field of winter wheat in the organic system. In this system (crop rotation: potato - spring wheat - red clover with grass grown two years - winter wheat + catch crop) neither mineral fertilisation nor pesticides were applied. Organic fertilisation included only manure application (30 t/ha) before potato cultivation. The area of a field covered by a particular cultivar was about 0.1 ha. Three old cultivars: Ostka Kazimierska, Kujawianka Więcławicka, Wysokolitewka Sztywnosłoma and six modern cultivars of winter wheat (Mewa, Roma, Kobra, Sukces, Zyta and Korwetta) were compared. Grain yield and intensity of leaf infestation by selected fungal pathogens were assessed. Grain yield was determined on the basis of samples taken from the control plots (20 m2). Assessment of leaf infestation by fungal pathogens responsible for Puccinia recondita and Erysiphe grraminis was done in the milk-dough growing stage (BBCH 77- 83). For each cultivar 40 plants were taken in 4 replications. The percentage of leaf area infested by fungal pathogens was assessed on the basis of EPPO Standards (1999). The analysis of variance was done with use of the statistical programme Statgraphics Plus 6.0. The significance of difference was evaluated on the 5% significance level using Tukey's test.

Results and discussion

Average for 2005 and 2006 grain yield of winter wheat for all cultivars amounted to 3.0 t/ha. In both years the largest yields were noted for modern winter wheat cultivars. Among them Zyta and Sukces yielded the best, respectively – 4.1 and 3.9 t/ha. Ear density was the main factor affecting higher productivity of these two cultivars in comparison to others. The 1000-kernel weight was an additional important factor influencing yield but it was only significant in 2005.

Old winter wheat cultivars yield for 2005 and 2006 averaged about 2.35 t/ha (Tab. 1). Yields were lower (about 1.2 t/ha) in comparison to the modern cultivars.

In 2006 very unfavourable weather conditions for crops were noted. The yields of winter wheat were the lowest since the experiment was established in 1995. A very hard drought in the second half of June and in the whole July significantly reduced nutrient uptake by plants and in consequence influenced the level of yields. However the last concerned only modern wheat cultivars. In such difficult conditions old cultivars gave similar yields as in 2005. This revealed a positive reaction of old cultivars on water deficiency stress.

The decrease of yield for all cultivars was mainly affected by a low level of resistance on fungal pathogens responsible for leaf diseases. In 2005 leaves of old cultivars were more infested by fungal diseases in comparison to modern ones (tab. 2). In the following, very dry year 2006 (Tab. 3), no significant differences between modern and old cultivars were noted with respect to infestation by fungal diseases. In both years Puccinia recondita was the most important pathogen, especially dominant in 2006.

Conclusions

The results showed many differences between old and modern winter wheat cultivars. Modern cultivars yielded about 1.2 t better than old ones. The decrease of yield for all cultivars was mainly affected by low level of resistance on fungal pathogens responsible for leaf diseases. Only in 2005 leaves of old cultivars were more infested by fungal diseases. It should be emphasized that old cultivars reacted better on water deficiency than modern ones.

Tab. 1: Grain yields and other elements of yield structure for winter wheat cultivars (2005-2006)

Year	Wheat type	Cultivar	Grain yield (t/ha)	Ear density (ears/m^2)	1000-kernels weight (g)
2005	**Modern wheat cultivars**	*Kobra*	3.51	330	42.1
		Roma	4.19	297	51.2
		Korweta	3.34	351	43.0
		Mewa	3.74	336	46.0
		Zyta	4.65	471	47.8
		Sukces	4.47	479	43.7
	Old wheat cultivars	***Ostka Kazimier.***	**2.58**	**263**	**31.3**
		Kujawianka Więc.	**2.29**	**298**	**28.2**
		Wysokolitewka	**2.03**	**303**	**25.8**
		Average for old cultivars	**2.30**	**288**	**28.4**
		Average for modern cultivars	**3.98**	**377**	**45.6**
2006	**Modern wheat cultivars**	*Kobra*	3.09	461	35.4
		Roma	3.20	466	35.6
		Korweta	3.39	504	34.0
		Mewa	3.14	472	36.6
		Zyta	3.57	507	38.8
		Sukces	3.32	545	36.1
	Old wheat cultivars	***Ostka Kazimier.***	2.38	411	39.0
		Kujawianka Wię.	2.68	524	35.5
		Wysokolitewka	2.23	442	30.7
		Average for old cultivars	**2.43**	**459**	**35.1**
		Average for modern cultivars	**3.28**	**492**	**36.1**

Tab. 2: Infestation (in %) of flag and under-flag leaf by fungal pathogens for different cultivars of winter wheat in the milk-dough growing stage (BBCH 77-83) in 2005

Cultivar	***Erysiphe grraminis***			***Puccinia recondita***		
	Leaf		**In total**	**Leaf**		**In total**
	flag	**underflag**		**flag**	**underflag**	
Kobra	0.8 c	5.1 c	5.8	0.9 b	10.2ab	11.1
Zyta	0.0 a	5.3 c	5.3	0.4 a	2.5 a	3.0
Roma	0.0 a	2.4 bc	2.1	0.2 a	6.9 ab	7.1
Sukces	0.1 a	0.2 ab	0.2	0.9 b	5.0 ab	5.9
Mewa	0.1ab	1.1 abc	1.2	0.2 a	4.2 ab	4.4
Korweta	0.0 a	0.2 ab	0.2	1.1 b	13.0 b	14.5
Kujawianka	0.2ab	1.0 abc	1.1	0.4 a	8.3 ab	8.7

Wysokolitewka	0.7 c	4.4 c	5.1	1.0 b	11.5 b	12.5
Ostka Kazimier.	0.5bc	1.4abc	2.0	0.2 a	6.5 ab	19.1

Tab. 3: Infestation (in %) of flag leaf by fungal pathogens for different cultivars of winter wheat in the milk-dough growing stage (BBCH 77- 83) in 2006

Cultivar	Share of leaf area with disease symptoms in %	
	Erysiphe graminis	*Puccinia recondita*
Kobra	2.9 de	47.7 f
Zyta	4.6 e	25.0 ab
Roma	1.0 c	46.2 ef
Sukces	1.0 c	43.0 def
Mewa	0.2 ab	35.7 c
Korweta	0.0 a	27.6 b
Kujawianka	1.6 cd	37.9 cd
Wysokolitewka	4.0 e	21.7 a
Ostka Kazimier.	1.0 c	49.6 f

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Biological control of kiwifruit and tomato bacterial pathogens

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Key words: natural extracts, organic agriculture, *Ficus carica*, *Allium sativum.*

Abstract

Biocontrol of bacterial pathogens is effected by using cupric salts associate to appropriate agronomical practices such as seed certification, irrigation and fertilization. In in vitro and in in vivo tests, aqueous extracts from Allium sativum and Ficus carica fruits reduce the survival and the damages (disease incidence and disease severity) caused by bacterial pathogens of kiwifruit (Pseudomonas syringae pv. syringae, Pseudomonas viridiflava) and of tomato (Pseudomonas syringae pv. tomato) plants. In vitro tests, both vegetal extracts show antimicrobial activity against all bacterial strains utilised at different concentrations (10^6 – 10^8 cfu ml^{-1}). In vivo tests Allium sativum and Ficus carica extracts confirm their antimicrobial activity on P. s. pv. tomato reducing DI and DS after two weeks until to 60% and 67% and to 32% and 22%, respectively.

Introduction

Biological control of parasites in organic agriculture crops is based on natural antagonists and substances present in nature. Bacterial diseases are a serious problem in greenhouse and in open field on different plants. Amongst them, *Pseudomonas syringae* pv. *syringae*, *Pseudomonas viridiflava* and *Pseudomonas syringae* pv. *tomato* are particularly dangerous on kiwifruit and tomato plants, respectively. At present, to control these bacterial pathogens, especially in organic agriculture, few effective strategies can be adopted. Copper treatments and appropriate agronomical practices, such as seeds certification, irrigation and fertilization, are suggested (Colin et al., 1984; Varvaro et al., 2001).

Due to the recent EU restriction on copper use in organic agriculture (Reg. EU n° 473/2002) and the increased movement of vegetal material among the EU and not EU countries, found effectiveness natural bactericidal/bacteriostatic compounds assume a relevant importance to control these bacterial pathogens especially in organic agriculture. As an alternative to copper compounds, few natural substances have been recently proposed, but further studies need to optimize their effectiveness (De Castro, 2001; Lo Cantore et al., 2004).

As potential natural substances effective against *P. s.* pv. *syringae*, *P. viridiflava* and *P. s.* pv. *tomato*, vegetal extracts from *A. sativum* and *F. carica* plants were utilised.

A. sativum was chosen for its antimicrobial properties, well known in human healthy, and for its properties to inhibit different enzymes, essential for microbial pathogen infections, by organosulfur compounds (Obagwu and Korsten, 2003).

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F. carica was chosen for their richness in phenols and flavonoids effective on different bacteria (Salameh et al., 2004; Zao et al., 2005).

The aims of this study were to verify, *in vitro* and *in vivo*, the antimicrobial activity of natural extracts, obtained from *Allium sativum* and *Ficus carica* plants, on *P. s.* pv. *syringae*, *P. viridiflava* and *P. s.* pv. *tomato*.

Materials and methods

A. sativum and *F. carica* fruits were sliced into small pieces and blended using twister blender for 10 min at room temperature. The extracts were obtained by centrifuging samples using sorvall RC 5 B (Newton, CT) centrifuge at 8,000 x *g* for 45 min to remove bigger particles.

In *in vitro* tests were carried out by the spot tests; aqueous extracts of *A. sativum* and *F. carica* fruits were utilised at a concentration of 10 g l^{-1} and of 60 g l^{-1} (dry weight), respectively. Spot tests were conducted on NSA medium (nutrient broth 8 g l^{-1}, sucrose 50 g l^{-1} and agar 18 g l^{-1}). Bacterial strains, characterized by an higher level of virulence and isolated from kiwifruit and tomato plants in Central Italy, were utilised at 10^6 and 10^8 colony forming units (cfu)/ml concentration. After distribution of bacterial suspensions (100 µl per Petri dish), natural extracts (4 drops, 30 µl each) were placed on NSA Petri dishes. After incubation at 25 ± 2°C for 48-72 h, eventual inhibition zones, measured in mm without any growth of each bacterial strain, were observed by a stereomicroscope and then measured (Klement et al., 1990). In *in vitro* spot tests were carried out under laboratory conditions and repeated five times, two replicates each.

In *in vivo* tests were carried out in greenhouse on tomato plants cv. San Marzano, 1 month old. Greenhouse conditions (temperature, relative humidity) were maintained at day and night temperatures of 25 ± 2°C and 15 ± 2°C, respectively, and relative humidity (RH) between 70-80% during whole experiments. The extracts of *A. sativum* and *F. carica* were used at a concentration of 10 g l^{-1} and of 60 g l^{-1} (dry weight), respectively. Bacterial strains of *P. s.* pv. *syringae* VT2, *P. viridiflava* VT3 and *P. s.* pv. *tomato* VT14 were utilised at 10^5 cfu/ml concentration.

In greenhouse, tomato plants were sprayed by each natural extract until leaves were homogeneously wet. Considering as preventive treatments by natural substances, 24 h their distribution, bacterial suspension was sprayed on plants with CO_2-pressurized hand-held sprayer; 2 h before and 2 h after bacterial inoculation, RH was maintained at 90% by automatic system to favour stomata opening.

After bacterial contamination, tomato plants were monitored daily for 15 days and disease incidence (DI) (n° of diseased leaflets/plant) and disease severity (DS) (n° of necroses/cm^2 leaflets) were analysed according to Steel et al. (1997).

In *in vivo* tests were repeated five times; for each combination (bacterial pathogen/natural extract) 60 tomato plants were used: 15 plants treated with *A. sativum* extract, 15 with *F. carica* extract, 15 with copper oxychloride (28%) as positive control and 15 untreated as negative control. All data obtained were statistically analysed using GraphPad Prism 4 software for analysis of variance (ANOVA), and the significance of the treatments were determined using Tukey's HSD test ($P \leq 0.05$).

Results

In *in vitro* spots tests, both natural extracts inhibit the growth of the different bacterial strains utilised. *A. sativum* fruit extract had an effect on all strains utilised, with highest effects against *P. s.* pv. *syiringae* VT2 at both bacterial concentrations (10^6 and 10^8 cfu ml^{-1}) (data not shown).

F. carica extract showed better effects than *A. sativum* extract on *P. s.* pv. *tomato* VT14, and light effects on *P. s.* pv. *syiringae* VT2 and *P. viridiflava* VT3 at both concentration (10^6 and 10^8 cfu ml^{-1}) (not shown).

In *in vivo* tests the use of both natural extracts confirmed their biocontrol effect on *P. s*. pv. *tomato*. Using *A. sativum* extract, considering untreated control values recorded, DI was reduced until to 60% and DS by 67,7%; by using *F. carica* extract, DI was reduced until to 32% and DS by 22% after 15 days (Fig.1).

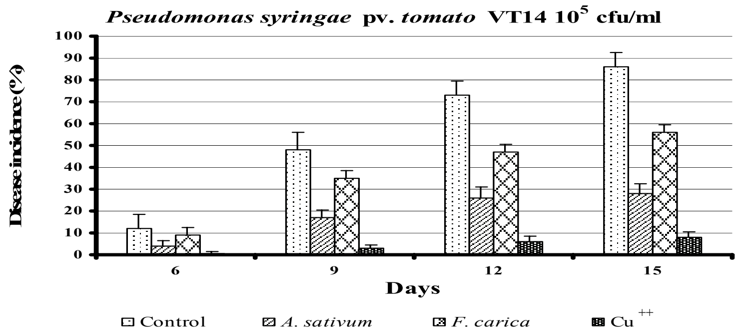

Figure 1: Disease incidence (DI) on tomato plants contaminated by *Pseudomonas syringae* pv. *tomato* VT14 by using *A. sativum* (1%) and by *F. carica* (6%) vegetal extracts.

Discussion and conclusions

The natural extracts tested seem to be useful for a biocontrol of *P. s.* pv. *syringae*, *P. viridiflava* and *P. s.* pv. *tomato* bacterial pathogens.

A. sativum and *F. carica* extracts successfully reduced disease incidence and disease severity caused by *P. s.* pv. *tomato*, and none negative effect was recorded on tomato plants.

The use of these natural substances appear to be particularly interesting to protect tomato plants in greenhouse. The antimicrobial activity of these natural substances showed to be effectiveness at least for 10 days, giving interesting opportunities to substitute or to be associated to copper compounds treatments normally used in organic agriculture.

Further studies are in progress to evaluate field-doses of these natural substances and to characterize their active principles.

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The effect of *Avena sterilis* L. invasion on weed abundance and diversity in conventional and organic cereal fields in the Mediterranean region

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Key words: *Avena sterilis*, invasion, diversity, cropping system, weeds

Abstract

The aim of this paper is to analyse the growth of the native invader weed Avena sterilis *L. (wild oat) and its invasion effect on weed community abundance and diversity in relation to cropping system (organic vs. conventional) in dryland cereal fields under Mediterranean conditions. To achieve this, a comparative experimental design involving one conventional and one nearby organic field was used. Our results show that the effect of* A. sterilis *invasion on resident weeds and cereal biomass depended on the cropping system. Species richness and diversity of weed community were more negatively affected by the invasion in the conventional field, whereas cereal biomass was drastically reduced in the organic field. The cropping system did not affect the invasive ability of* A. sterilis, *but the higher* A. sterilis *biomass recorded in the conventional field suggests strong potential long-term invasions in this system.*

Introduction

The importance of weeds supporting biodiversity in agroecosystems is well known (Marshall *et al*., 2003). However, the agricultural intensification in recent decades (cereal monoculture, fertilisation, herbicides) has dramatically reduced weed diversity in dryland cereal fields. Dryland cereal weed communities are characterized by the dominance of a few species, among which some grasses (i.e. *Lolium rigidum*, *Avena sterilis*) (Romero *et al*., 2008) are now considered to be serious agricultural pests. The effect of native weed infestation and weed management practices on crop yield have been widely studied (Hole *et al*., 2005). In contrast, less research has been conducted on the effect of the invasion by native weeds on weed abundance and diversity. The invasion by native weeds such as *Avena sterilis*, one of the most troublesome weeds in many Mediterranean climate areas (Fernández-Quintanilla *et al*., 1997), could be an important agent driving the decline in abundance and diversity of weed populations.

The pattern of resource availability can affect weed density, time of emergence, and weed-crop interactions. On one hand, these factors can modify weed community abundance and diversity (Liebman *et al*., 2001); on the other hand, they can determine invasive success (Davis and Pelsor, 2001). Thus, the different rate of nutrient release of chemical fertilisers and manure in conventional and organic cereals, respectively, can affect the relationships among wheat, *A. sterilis*, and the resident weeds. Chemical fertilisation usually favours crop species, but this general pattern depends on the life-history traits of the interacting species.

The aim of the present study is to analyse the growth of the native invader weed *A. sterilis* in relation to cropping system (organic vs. conventional) and the effect of its

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invasion on wheat yield and weed community abundance and diversity in dryland cereal fields. The experiment is based on a simulated invasion through seeding *A. sterilis* at three different densities in two nearby dryland cereal fields, one conventionally and one organically managed.

Materials and methods

The study was carried out in an agricultural area in Catalonia (NE Spain). Two nearby commercial winter wheat fields were selected, one conventional and one organic. Both fields had similar organic matter, N content, and C/N ratio. The conventional field was fertilised with a granular application of NPK (10:7:16) at 300 $kg \cdot ha^{-1}$ before sowing and with $N\text{-}NO_3$ at 50 $kg \cdot ha^{-1}$ in late winter, whereas the organic field had been fertilised with composted manure one year earlier. There was no control of weeds in either field to avoid the confounding effect of management and invasion during the experiment. Six 17 m $\times$ 2 m plots were randomly delimited in each field. Each plot was divided into four square subplots of 4 m^2, 3 m apart. Three randomly selected plots were sown at three densities of *A. sterilis*: *c.* 165, 830, and 1670 $seeds \cdot m^{-2}$ (hereafter referred to as treatments A1, A2 and A3) in order to obtain a gradient of invasive intensity. The fourth plot was not sown with *A. sterilis* and constituted a control (hereafter referred to as treatment A0). Seeds had been collected in June 2006 from natural populations. In mid-October, once *A. sterilis* seeds had been added, 200 $kg \cdot ha^{-1}$ of wheat (*Triticum aestivum*) was sown. Two plots were rejected in the organic field because of poor crop establishment. In June four 25 cm $\times$ 25 cm samples were randomly selected from each subplot and total aboveground biomass was clipped at ground level and sorted into species. The mean weights of wheat, *A. sterilis*, and the resident weed species were computed for each subplot after drying them at 60ºC for 48h.

Weed community structure was evaluated by means of biomass, species richness, and Shannon's diversity index. The effect of management (conventional vs. organic) and *A. sterilis* invasion on crop and resident weeds biomass and on weed community structure were analysed by means of a cross-nested ANOVA using the GLM procedure of SPSS 14.0. Non-proportional data were log-transformed and the arcsine square root transformation was applied for proportional data to achieve normality and homoscedasticity of residuals when necessary. A non-parametric Kruskal-Wallis test was used when transformed data were not normal. The level of significance was $\alpha = 0.05$.

Results

Total biomass was higher in the conventional than in the organic field ($F_{1,8} = 61.9$, $P < 0.001$), and no significant differences between treatments were found within each field (Tab. 1). Wheat biomass was also higher in the conventional field ($F_{1,8} = 46.6$, $P < 0.001$), and decreased from A0 to A3 in both fields ($F_{3,24} = 37.7$, $P < 0.001$). Note that the ratio of wheat biomass to total biomass was not significantly different in the non-invaded subplots for both fields ($F_{1,8} = 0.40$, $P = 0.85$).

A. sterilis biomass was significantly higher in the conventional field ($F_{1,8} = 79.3$, $P < 0.001$) and increased from A1 to A3 in both fields ($F_{3,24} = 99.7$, $P < 0.001$; Tab. 1). *A. sterilis* invasion, assessed as the ratio of *A. sterilis* biomass to total biomass, did not differ between fields ($F_{1,8} = 0.41$, $P = 0.54$), and increased significantly from A1 to A3 in both fields (Tab. 1).

The relative importance of resident weeds (the ratio of resident weed biomass to total biomass) was significantly higher in the organic than in the conventional field ($F_{1,8}$ = 17.4, P < 0.05). Total resident weed biomass of the conventional field decreased significantly in *A. sterilis*-invaded subplots, whereas it was not negatively affected in the organic field (Tab. 1).

Species richness ($F_{1,8}$ = 23.5, P < 0.001) and weed diversity ($F_{1,8}$ = 32.8, P < 0.001) were significantly higher in the organic field. They did not differ significantly among treatments in the organic field but decreased in *A. sterilis*-invaded subplots in the conventional field (Tab. 1).

Tab. 1: Mean (± S.E.) of different crop and weed parameters, species richness and diversity for each *Avena sterilis* treatment. Different letters indicate significant differences between treatments for each variable with LSD test.

	A0		A1		A2		A3	
Conventional								
Total Biomass (TB) (g	1605,	± 116 a	1453,	± 107 a	1579,	± 78,8 a	1723,	± 143 a
Wheat Biomass (WhB) (g m^{-2})	1303, 6	± 141 a	682,5	± 46,9 b	500,9	± 56,4 bc	343,4	± 75,6 c
A. sterilis Biomass (AB) (g m^{-2})	20,6	± 11,1 a	678,3	± 55,7 b	1026, 3	± 81,7 c	1321, 7	± 70,9 d
Weed Biomass (WB) (g m^{-2})	281	± 71,6 a	92,9	± 28,9 b	52,40	± 19,6 b	58,8	± 19,7 b
WB/TB	18,1	± 0,05 a	5,9	± 0,01 b	3,13	± 0,01 b	3,21	± 0,01 b
WhB/TB	80,6	± 0,05 a	47,3	± 0,03 b	32,10	± 0,04 c	19,1	± 0,03 c
AB/TB	1,3	± 0,01 a	46,7	± 0,02 b	64,77	± 0,04 c	77,7	± 0,03 d
Species Richness †	6,2	± 0,5 a	4,0	± 0,00 b	3,17	± 0,31 c	2,33	± 0,42 c
Diversity (H') †	0,7	± 0,2 a	0,7	± 0,13 a	0,40	± 0,18 ab	0,04	± 0,02 b
Organic								
Total Biomass (TB) (g m^{-2})	961,9	± 136 a	682,9	± 69,1 a	1045, 2	± 109 a	1062, 3	± 113 a
Wheat Biomass (WhB) (g m^{-2})	804,8	± 146 a	138,1	± 30,1 b	135,0	± 29,2 b	33,4	± 12,5 c
A. sterilis Biomass (AB) (g m^{-2})	4,9	± 4,11 a	277,5	± 69,2 b	692,5	± 27,2 c	942,2	± 95,3 c
Weed Biomass (WB) (g m^{-2})†	152,3	± 24,9 a	235,9	± 22,7 b	217,7	± 74,8 ab	86,7	± 17,2 a
WB/TB	17,5	± 0,05 a	38,8	± 0,08 b	19,5	± 0,06 a	8,1	± 0,01 a
WhB/TB	82	± 0,04 a	20,9	± 0,04 b	12,7	± 0,02 b	3,1	± 0,01 c
AB/TB	0,05	± 0,00 a	40,3	± 0,06 b	67,8	± 0,06 c	88,9	± 0,01 d
Species Richness	9	± 1,3 ab	12,4	± 1,23 a	8,3	± 2,21 ab	7,8	± 1,31 b
Diversity (H')	1,2	± 0,2 a	1,4	± 0,08 a	1,0	± 0,29 a	0,8	± 0,19 a

†Paired comparison between treatments carried out by Kruskal-Wallis test.

Discussion and conclusions

Although the higher availability of resources in the conventional field allowed it to sustain a higher total biomass, the ratio of wheat to total biomass in non-invaded subplots was similar in the two fields. Management did not affect *A. sterilis* invasion, evaluated as the ratio of *A. sterilis* biomass to total biomass. However, *A. sterilis* invasion affected weed and wheat biomass differently, depending on the cropping system. In the conventional field, *A. sterilis* out-competed efficiently resident weeds. Hence, total weed biomass, species richness and diversity decreased as the *A. sterilis* invasion became more intense. Conversely, weed abundance, species richness and diversity were not significantly affected by the *A. sterilis* invasion in the organic field, but wheat production was drastically reduced. The slow nutrient release from manure in the organic field may slow down wheat establishment, which modifies the competitive interactions among wheat, *A. sterilis*, and resident weeds. The elevated levels of *A. sterilis* biomass in the conventional field suggests that this field could potentially be subjected to intense long-term invasions, as aboveground biomass is related to seed production (high propagule pressure). The effect of an *A. sterilis* invasion on the weed community should be evaluated over the long term, and weed management should be taken into account. In our study, the experimental addition of *A. sterilis* seed under no weed control conditions allowed us to evaluate the short-term effect on the weed community. Despite the importance of seed bank in buffering year-to-year changes in seed production, a decrease in the resident weeds' seed rain as a consequence of their lower biomass in *A. sterilis*-invaded subplots could reduce the population size of some species and contribute to local extinction. According to our results, weed management efforts must be made to keep *A. sterilis* populations under a threshold to prevent yield losses and a decline in weed community diversity in conventional fields, as well as to avoid drastic yield losses in organic fields.

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Efficacy Evaluation of Some Copper Formulations for the Control of Grapevine Downy Mildew with Low Dose Applications

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Key words: *Plasmopara viticola*, downy mildew, copper, organic farming, disease control

Abstract

The aim of this study was to evaluate the efficacy of old and new copper formulations to control downy mildew Plasmopara viticola (Berk. et Curtis) Berl. et. De Toni). Field trials were carried out over the years 2002, 2004 and 2005 in a grapevine growing area in the Po Valley with a high disease pressure. Among the traditional copper formulations, hydroxide-based products gave the best results. Other new copper formulations, including foliar fertilizers, simple adjuvants and resistance inducers were evaluated. In particular, resistance inducers with a low percentage of copper gave promising results even though some of them show some phytotoxic problems.

Introduction

Due to the EU Regulation n.473/2002, the limitation of 6 kg/ha of copper that can be distributed in the environment, led to change the downy mildew (*Plasmopara viticola* (Berk. et Curtis) Berl. *et.* De Toni). control on grapevine (*Vitis vinifera*) in organic farming, particularly in the north of Italy where the disease pressure in some years is very high (Scannavini et al., 2000; Pontiroli et al., 2001; Cravero et al., 2002: Sancassani & Rho, 2002). The efficacy evaluation of reduced dosage of copper formulations along with new alternative copper-based products permitted in organic farming, was needed. In this paper, field trials located in a grapevine growing area with a high disease pressure, over three years, is presented.

Materials and methods

Trials were carried out over the years 2002, 2004, 2005 in a commercial organic farm located in Castelfranco Emilia (Italy) on vines cv Lambrusco Grasparossa of 6 years old, and vine density 3.5 x 2 m. Trials were set up following a randomized block design with 4 replicates and 6 plants/plot. In 2002-2004, the first chemical was applied at 80% of disease incubation, while subsequent sprays were carried out at 7 days interval. In 2005, all the chemicals were applied preventively. Chemicals were applied using a knapsack sprayer distributing 400-1000 l/ha depending on vine growth. Formulation's features are summarized in table 1. Disease severity and incidence

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were assessed on 100 leaves and 50 bunches per replicate. Data were arcsine transformed and statistically analyzed using ANOVA. Means were separated using SNK test (p≤0.05).

Tab. 1: Formulations tested each year and doses of application

Year			Commercial name	Active ingredient	a.i. % or g/l
2002	2004	2005			
*			Poltiglia Bord. Disperss	Cu hydroxy sulphate	20
*			Rame azzurro F2	Cu hydroxide	350
*			Cobre Nordox Super 75	Cu oxide	75
*			Peptiram 7	Aminoacids+Cu+peptides	89,6
*			Kendal	Oligosaccarids+glutatione +vegetal extracts	-
*			Fitoil	Soybean oil	40
*	*	*	Cuprocaffaro micro	Cu oxychloride	37,5
	*	*	Kocide 2000	Cu hydroxide	35
	*	*	Kocide 2000+molasses	Cu hydroxide	35
	*	*	ATO FAP 17	Cu hydroxy sulphate	40
	*		Oligal rame	Cu sulphate	172
	*	*	Airone	Cu hydroxide+Cu oxychl.	272
	*	*	Heliocuivre	Cu hydroxide+Terpenics	40
		*	Fertleader rame S	copper (sulphate) + seaweed extracts	6
		*	Kendal TE	Cu (23), Mn (0.5), Zn [illegible]	23
		*	Netram	Cu Penta-hydrated sulph.	60

Results

In 2002, weather conditions were favourable for disease development. Sprays were carried out on: 7/5, 14/5, 21/5, 28/5, 4/6; 12/6 20/6; 27/6, 04/7; 13/7.. Symptoms of the disease occurred on 17 may after the second spray. Results showed that all formulations and strategies applied, significantly reduced the infection compared with the check. However none of them proved to be effective in reducing the infection on bunches. Among the traditional formulations, rame azzurro F2 gave the best protection. Plots treated with Peptiram showed symptoms of phytoxicity with necrotic spots on leaves.

Tab. 2: Results in 2002: final assessment on 19st july

Commercial name	Dose (g or ml/hl)	Cu ion kg/ha (13/07)	% inf. leaves	% inf. leaf area	% inf. bunches	% inf. bunch area
B.mixture Disperss	600	9.6	30.3 cd	0.8 bc	70.0 bc	9.5 bc
B.mixture Disperss	300	4.8	56.8 b	2.1 c	87.5 ab	14.7 c
B.mixture Disperss + Fitoil	300+300	4.8	52.8 b	1.9 bc	83.8 ab	14.0 b
Rame azzurro F2	230	6.44	19.3 d	0.5 bc	46.3 c	3.4 bc
Cobre Nordox Super 75	110	6.6	31.3 cd	0.9 bc	62.5 bc	4.3 bc
B.mixture Disperss + Peptiram 7 (1)	600+200	5+ 0,896	36.8 c	1.3 bc	50.0 c	4.0 bc
Cuprocaffaro micro	300	9	32.3 c	1.2 bc	62.5 bc	6.2 bc
untreated control	-		94.5 a	7.3 a	100.0 a	65.2 a

(1) Applications with Bordeaux mixture were carried out on 7/5, 14/5, 17/5.

Tab. 3: Results in 2004: final assessment on 1st july

Commercial name	Dose (g or ml/hl)	Cu ion kg/ha (25/06)	% inf. leaves	% inf. leaf area	% inf. bunches	% inf. bunch area
Kocide 2000	200	4,48	53,3 cd	5,0 bc	59,0 c	8,6 c
ATO FAP 17	185	4,736	70,4 b	7,4 b	78,0 b	18,5 b
Oligal Rame	100	1,10	63,6 bc	6,5 bc	68,5 bc	18,6 b
Kocide 2000 + molasses	175 + 300	4,48	33,6 e	2,0 c	61,5 bc	10,8 bc
Airone	250	4,352	51,5 d	4,0 bc	62,0 bc	11,6 bc
Heliocuivre	125	3,2	51,3 d	4,4 bc	69,0 bc	12,7 bc
Cuprocaffaro micro	300	7,2	54,3 cd	5,3 bc	67,5 bc	12,9 bc
untreated control	-		89,1 a	22,2 a	95,0 a	34,9 a

In 2004, at the beginning of the season weather conditions were very favourable for the disease development and infection occurred early on bunches. Sprays were carried out on 7/5,14/5, 21/5, 28/5, 4/6, 11/6, 18/6, 25/6. This situation led to an insufficient disease control for all the formulations tested. Best results were achieved using copper hydroxide formulations, and on bunches in particular, Kocide 2000 applied alone or in mixture with molasses (Table 3).

In the trial performed in 2005 new alternative formulations were tested. Climatic condistions were not favourable for the disease because of very few rain events. All the sprays were carried out preventively on 4/5, 10/5, 16/5, 21/5, 27/5, 8/6, 17/6, 24/6; 1/7, 8/7 before any rain event. At the end of the trial, all the formulations adequately protected the leaves and bunches.

Tab. 4: Results in 2005: final assessment on 22nd july

Commercial name	Dose (g o ml/hl)	Cu ion kg/ha (8/07)	% inf. leaves	% inf. leaf area	% inf. bunches	% inf. bunch area
Kocide 2000	200	5,6	0,6 b	0,1 b	0,0 b	0,0 b
ATO FAP 17	185	5,9	1,0 b	0,9 b	0,5 b	0,0 b
Kocide 2000 + molasses	200 + 300	5,6	0,5 b	0,9 b	0,0 b	0,0 b
Fertileader Rame S	300	1,4	2,4 b	0,3 b	1,0 b	0,0 b
FertileaderRame S & Cuprocaffaro micro	150 + 150	5,2	2,8 b	0,4 b	1,5 b	0,0 b
Airone	250	5,4	0,6 b	0,1 b	0,0 b	0,0 b
Heliocuivre	125	4,0	0,4 b	0,0 b	0,0 b	0,0 b
Kendal Te	300	5,6	3,3 b	0,4 b	0,5 b	0,0 b
Cuprocaffaro micro	300	9,0	2,7 b	0,3 b	1,0 b	0,0 b
Netram	150	0,72	2,0 b	0,3 b	4,0 b	0,1 b
untreated control	-		54,0 a	8,4 a	45,5 a	6,4 a

Conclusions

When climatic conditions are very conducive for the disease and copper sprays have to be applied at shorter interval, the respect of EU limitation may lead to have damage at harvest. With this respect, promising results are given by the new formulations at reduced copper content Peptiram and Netram, even though the former showed phytotoxicity problems. Results showed that, among the traditional copper formulations, only cu hydroxide permits to contain the disease and at the same time reduce the copper distribution up to 5 kg/ha. However more investigations with higher disease pressure are needed

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Olive fly (*Bactrocera oleae*) activity, fruit infestation and temperature in an organic table olive orchard in southern Crete

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Key words: Olive fly, Bactrocera oleae, organic olives, temperature, climate

Abstract

Olive fly activity and olive fruit infestation was monitored in a table olive orchard in southern Crete throughout most of 2006 using McPhail traps. Flies were trapped weekly for 40 weeks, starting at the beginning of February. The fly data was split into 10 four-week periods. Male, female and total fly activity was significantly related to sampling period, maximum temperature and relative humidity but the pattern of catches was not consistent. Activity increased from February until July but declined in August and was very low in September, October and November. The low activity in the last three months was reflected in low fruit infestation levels, with a maximum of 3.6% in October which contrasts with infestation levels usually around 30%. Olive fly mortality is high above 31°C and the average mean maximum temperature in the four months June-September was above 34°C. High summer temperatures, with low humidities, appear to have considerably limited olive fly activity and fruit infestation and pest control measures may have to be adapted to these conditions.

Introduction

Bactrocera oleae (Rossi), the olive fly, is the most important pest of olives throughout the Mediterranean region and has badly affected olive oil yield in Crete for a considerable time (Neuenschwander & Michelakis, 1978). Changes in farming practice in general to more organic and low-input systems, generally the product of concerns over food quality, have been applied to olive production (Crovetti, 1996). Problems such as high resistance to organophosphate pesticides (Skouras et al., 2007) has led to the development of mass trapping to limit olive fly damage (Haniotakis et al., 1991). These baited traps, with food or sex attractants, and a lethal agent are put out throughout an orchard prior to fruit establishment and have been shown to be more effective than spraying in lowering fly numbers and infestation (Broumas et al., 2002).

In 2006, as part of a wide-ranging investigation into a number of aspects of organic olive production, the activity of olive flies in a table orchard near Moires in southern Crete was monitored for 40 weeks using a standard sampling method. The activity of flies in a harvest year was related to temperature and humidity and fruit infestation levels were estimated.

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Materials and methods

The survey area was an organic table olive orchard near the town of Moires in the Messara plain, southern Crete. 16 blocks of 80 olive trees (var Kalamon), of similar height and density, were sampled using McPhail traps with the food attractant Entomela 55SL, a standard method for assessing olive fly numbers. Sampling started on February 1 2006 and 40 weekly samples were taken. The traps were emptied, the catch sorted in the laboratory and the numbers of male and female olive flies counted. Estimations of fruit infestation by olive fly were carried out on six trees in each block. A total of 120 fruit from the six trees were examined for active and non-active infestation involving egg punctures, alive and dead eggs and larvae. These estimations were carried out every week from 1st July to 15th November 2006, when olive fruits were mature and harvesting began. Temperature and humidity measurements were taken by a HOBO HO8 (Onset Corporation) every one hour, in a Stephenson screen in the middle of the orchard. Daily maximum temperature and mean daily relative humidity values were used in the statistics. The weekly male, female and total olive fly catches were combined into 10 sequential four-week periods whilst monthly percent total olive fruit infestation (July-November) was calculated. Linear mixed-effects models were used to generate analyses of variance using sampling period as a fixed factor and maximum temperature and relative humidity as continuous variables, with block as a random factor. The mean fly catches and percent infestations were compared using the Tukey HSD test and all analyses were carried out in the R statistical environment (R Development Core Team, 2007).

Results

The linear mixed effects models produced very highly significant ($P<0.0001$) relationships with male, female and total olive fly catches with sampling period and relative humidity. However, the models with maximum temperature were not as significant. Male and female flies were less significantly related to temperature ($P<0.01$) than the totals ($P<0.001$). The mean number of male, female and total olive flies recorded in the 10 four-weekly periods, together with the mean maximum temperature and relative humidity for each period are shown in Tab. 1. Most male flies were caught in periods 5 and 6 (June and July), significantly different from the other means. There were lower, not significantly different, catches in periods 1, 2, 3, 4 and 7. Fewer females were trapped than males, with the highest mean in period 6, not significantly different from period 4. Similar non-significant mean numbers of female flies were trapped in periods 3, 4 and 5 and in periods 1, 2 and 7. The total means peaked in period 6, with high numbers also in period 5. More flies were recorded in periods 3 and 4 (April and May) than in periods 1, 2 and 7 (February, March and August) but very few flies were trapped in periods 8, 9 and 10 (September, October and November).

The mean maximum daily temperatures were highest and not significantly different in periods 6, 7 and 8. All other mean temperatures differed significantly from each other with an increase in means from period 1 to period 5 and a decrease in periods 9 and 10. The mean daily relative humidity values were lowest means in periods 6 and 8, significantly lower than in periods 7 and 5. Humidity became lower as temperature increased in the first four periods, increasing as the temperature fell in periods 9 and 10.

Tab. 1: Mean number of olive flies, ± SE, caught in McPhail traps in the ten sampling periods, together with the mean daily maximum temperature and relative humidity for the sampling periods.

Period	Males	Females	Total	Maximum Temperature	Relative humidity
1	5 ± 0.8^{bc}	4 ± 0.7^{cd}	9 ± 1.3^{cd}	17.9 ± 0.25^{h}	72.5 ± 0.84^{ab}
2	4 ± 0.6^{bc}	4 ± 0.5^{cd}	8 ± 1.0^{d}	21.2 ± 0.49^{g}	71.0 ± 0.40^{b}
3	8 ± 1.1^{b}	9 ± 0.9^{b}	18 ± 1.9^{bc}	25.8 ± 0.34^{e}	64.8 ± 0.81^{c}
4	7 ± 0.8^{b}	10 ± 1.2^{ab}	18 ± 2.0^{c}	28.2 ± 0.91^{d}	55.3 ± 1.81^{d}
5	18 ± 3.6^{a}	7 ± 1.2^{bc}	25 ± 4.2^{ab}	34.6 ± 1.00^{b}	49.8 ± 1.25^{e}
6	20 ± 2.1^{a}	13 ± 1.2^{a}	33 ± 3.0^{a}	36.8 ± 0.49^{a}	41.6 ± 0.12^{f}
7	4 ± 0.6^{b}	3 ± 0.6^{d}	7 ± 1.2^{de}	37.6 ± 0.28^{a}	47.8 ± 1.91^{e}
8	1 ± 0.2^{c}	1 ± 0.2^{de}	2 ± 0.3^{de}	37.0 ± 0.82^{a}	43.1 ± 1.81^{f}
9	0 ± 0.1^{c}	0 ± 0.1^{e}	0 ± 0.1^{e}	30.6 ± 0.78^{c}	64.6 ± 2.06^{c}
10	0 ± 0.1^{c}	0 ± 0.1^{e}	1 ± 0.2^{d}	23.3 ± 0.41^{f}	74.9 ± 0.52^{a}

Superscripts indicate significant differences between means ($P<0.05$)

The mean percentage olive fruit infestation in the five months surveyed are shown in Tab. 2, together with comparable results from a survey in central Greece in 1983 by Broumas et al. (1985). Infestation was lowest, and not significantly different, in July, August and September 2006 but although the means for October and November were significantly higher than for July, infestation was still very low at 3.6% in October. The results from central Greece in 1983 indicate a considerable increase in fruit damage in October and November, to around 30%.

Tab. 2: Mean (%) total olive fruit infestation, ± SE, in the five months before harvesting together with comparable data from western Crete in 1983 (data from Broumas et al. 1985).

Month	2006	1983
July	1.5 ± 0.34^{c}	2.4
August	2.7 ± 0.28^{abc}	4.9
September	1.9 ± 0.41^{bc}	5.4
October	3.6 ± 0.49^{a}	28.0
November	3.1 ± 0.48^{ab}	30.4

Superscripts indicate significant differences between means ($P<0.05$)

Discussion

Although the linear mixed effects models all gave significant responses to sampling period, maximum temperature and relative humidity, the mean catches showed that the relationships were not consistent. Olive fly activity increased throughout the year until the end of July (period 6) in close association with increasing temperatures and decreasing humidity, but there was a rapid decrease in activity in August (period 7) and very little activity in September, October and November (periods 8, 9 and 10). The usually reported pattern of fly activity follows a pattern of a number of generations in the first half of the year, maximum activity in June and July and then two more activity peaks in September/October and November (Broumas et al., 1985). The activity peaks between September and November usually result in fruit infestation, in the case of Broumas et al. (1985), of around one-third of the crop, which was thought not to be economically damaging because of mass trapping. However, in the table olive orchard surveyed the maximum damage was below 5%. Mortality of olive fly eggs and of the first two larval instars is related to daily maximum temperature and mortality of both larvae and adults is considerable above 31^{o}C (Crovetti, 1996). There is also evidence that low humidity make conditions unsuitable for breeding (Katsoyannos, 1992). With mean maximum temperatures above 31^{o}C in June, July, August and September 2006 in the orchard surveyed, it appears that the crash in activity seen in the last three sampling periods was due to high summer temperatures, with low humidities possibly having a compounding effect.

Conclusions

The high summer temperatures recorded in southern Crete since 1995 may have repercussions for olive fly control in the region. If ambient climatic conditions are limiting olive fly activity and fruit infestation, then it is likely that intensive pest control measures will not be required.

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Influence of *Vicia hirsuta* control with kainite on winter cereals

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Key words: *Organic farming, hairy tare, kainite, crop damage, corn yield*

Abstract

In four field experiments (2002, 2003) the influence of Vicia hirsuta control with kainite applications (59% NaCl, 17% KCl, and 16% $MgSO_4$) on growth of winter cereals was examined. Leaf damage (yellowing) of both winter wheat and winter rye increased with increasing kainite concentrations. At early application dates [growth stages (GS) 23-32] crop damages were low (up to 16.8%) and crop stands recovered rapidly from the injuries caused by the salts. The application of kainite solutions (350 kg ha^{-1}) at later growth stages of winter wheat (GS 39) caused severe crop damages up to 48% and crop regeneration was low. Yield relevant damages of winter crop caused by using kainite were not determined. The overhead potash fertilisation with kainite granulate (53.5 kg K ha^{-1}) at GS 23-24 of winter wheat and GS 27-29 of winter rye, resulted in lower crop yield and grain weight due to the enhanced growth of V. hirsuta.

Introduction

Hairy tare (*Vicia hirsuta*) as a climbing legume weed can find optimal growing conditions especially in organic winter cereals, in particular in cold springs. Severe infestation with this weed may seriously affect the crop through competition for water, nutrients and light and may also cause problems at harvest resulting in reduced crop yield and product quality.

Weed control under Organic Farming conditions is generally carried out by preventive and mechanical measures (harrowing, hoeing) as well as by flame weeding (Struik & Bonciarelli 1997). A considerable disadvantage of indirect or physical control measures against *V. hirsuta* is often the low efficacy and insufficient reliability particularly at early spring (Lindemuth 1924, Habel 1957). Weed regulation with permitted raw salts like kainite could present a low cost addition of control measures used nowadays. Kainite dust broadcast on the dew wet plants can completely destroy the leaf tissue as a result of plasmolysis, thereby destroying young weed plants (Vasters & Remy 1914, Uhl 1952). The optimal conditions for successful control of *V. hirsuta* in winter cereals are described in detail by Lukashyk et al. (2008). The most important results from this study showed that solutions of kainite were sufficient to control *V. hirsuta* in all developmental stages. Nevertheless, efficacy was highest at early weed growth stages (< 4 leaves). Increasing chloride concentrations of kainite resulted in an increased degree of efficacy. The kainite efficacy was heavily dependent on weather conditions. It was sufficient at the time of high air humidity, warmth and absence of rainfall before and after kainite application.

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The main aim of the investigations presented here was to test the influence of *V. hirsuta* control with kainite on winter cereals at different crop growth stages. Secondly, the efficiency of kainite as crop fertiliser has been investigated.

Materials and methods

In 2002-2003, two-factorial field experiments (randomized complete block design, four replications, plot size 1.5 x 10 m) with kainite (59% NaCl, 17% KCl, and 16% $MgSO_4$, Kali & Salz GmbH 2002) were conducted in winter wheat (*Triticum aestivum* L., cv. *Pegassos*) and winter rye (*Secale cereale* L., cv. *Nikita*), respectively. The trial sites were located at two organic farms in North-Rhine Westphalia, Germany.

In 2002, different concentrations of kainite (dust: 150, 300, 450 kg ha^{-1} and solution: 250 kg ha^{-1}) were applied once at different growth stages (GS) of winter cereals (wheat: GS 24, 30, rye: GS 29, 32). In 2002, the trial in winter wheat was modified due to insufficient efficacy of kainite (dust formulation) on *V. hirsuta* at first application time (GS 24). Plots of this trial that had not been treated until then were applied with kainite solutions only (150, 250 and 350 kg ha^{-1}, 1000 l ha^{-1}) at GS 39 of wheat. Latter kainite concentrations were repeated sprayed in 2003 in both cereal crops (wheat: GS 23, 30, rye: GS 27, 32). The kainite dust (grain size ≤ 0.5 mm) was broadcast on the wet leaves in the morning dew. The kainite solutions including adhesive adjuvants (ProFital fluid, 0.1%) were applied under dry weather conditions. In order to examine the fertilising effect of kainite on the crop one treatment of granulate kainite (600 kg ha^{-1} = 54 kg K ha^{-1}) was included in all trials. Granulate was broadcast among the cereals rows always at first application time. The parameters assessed were crop damage and regeneration, stand density, grain yield as well as thousand-grain weight. Crop damage and regeneration were estimated by visual evaluation of yellowed leaf area (10 days after application) and of covered ground by crop (before and 30 days after application) on entire plot, respectively. The statistical analysis of data was carried out with ‘Statistical Analysis System’ (SAS-Institute-Inc. 1999). Parameter means were compared by Tukey’s multiple post-hoc test (□ = 0.05).

Results and Discussion

Crop damage and regeneration

In 2002 and 2003, kainite applications at GS 23-32 of winter cereals reduced crop leaf area by a maximum of 16.7%. Applications of kainite solutions at later growth stages of winter wheat (GS 39) caused severe crop damages (yellowing of leaf area), which positively correlated with the kainite concentration. The application of 150 kg ha^{-1} kainite (= 13 kg K ha^{-1}) caused significantly lower damages (20%) compared to the highest concentration of 350 kg l^{-1} (= 31 kg K ha^{-1}), which resulted in a loss of 48% of the crop leaf area. Cereal resistance to kainite applications at early growth stages is probably due to morphological features like leaf position/thickness and protecting wax layers (Wehsarg 1931). Leaves of monocots, such as winter cereals are more upright and, therefore, have a smaller contact surface compared to dicotyledonous plants (Vasters & Remy 1914, Korsmo 1930, Hock et al. 1995). This fact would explain the small damage on the cereal crop at GS 23-32. Compared to the early application time the leaf area at GS 39 of the winter crop was larger and the leaf position more horizontal. Consequently, the enhanced adhesion of kainite on the leaf surface allowed an easier penetration into the leaf tissue, thereby inducing greater damages.

Cereal crops recovered rapidly from injuries caused by kainite applications at GS 23-32. Monocots like winter wheat with protected growing points that are located near the soil surface were able to reproduce shoots shortly after the flame weeding induced damage (Ascard 1995). The leaf area loss in winter wheat after the application at GS 39 could only partly be compensated by the re-growth of new leaves.

Yield parameters of winter crop

In 2002, the application of kainite solutions at later development stages of winter wheat (GS 39) tended to result in lower grain yields (not significant) compared to the untreated control (Table 1), although *V. hirsuta* control was sufficient (data not shown). This result can be explained by the severe growth delay of wheat through considerable leaf area loss (up to 48%). At the same time kainite applications (250 kg ha^{-1}) at GS 32 of winter rye increased grain yield significantly compared to the treatment with kainite granulate (54 kg K ha^{-1}) (Table 1).

Tab 1: Grain yield (GY, dt ha^{-1}), stand density (SD, ears per m^2) and thousand-grain weight (TGW, g) of winter cereals as affected by kainite concentration and formulation (D - dust, G - Granulate, S - solution) as well as application time (crop growth stage - GS), 2002.

Kainite concentration (kg K ha^{-1})	Winter wheat (GS 39)					
	GY (dt ha^{-1})		SD (ears per m^2)		TGW (g)	
Untreated control	28,8 a		342 a		40,0 a	
13 (S)	27,9 a		339 a		37,6 a	
22 (S)	28,5 a		336 a		38,7 a	
31 (S)	26,9 a		319 a		38,3 a	
54 (G)	16,2 b		314 a		33,3 b	
	Winter rye					
	GS 29			GS 32		
	GY	SD	TGW	GY	SD	TGW
Untreated control*	49,6 a	368 a	29,4 a	49,6 ab	368 a	29,4 a
14 (D)	49,3 a	359 a	30,0 a	46,4 ab	375 a	29,1 a
22 (S)	51,6 a	365 a	29,7 a	53,0 a	380 a	30,1 a
27 (D)	50,1 a	350 a	29,9 a	48,9 ab	356 a	29,1 a
40 (D)	48,2 a	355 a	29,1 a	49,6 ab	361 a	29,1 a
54 (D)	49,3 a	359 a	30,3 a	48,4 ab	377 a	29,6 a
54 (G)*	44,9 a	367 a	28,2 a	44,9 b	367 a	28,2 a

Different letters within the same column indicate significant differences (Tukey's Test, □= 0.05). *same treatments for both application times

This fact is probably due to the improved crop growing conditions after *V. hirsuta* control. In plots where kainite granulate was applied as a fertiliser *V. hirsuta* growth was enhanced (Lukashyk et al. 2008), resulting in a severe reduction of winter wheat yield (43.8%) and lower thousand-grain weights (16.8%) compared to the untreated control (without kainite) (Table 1). Winter rye also tended to give lower grain yield in fertilised plots compared to the other treatments. To conclude, besides the herbicide effect kainite applications enhance the development of both crop and *V. hirsuta* due to the fertilizing effect. However, *V. hirsuta* as a legume weed with self-sustaining nitrogen supply developed much better than the cereal crops in our experiment. The enhancing effect from kainite on the growth of cornflower (*Centaurea cyanus* L.) has also been observed in winter rye (Remy & Vasters 1915). According to Apenrade (1912) and Wehsarg (1931), kainite can be used for both weed control and overhead potash fertilisation of the crop.

In 2003, crop yield parameters were not significantly affected by the tested treatments. However, all kainite applications tended to result in higher corn yield of both winter cereal crops compared to the untreated control.

Conclusions

The results of this study showed that yield relevant damages of winter cereals caused by using kainite were not determined. In order to avoid fertiliser effects on weeds kainite should be applied to winter cereals under optimal weather conditions at GS 20-25 to achieve greatest efficacy on *V. hirsuta* and lowest potential for crop damages. The time span in which kainite can be applied in winter rye is short due to the rapid development of the crop.

Acknowledgments

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Efficacy of indigenous botanicals and bio-rationals in the management of cabbage pests in an organic farming system

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Key Words: Biological control, botanicals, cabbage, concoctions, pests

Abstract

Cabbage is an economically important crop in Uganda. Pests are number one constraint limiting qualitative and quantitative production. Organic cabbage production is picking up and farmers use botanicals to control pests. Used botanicals are not evaluated scientifically, though there is a rich indigenous knowledge about pest management. This has resulted into misuse of botanicals, and as such, pest management is labour intensive and uneconomical. Therefore, a study was conducted during to growing seasons to evaluate farmer used botanicals against major cabbage pests. Pests usually found on cabbage were recorded. Note was taken of percentage number of leaves damaged by the diamond back moth, aphids and the cabbage lopper per plant per treatment. Yield was also noted at harvest stage. Generated data was analyzed for variance (ANOVA) using SPSS and graphs were made using Excel computer programme. Use of Tephrosia powder and solution was found to be the most effective treatment against cabbage pests. This treatment was better than a mixture of citronella, chili, andTephrosia solution. Tephrosia powder and solution, as well as chili solution spray are recommended for use against cabbage pests in the organic farming system.

Introduction

White cabbage (*Brassica oleracae*) is one of the most widely grown and eaten vegetables in Uganda (Mukiibi, 2001). Most production takes place during the rain season. For maximum economic benefit and better profit margin, farmers grow some cabbage crop in the dry season. During the dry season, both nursery and field crops are infested with diamond back moth (*Plutella xylostella*) and aphids (*Aphis gossypi*), cabbage lopper (*Helicoverpa armigera*) (Kakuhenzire *et al*., 1997). Some biological control activity has been observed in the field with coccinelids and *Didegma* spp being most common. However, biological control is not sufficient during the dry season. Environment friendly pest management practices are, therefore, required during this time. Farmers control these pests by applying a concoction of botanicals, but with neither specific rates nor concentrations (Table 1).

This situation of smallholder farmers is the same in organic cabbage production. In Uganda, the most commonly used botanicals are Citronella (*Cymbopogon nardus*), African marigold (*Tagetes erecta*.), Muluku (*Tephrosia* spp.), and various types of chilie (*Capsicum* spp.). These materials are used individually or in mixture. Nevertheless, efficacy of these botanicals/ bio-rationals has not been scientifically evaluated in Uganda.

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Tab. 1: Botanicals used in agricultural production (Stoll, 1998)

	Plant species	Part of plant used	Target pests/ used as
1.	Cymbopogon citratus (Lemon grass)	Leaves	Repellent: various insects
2.	*Cymbopogon nardus* (Citronella grass)	Leaves	Repellent: banana weevils, aphids, diamond back moth
3.	*Tagetes erecta* (African marigold)	Leaves and stem	Repellent: various insects
4.	*Tephrosia* spp. (Muluku)	Leaves and roots	Miticide: pigs mange (olukuku), mites

This study aimed at evaluating the efficacy of various botanicals traditionally used against cabbage pests in organic cabbage farming systems.

Materials and Methods

Field experiments were established between October 2005 and June 2006. Two cabbage crops were planted using variety Copenhagen. Twenty five plants were planted in 4 m² plots. Five treatments were applied. Each treatment was replicated three times. Applied treatments included:

T1- Citronella grass was harvested from strip bands elsewhere and mulched in a cabbage crop sprayed with a chili solution spray of 250g of chilli powder per 10 litres of water, prepared just before use

T2- Tagetes solution with 250g of dry powder of Tagetes leaves per 10 litres of water, allowed to stand for 12hrs socked overnight, was applied

T3- *Tephrosia* powder was dusted onto plants at rate of 50g per plant and a *Tephrosia* solution of 250g dry powdered leaves, allowed to sock overnight for 12 hours in 5 litres of water was applied

T4- A mixture of treatment (1) and (3) was applied for this treatment

T5- Water was applied without any mixtures as a control

All treatments were applied once every fortnight. Data was collected once a week from all 25 plants in the plot by counting the number of leaves infested by diamond back moth (*Plutella xylostella*), aphids (*Aphis gossypi*), and cabbage lopper (*Helicoverpa armigera*) per plant per treatment. Yield per treatment was also recorded at harvesting stage. Data was analysed for ANOVA SPSS statistical programme, and graphs were made in excel.

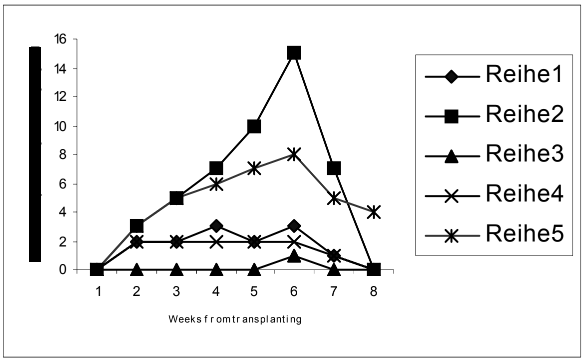
Results

Cabbage pests, which include diamond back moth (*Plutella xylostella*), aphids (*Aphis gossypi*), and cabbage lopper (*Helicoverpa armigera*) were observed in the cabbage field. Application of Tephrosia powder (50g per plant) and *Tephrosia* solution (250g per 5l of water) was most effective in keeping all three pests damage of the cabbage crop low (Figures 1 and 2). These treatments were significantly different from the control for both the first and second seasons (Tables 2). The mixed treatment with citronella mulch, *Tephrosia* powder and *Tephrosia* solution came second in effectiveness against the three insect pests. Both treatments 4 and 3 were significantly different from the control in the first and second seasons. Tagetes solution (250g per 10l of water) alone was least effective, though it was better than the control during both seasons (Figures 1 and 2). A short-term efficacy was noted, where citronella grass mulch only was applied (Figures 1 and 2). A fortnightly rise and fall in pest damage was observed in this case. This treatment was significantly more effective than where mulching and *Tephrosia* powder plus *Tephrosia* solution was applied, as well as the control, which had only water applied as shown in tables 2, and figures 1 and 2.

Even though pest damage in season one was lowest in treatment 3, treatment 4 had better cabbage yield (t/ha) (not shown). It is surprising to note that the yield for the control was better than that in treatment 3, though not significantly different (not shown). Treatment 4 had the highest total yield. Nevertheless, treatment 3 had the highest yield (t/ha) during the second season. It was followed by treatment 1, which involved mulching with citronella grass and spraying with chili solution. Treatment 4 came third and was significantly different from the control. In this case we can say that treatment 4 was most consistent both in controlling pest damage and maintaining high yield.

Discussion and Conclusion

There rich indigenous knowledge on botanicals has scientific justification. Farmers applied botanicals against cabbage pests without validation, but could still observe their effectiveness, which this study unveils. From our results it is evident that all used botanicals are effective against the three major cabbage pests in Uganda. Treatments 3 and 4 were consistently effective and gave high yields. This reflects the reason why farmers always go for a concoction as opposed to single botanical use.



T1

T2

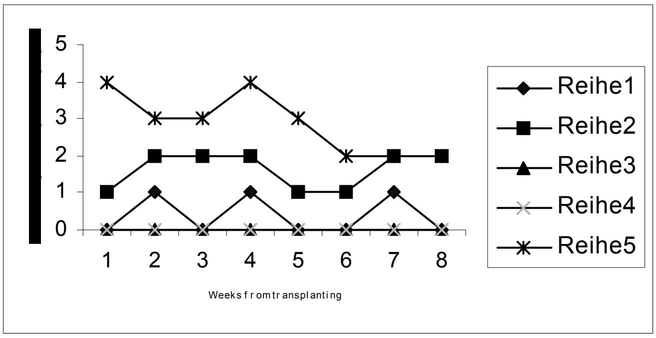
T3

Figure 1: Treatment effect on insect pest damage on cabbage leaves during the first season

T4

T5

However, it is clear that *Tephrosia* powder and solution (T3) gave the most cost effective cabbage pests control package, and could be recommended for use instead of the concoction in treatment 4. This reduces labour intensity and reduces genetic erosion of the beneficial plant.



T1

T2

T3

T4

T5

Figure 2: Treatment effect on insect pest damage on cabbage leaves during the second season

The effective use of *Tephrosia* powder formulation indicates the potential to harvest the botanical during periods of less work load and store it for use later in the season. Furthermore, the fortnightly efficacy of treatment 1 (*Citronella* mulch with fortnightly chili spray) shows that chili was more effective than citronella grass mulch. However, its surprisingly high yield could be due to the mulch, which adds to soil fertility and preserves moisture. This, too, is a promising cabbage control package, which could be cost effective for farmers growing both the essential oil crop and vegetables. We, therefore, recommend the use of *Tephrosia*, *Citronella* and chilli botanicals in the organic cabbage production system. However, farmers may not need to go for very complex concoctions as one or two botanicals can be good enough in keeping pests below the economic threshold. Where possible, the chili spray could be done on weekly intervals instead of bi-weekly. However, basing on these findings, it is not advisable to use African marigold (*Tagetes erecta*) alone against cabbage pests.

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Laboratory Studies of the Activity of Spinosad against Leptinotarsa decemlineata (Say) Depending on Different Temperature

Kowalska, J.[1]

Key words: *Leptionotarsa decemlineata*, spinosad, temperature, control

Abstract

Mortality of the Colorado potato beetle larvae (Say) and adults caused by commercial formulation of spinosad at 15, 20 and 25^{0}C was determined under laboratory conditions. The insects and the leaves of potatoes were sprayed with the insecticide. Thus, the insecticide was toxic by exposure to treated surfaces and ingestion. Three concentrations of insecticide were used: 0.2%, 0.1% and 0.05%. The effect was assessed the 6th day after treatment. All concentrations caused mortality both adults and larvae; however mortality of tested insect stages increased as concentration of spinosad increased. For adults was observed the highest mortality in combination with 0.2% at 15^{0}C, whereas at this same temperature in combination with 0.1% was reached the lowest mortality. In tests with the larvae was observed that 0.2% of spinosad caused the lowest mortality at 25^{0}C, whereas concentration 0.1% of spinosad reached the best results at this same temperature. For adults and larvae concentrations 0.05% of spinosad reached the lowest mortality and differences between results in this combination depend on temperature were not observed.

Introduction

Colorado Potato Beetle (*Leptinotarsa decemlineata* Say), CPB, is a very important pest of organic farming. This pest may be managed culturally by crop rotation or destruction of crop debris. In conventional agriculture, the insecticides including imidacloprid or neonicotinoid compounds are commonly used to control of CBP populations, but this pest rapidly develops resistance and additionally these insecticides are forbidden in organic farming system (Council Regulation EEC No 2092/91). In Poland, until now, spinosad is used to control of pests of ornamental plants and in the orchards. Proposed research can contribute to extend the spectrum of susceptible pests. The aim of current study was to evaluate the toxicity of a commercial spinosad formulation to *L. decemlineata*. Effects of post-treatment temperature and stage of development of insects on mortality were investigated.

Materials and methods

In June and July, the adults and larvae of *L. decemlineata* were collected in Western region of Poland. The insects were fed in an insectary. Larvae of the 3th and 4th instar and adults were used in the experiments. Bioassays were conducted in the laboratory using the Petri dishes. The insects and leaves of potatoes were sprayed with different concentrations of spinosad. Experiments have done with Biospin®, a commercial formulation of spinosad (120 g a.i. /L product; DowAgroScience). Solutions of

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spinosad (0.2%, 0.1% and 0.05%) were prepared in distilled water. Volume of water (500 l/ha) were equivalent to that of applied in the field. To investigate the effect of post-treatment temperature the Petri dishes were incubated in the dark at 15, 20 and 25^{0}C. Total number of insects used in each experiment was 50 insects. Each test was performed using two replicates. Summary mortality is presented after 6th day. The data obtained were subjected to ANOVA. The significance of differences was examined using Tukey's test.

Results

Analysis of variance showed significant differences in mortality between temperatures and concentrations of spinosad for both adults (F=13.87, P<0.05) and larvae (F=8.06, P<0.05) (Fig 1 and Fig. 2).

All concentrations caused mortality both adults and larvae, however mortality of tested insect stages increased as concentration of spinosad increased. For adults was observed the highest mortality in combination with 0.2% at 15^{0}C, whereas in this same temperature in combination with 0.1% was the lowest mortality. In tests with the larvae was observed that 0.2% of spinosad caused the lowest mortality at 25^{0}C, whereas concentration 0.1% of spinosad reached the best results at this same temperature. For adults and larvae concentrations of 0.05% spinosad reached the lowest mortality and differences between results in this combination depend on temperature were not observed. In the table are included mean results depending on used concentration and temperatures in replicate.

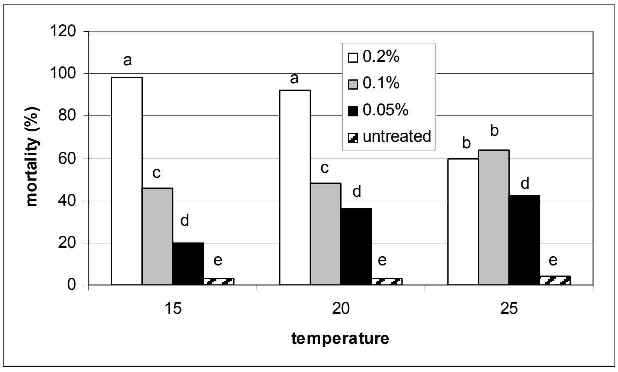

Figure 1: Effect of spinosad on the larvae of *L. decemlineata* depending on temperature (Within the figure, means followed by the same letter are not significantly different)

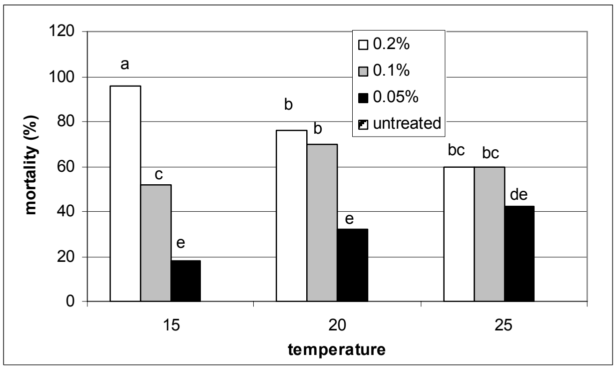

Figure 2: Effect of spinosad on adults of *L. decemlineata* depending on temperature (Within the figure, means followed by the same letter are not significantly different)

Tab. 1: Average mortality of different stages of development of *L. decemlineata* depending on temperature and concentrations of spinosad

Temperatures/ Concentrations of spinosad	Mortality of CPB larvae/replicate ± SD	Mortality of CPB adults/ replicate ± SD
15^0 C	27± 1.8b	28 ± 1.9a
20^0 C	29.3± 1.8b	30.3 ± 1.9a
25^0 C	34 ± 1.8a	27.3 ± 1.9a
0.2%	47.3±1.8a	39.3±1.9a
0.1%	28±1.8b	31±1.9b
0.05%	14.6±1.8c	15.3±1.9c
untreated	2.0±1.8d	0.0±0.0d

Within each columns, means followed by the same letter are not significantly different, n=50 insects/replicate

Discussion

Spinosad is derived from fermentation products of actinomycete bacterium (Mertz and Yao 1990). Depending on the species, stage of development or mode of application spinosad may be various toxic. The active components, spinosyn A and spinosyn D can effective control pests of the orders Lepidoptera (Sparks *et al.* 1995, 1998), house flies (Scot 1998), eggplant flea beetle (McLeod *et al*. 2002) and stored-product insect species (Huang *et al.* 2004). This insecticide is effective to insect species that are resistant to some synthetic insecticides (Lui *et al.* 1999) and has a limited impact on non-targeted organisms (Sarfraz *et al*. 2005). In the laboratory, spinosad treatments were toxic to *Mamestra configurata* Walker, *Phyllotreta cruciferae* Goeze (Elliot *et al*. 2007). Among beetle species toxicity is various, for example spinosad was over 400 times more toxic to adult of *Rhyzopertha dominica* F. than to adult *Tribolium castaneum* Herbst (Toews and Subramanyam 2003). The effect of spinosad depends on mode of application and temperatures. Temperature has no effect on the toxicity of spinosad to stored-product beetles (Fang and Subramanyam 2003), whereas in the grasshoppers that is important factor for mortality of pest (Amarasekare and Edelson 2004).

The data of this study showed that temperature influences an effect of spinosad on larvae of *L. decemlineata* and adults. The larvae of *L. decemlineata,* like *Oulema melanoplus* (L) and adult *Epitrix fuscula* (Crotch) are characterized by different susceptibility to spinosad applied to foliage.

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Plant Health and the Science of Pests and Diseases

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Keywords: agroecology, phytiatry, plant protection

Abstract

The health/disease duality has developed alongside human history either as a struggle for survival or as a challenge of the human being to effectively get to know himself. To speak about pests and diseases of plants may not be as exciting as when speaking of human beings; however, entomology and phytopathology hold methodological similarities to conventional medicine, which, thus, allow for correlations among them. After all, plant protection and human medical science are based under common epistemological principles of modern scientific thought. Hence, the goal of this essay is to disclose certain disagreements of the disciplines of phytopathology and entomology with agroecological based science; yet, giving way to a discussion according to ecological principles. This is a theoretical essay, based on bibliographical research and on the direct experience of the authors with family farmers in the South of Brazil during the last 20 years.

Introduction

It seems unquestionable that human thought has evolved, and, with it, the organization of knowledge as the rest of the real/concrete world. Yet, such thinking is not hegemonic. The science of diseases and epidemic pests of human beings - medicine - has been construed by means of rational thought and observation, by thinking and reflecting on the phenomena, the processes, the causative powers of illnesses; therefore, on the ways in which we could possibly intervene in them. It was the Hellenic civilization that, before 300 B.C., gave way to the first reported account of the Western philosophical tradition, conceiving health as *soteria* [gr.] = harmony or saving; disease/illness as *pathon* = suffering, passion, lack of freedom; and therapy/cure as *therapeia* = body care, serve, to render praying. It is noteworthy that the etymological meanings of these terms are quite different to those underlying contemporary medical practice and, just the same, plant protection science. In spite of efforts to alleviate human suffering, the modern medical system paradoxically cannot avoid the resurgence of infectious diseases (Foladori, 2005). In comparison, agronomical science has established a conventional approach which subordinates the scientific disciplines of entomology and phytopathology to the development of technologies for a maximum yield. This orientation gave rise to the contradiction of offering food security by means of a system that increasingly demands use of pesticides (Tansey & Worsley (1997). The objective of this work is to unveil some contradictions between conceptions of plant protection and agricultural production

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systems, including intensive organic systems, when analyzed in the light of agroecological principles; therefore, opening the discussion for a new perspective towards the development of a science in actual support of sustainable agricultural.

Materials and methods

This work is based on theoretical analysis of current bibliography and on personal accounts of encounters with organic and non-organic farmers of the South of Brazil.

A) The history of the disease/health process

The illness/health process can be delineated by means of several historical phases, with some overlapping, giving explanation to this phenomenon (Machado, 2000). All the same, it was only by the second half of the XIXth century, with the contributions of Pasteur and Koch, that the modern scientific paradigm of medicine was first construed: biological agents were appointed as the cause of diseases and a method for verification was established. The methodological procedure has since then been successful and, yet, extended to animal and plant disease diagnoses as well. At times, this procedure may be further extended to epidemiological studies, when a population is affected by means of host and pest interaction. Incidentally, at the same time, Darwin stated that natural selection was the major force in the origin of new species, due to the competitive ability among lines within the same genetic basis, which further corroborates the idea that biological interactions, such as parasitism and plagues, are no more than constant faith and struggle for survival (Boff et al., 2003; Abdalla, 2006).

Pasteur determined that the causing agents of diseases among silkworms and of sour wine were microbial agents. By isolating the cause one could make the silkworm healthy and with quick heating, yet, save the wine. The underlying idea of both processes is that the microbiological agent and the host cannot come together.

B) Experience with family farmers

During the last 20 years, several family farms of the “Alto Vale do Itajai” and of the “Planalto Serrano Catarinense” regions were visited and on-farm research was done. This direct contact has allowed us to get a better idea of how farmers actually and effectually deal with pest and disease problems on crops and animals and what their references of knowledge are when deciding to intervene and treat the affected crops or apply drugs to the livestock or, yet, if care is granted to the family members as well.

Results and Discussion

A) Divergencies and contradictions

Pests and diseases on plants are generally perceived as undesirable events on farms. They clearly compete with human beings and, thus, must be eradicated or, at least, well controlled. The conceptual basis of this currently generalized farming way of thought probably came from the green revolution knowledge package, influenced by Pasteur’s microbiological paradigm and the Darwinian ideas of evolution by means of the survival of the fittest.

In the “Alto Vale do Itajai” and “Planalto Serrano Catarinense” regions of Santa Catarina State, Brazil, we observed that the logical basis for the intervention and management of pests and diseases on crops is the same for the conventional as well as for the majority of organic farmers, mainly if they are dealing with intense crop farming. As a consequence, organic farmers increasingly search for external inputs to solve pest and disease problems, for example, biological control agents, resistance inducers, and a series of intervention measures using homemade preparations, plant extracts, etc. When doing so, farmers give expression to the idea that the nearby nature cannot help them under such agricultural conditions; hence, rescue must come from external sources. In spite of worldwide advocation of integrated pest and disease control - IPM - as an ecologically sound program, most experiences in Brazil failed to replace pesticides, and, in some cases, where an alarm system (forecast) was followed, an increase in the use of pesticides was further stimulated in order to fulfill the objectives of the prevention method itself. The use of external inputs for the solution of most internal problems in production systems diverges from the agroecological principle of promoting resilience by conceiving agriculture as an image of nature; consequently, such an approach fails to take into account that local and internal resources are the best solutions (Soule, 1992). Farmer Field Schools, supported by FAO programs, may be a good example to empower farm knowledge. Moreover, the mere implementation of technological interventions does not necessarily increase yield, as demonstrated by Gonçalves (2001), whose data clearly showed no effect of the intervention measures to control pests and diseases on onion crops in comparison to the non-intervention ones, as long as the system was running under healthy soil conditions. In fact, if one considers health as a matter of nutrition as postulated by Chaboussou (1969) through the Trophobiosis theory, perhaps recovering the ancient Hippocratic idea (300 BC) of "your meal is your medicine", one must ask: why is it that such an idea is not recognized by the whole of the organic movement?

According to our point of view, and from what we could learn with the farmers, the discussion of plant health must start from conceptual principles other than those underlying the parasite/pathogen x host duality. Moreover, in the 60's to the 70's, environmental problems were thought to be threatening all life on earth. Society was concerned with the development of new technologies, regardless of their effective need or not. As a consequence, it was from this standpoint that a new approach of science, which took ecological principles into account, gave ground to supporting the public debate, and the world movement of organic agriculture was launched. However in Latin America, because of the socio-economic and political situation, the public debate on conventional agriculture embraces not only environmental questions but social and political issues as well, making the organic movement a further opportunity to change present socio-economic relations into ones based on principles of cooperation, fair market and farmer sovereignty. One may yet argue that Agroecology, as the science to provide appropriate technologies, takes a rather different role, whether it is required merely for environmental concerns, as in the Northern countries, or has, in addition, a socio-political orientation, as in the Latin-American countries.

B) Ecological emergence for new plant health rationality

Ecological based changes of agricultural systems should start from the assumption of mutual aid and cooperation among all living systems, as a permanent call for the improvement of the production systems (Abdalla, 2002; Kropotkin, 1902). Regulatory mechanisms of pest and disease epidemics should be realized by means of symbiosis, multitrophic interactions, antagonism/ synergism, cooperative attitudes and tolerance as to improve harmony in the living systems, which may yet include crops (Boff et al., 2003). The challenge in designing agroecosystems for sustainable agriculture is to optimize yields, considering the diversity of life, the complexity of the living systems and the social compromise with healthy food. Resilience of agricultural systems should be the target for such designs, for it can grant a dynamic equilibrium, absolving the impacts from biologic disturbances, such as pests and diseases. As such, agroecology entails a plant medicine, which has the perspective of promoting cooperation, niche co-existence, and the transversality of knowledge (Abdalla, 2002). If such requires scientific knowledge not to be found within the boundaries of the disciplines of entomology and phytopathology, than it probably is the opportunity to build a new scientific body for the care of plants in agroecosystems. Would Phytiatry be a suitable plant care science?

Conclusions

Agroecology calls for a new rationality other than that which was built within the scientific disciplines of entomology and phytopathology. This new scientific body for plant health must consider cooperation as a common event among all living systems. Complexity, complementarity and multifuntionality are primordial dimensions to build a science to deal with plant health in harmony with agroecological principals.

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Soil Fumigation with Allium Sulfur Volatiles and Allium By-Products

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Key words: biofumigation, *Allium* spp., by-products

Abstract

Like Brassicaeae spp., Allium spp.have biofumigation properties attributed to sulfur components, mainly three disulfides: dimethyl disulfide (DMDS), dipropyl disulfide (DPDS); and diallyl disulfide (DADS), with an efficacy superior to that of DMDS. In this study, the biofumigant activity of Allium (onion and leek) by-products was investigated in vitro and in vivo. In vitro, the experimental model consisted of a host-pathogen system: cucumber-Pythium ultimum. The results of the bioassay show that cucumber plants in compost inoculated with the pathogen and containing onion or leek by-products show better vegetative growth than the control. In vivo, soil biodisinfection with onion by-products in asparagus leads to a yield intermediate between the untreated soil and the methyl bromide treatment. Another aim of the present study was to get more data about the nematicidal activity of disulfides. The activity of DMDS and DADS was evaluated on two nematode species.

Introduction

The substances implicated in the beneficial effect of *Allium* spp. on human health are mainly sulfur compounds, such as disulfides (DS) and thiosulfinates (Ti) (Agarwal, 1996). These chemicals are also responsible for the natural defences of these species against herbivoro[1]us pests and pathogens. They are insecticidal, fungicidal, acaricidal, nematicidal, and bactericidal (Auger et al, 2004).

When tissue of an *Allium* is crushed or degraded by micro-organisms, an enzyme, alliinase, which is stored in the vacuoles, reacts with S-alk(en)yl-L-cysteine sulfoxides (RCSO) (Lancaster et al, 1988) to give sulfenic acids (Ferary and Auger, 1996). In onions and leeks, several RCSO (R= methyl, propyl, 1-propenyl) are present and a complex rearrangement occurs to give mainly dipropyl disulfide, DPDS (Arnault et al, 2004) as the endproduct of biosynthesis. For some wild *Allium* spp., such as bear's garlic (*A. ursinum*), the major RCSO is methiin (S-methyl-L-cysteine sulfoxide); it gives dimethyl thiosulfinate (DMTi), which gets rearranged into DMDS.

The nematicidal and fungicidal activity of *Allium* has been widely reported (Auger et al, 2004); this great pesticidal potential allows us to envisage the use of *Allium* spp. for soil fumigation (Auger et al., 1994).

In the Val of Loire, asparagus is a traditional crop representing an important economic activity. However, the soils increasingly show the phenomenon of soil stress.

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Therefore, in place of methyl bromide, which now is definitively banned, the maintenance of these cultures requires the use of new fumigants. Among the alternatives, biodesinfection with *Allium* spp. is an interesting method. In this study, we evaluated the fungicidal activity of onion and leek by-products *in vitro,* with an experimental model, and *in vivo,* with field experiments (asparagus). We also studied the nematicidal effect of DMDS on other soil pests, especially two nematodes, *Meloidogyne graminicola* and *Heterodera sacchari*

Materials and methods

Fungicidal test: *Pythium ultimum* type test

The compost used in glass jars was artificially infected with *Pythium ultimum*, with its presence controlled to obtain a high level of infection and a homogenous inoculate.

The by-products were mixed, wetted, and homogenised with the compost and transferred into the jars, just covered by an aluminium sheet that allows gas exchange.

For each test, we used a sterile standard without *P. ultimum* inoculation, and an infected standard inoculated with the fungus. We tested the activity of *Allium* by-products at three different times: 15 days, and one and two months. After these periods, we tested the capacity of the compost to be used for a culture. For this purpose, seeds of cucumber, a plant very sensitive to *P. Ultimum*, were put in contact with the compost. At the end of the growth period (13 days) the healthy, necrotic, and dead plants were counted.

Two disulfides were tested, DMDS and DPDS, with two amounts of by-products in the compost: 120 and 240 tonnes/ hectare (T/Ha).

Nematicide tests

Heterodera sacchari is a cyst nematode common in Africa and some Asian countries. This cyst-forming nematode has sedentary endoparasitic habits (Nobbs et al., 1992). Rice (*Oryza sativa*) and sugarcane (*Saccharum officinarum*) are the major field crops infected by this nematode.

Meloidogyne graminicola (rice-root nematode) is a common species in the tropics and subtropics, where it infects numerous grasses, including rice (Prot et al., 1993).

Because infesting larvae are the most sensitive to biofumigants at day 2 (d2), we calculated the LC50 (lethal concentration for 50% of the population) with DMDS for the two nematodes species at d2.

Field experiment

In 2002, the asparagus parcel was prepared and disinfected with *Allium* by-products and methyl bromide, which constitutes the reference. An undisinfected parcel was also used. An elementary parcel was composed of three ranks of asparagus (128 plants, 144 m²). The control was the central rank. The biodisinfection effect was evaluated by incorporation of onion and leek by-products (75 T/ha).

Asparagus was planted in the parcel in April 2003; we measured productivity at the harvests in April 2004 and 2005.

Results

Fungicidal tests

Compared to the infected standard, where the plants show necrosis, not only was the sample with DMDS treatment healthy, but moreover a stimulant effect could be observed. Furthermore, DMDS was more toxic than DPDS.

Figure 1 shows the results for 240 T/ha of *Allium* by-products in the soil. With onions we can observe a Concentration-Time (CT) effect that is characteristic: 74% at 15 days and 94% at 1 month. Leek by-products were less efficient than the onion treatment. The optimum disinfectant effect is reached sooner for the 240 T/ha dose (1 month) than with 120 T/ha (2 months).

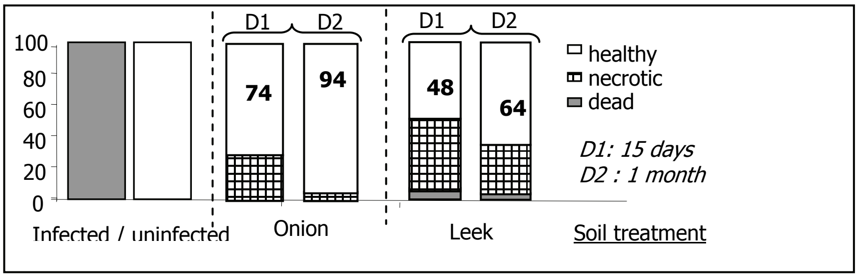

Figure 1: Percentage of healthy, necrotic and dead cucumbers after *Allium* by-products were incorporated in the soil (240 T/ha).

Nematicide tests

The LC50 of d2 larvae *(H. sacchari*) is 0.79 µl/l. *M. graminicola*, for which LC50 = 1.6 µl/l, seems to be more sensitive to DMDS than *H. sacchari*.

Field experiments

Two years after planting, the parcels disinfected with *Allium* by-products had lower productivity than the ones disinfected with methyl bromide. But the incorporation of onions leads to an intermediate yield between the methyl bromide reference and the undisinfected parcel (Figure 2).

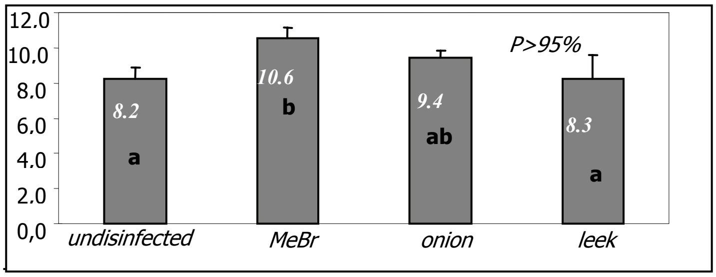

Figure 3: Yield (T/ha) of asparagus under four different disinfection conditions: undisinfected, MeBr, onion, and leek.

Conclusion

This study shows *in vitro* and *in vivo,* with field experiments, the disinfection effect of *Allium* spp., particularly onion by-products. The result can be explained by the kind of by-product used. For onions, the by-products are unmarketable onions bulbs, while for leeks they are the wastes from peeling, i.e. the green leaves, which are well known to contain less sulfur compounds, in accordance with their lower dry matter content. DPDS, the gas produced by onion and leek by-products in soil, persists for more than one month (Arnault et al., 2004). The results point to the ability of *Allium* by-products to disinfect a soil. The doses, contact time, and characteristics of the by-products are very important.

Discussion

Allium spp. offer good potential for soil disinfection, but the practice in the field must be improved. For this purpose, the choice of *Allium* spp. can be modified. As DMDS is much more effective as a disinfectant and pesticide than DPDS, *Allium* spp. with high potential levels of DMDS could be tested, so that the doses incorporated in the field could be reduced. Some wild *Allium* species contain more DMDS than marketable *Allium*. For example, *A. vineale (*wild garlic*) and A. ursinum (*bear's garlic), contain more than 50% of methiin, the DMDS precursor (Keusgen et al, 2002).

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Pest and Disease Management of Potato Crops with Homeopathic Preparations and Germplasm Variability *

Boff, P.[1], Madruga, E.[1], Zanelato, M.[2,3] & Boff, M.I.C.[2]

Keywords: plant homeopathy, genetic resistance, potato

Abstract

The Plateau of Santa Catarina state, Brazil, is the main potato seed producer of the country. Its regional climate, however, with wet summers has been pointed out as the main factor for restricting productive quality and raising prices. This research had, thus, the objective of studying the efficacy of homeopathic preparations, homemade formulations and genetic variability in the management of pests and diseases at field conditions on organic farming systems of potato crops. Two field experiments were installed during the 2006/07 crop season. In experiment 1, the following genotypes were planted as treatments: Catucha and Epagri (landrace), Monalisa and Agata (Holland), and Panda (Germany). In experiment 2, the statistical design was a split plot with the Monalisa, Catucha and Epagri genotypes as sub plots, and nine spray preparations as the main plot as follows: Chamomilla 60CH, Silicea 60CH, Kali 60CH, Thuya 60CH, biotherapic of Phytophthora infestans 60CH, water 60CH, the homemade preparations of Bordeaux mixture at 0,3% and of propolis extract at 0,5%, and, finally, a no-intervention treatment. Results showed that the Catucha genotype, a bred landrace, yielded 21 t ha^{-1} and presented the lowest disease incidence. Even though no preparation differed significantly from another; the Thuya homeopathic treatment yielded the best results with more than 26 t ha^{-1}. Natural enemies were not affected by any of the spray preparations.

Introduction

The state of Santa Catarina, in the South of Brazil, is a main producer of potato seed tubers (*Solanum tuberosum*) (Souza, 2005). The crop is typically grown in family farms with a high labor input. Climatic conditions allow breeding in almost every season of the year, but commercial varieties show high susceptibility to pests and diseases (Souza & Silva, 2007). As a consequence, farmers use a lot of pesticides to fill commercial requirements of consumers and industries alike (Bull and Hathaway, 1986). On the other hand, such use raises public concerns, either due to chemical residues in food or in the public water supply, as crops are located within the micro catchment area. Hence, farmers are changing and adopting more ecologically integrated or purely organic production systems (Boff et al, 2004). And as the latter

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grow, so does the demand for potato tuber seeds from organic production systems as well. All the same, during transition from one system to another, an alternative technology, completely replacing agrochemicals, is required. Accordingly, this research was carried out to evaluate the efficacy of homeopathic preparations and the use of landrace bred clones for managing pests and diseases on potato crops.

Materials and methods

Two field experiments were carried out at the Lages Experimental Station of EPAGRI–Agricultural Research Institute of Santa Catarina, Brazil, in an organically managed area during the last two years.

Experiment 1 was planted on October 19, 2006, and Experiment 2 was planted on October 26, 2006. In experiment 1, the statistical design was of randomized blocks with four replicates. Treatments were represented by the Catucha and Epagri (landrace varieties), the Monalisa and Agata (Holland) and the Panda (Germany) germplasms. All plots were sprayed equally with the homeopathic preparation *Silicea 60CH*.

In experiment 2, the statistical design was a split plot with randomized blocks and four replicates. In the subplot, the germoplasms of Catucha and Epagri (landrace germoplasm), and of Monalisa (Holland) were planted. In the main plot, plants were treated with the following homeopathic preparations: *Chamomilla* 60CH, *Silicea* 60CH, *Kali* 60CH, *Thuya* 60CH, biotherapic of *Phytophthora infestans* 60CH, water 60CH, and a homemade preparation of Bordeaux mixture at 0,3% and propolis extract at 0,5%. The control treatment consisted of non-sprayed plots.

Homeopathic remedies were prepared according to the Hahnemann method as described in the Brazilian Homeopathic Pharmacopoeia (1997). The dosage used for the homeopathic preparations was 12 ml per liter. Preparations were applied in two-week intervals, 15 days after emergence until flowering.

Evaluations of disease intensity, pest incidence and yield at harvest were made. Diseases were estimated according to the intensity of the foliar symptom (1=absent to 6=more than 50%). Insects were directly counted and expressed in numbers per plant.

Results

A) Experiment one - Potato genotypes

The highest yield was obtained with the Catucha landrace potatoes, in contrast to Agata (Holland), which granted the lowest yield (Tab. 1).

The Epagri landrace germplasm was as good as Monalisa but worse than Catucha.

Agata was the most susceptible to *Phytophthora infestans* and to *Alternaria solani*. Monalisa presented the high number or *Diabrotica pest.*

Tab. 1: Yield, disease and pest intensity of potato varieties grown under organic systems, 2006/07, Brazil. Data from four replicates.

		Intensity (1 to 6)		Number per plant	
Cultivar	T ha^{-1}	Alternaria solani	Phytophthora infestans	Diabrotica speciosa	Natural enemies
Catucha (Brazil)	21.36 a	1.4 c	1.7 b	9,5 ab	3,5 nd
Monalisa (Holland)	12.22 ab	1.7 bc	4.1 a	14 a	5,0
Epagri (Brazil)	14.25 ab	1.3 c	1.1 b	7,5 b	3,0
Panda (Germany)	11.68 ab	2.2 b	1.3 b	8,3 b	4,3
Agata (Holland)	3.30 b	5.3 a	5.2 a	9,8 ab	2,0
C.V.(%)	54	12	20	25	37

* Different letter in the columns indicate statistically significant differences for P<0.05;

nd=not significantly different

B) Experiment two - Homeopathic preparations

Cultivars and homeopathic preparations were not statistically correlated concerning yield, pest and disease. Although treatments did not statistically differ from one another, the homeopathic preparation *Thuya* 60CH rendered the highest yield (Tab. 2). Preparations did not affect natural enemies.

Tab. 2: Yield, disease and pest intensity of potatoes treated with homeopathic preparations, 2006/07, Brazil. Data from five replicates.

		Intensity (1 to 6)*		Number per plant*	
Preparation	T ha^{-1} *	Phytophthora infestans	Alternaria solani	Diabrotica speciosa	Natural enemies
Bordeaux mixture	23.25	1.6	0.7	0.7	0.3
Bee propolis	23.78	1.9	0.5	0.5	0.5
No Intervention	21.32	2.1	0.4	0.4	0.2
Chamomilla 60CH	22.39	2.0	0.9	0.9	0.3
Silicea 60CH	23.68	2.3	0.4	0.4	0.2
Kali 60CH	26.24	1.9	0.4	0.4	0.5
Thuya 60CH	26.63	1.9	0.8	0.8	0.9
P.infestans 60CH	25.27	2.2	0.4	0.4	0.5
Water 60CH	26.26	1.8	0.6	0.6	0.4
MSD					

* Not statically significant different for P<0.05;

Discussion and Conclusions

Cultivars seem to play a more significant role than spray interventions for managing pests and diseases on organic potato crop systems. Homeopathic preparations are as good as the Bordeaux mixture, a standard spray generally used on organic farm systems.

Landrace bred cultivars are more resistant to pests and diseases and also grant higher yields than introduced ones. The “Catucha” genotype presented the best performance. Despite no significant differences among themselves, homeopathic preparations improved yield in comparison to the untreated plots.

It can be argued that the homeopathic cure for plant diseases is a holistic and complex system that interacts with other agroecological factors, such as soil and climate (Toledo et al., 2003). Even though its impact is statistically insignificant, a homeopathic treatment is as sufficient for an organic system as the standard Bordeaux mixture, without any residual effect as well (Bonato, 2006).

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Cropping techniques wheat

Improvement of winter wheat baking quality in ecological cultivation by enlargement of row spacing and undersown intercrops

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Key words: organic farming, winter wheat, row spacing, baking quality, undersown intercrops

Abstract

Under ecological crop growing conditions, considerable problems consistently arise in fulfilling the baking quality of winter wheat demanded by consumers. The "wide row" procedure shows promising potential for effectively using the nutrient supply in ecological cultivation for the production of winter wheat with high baking performance. Increasing the distance between rows of winter wheat from 12.5 cm to 50 cm proved advantageous for the indirect quality parameters sedimentation value and gluten and crude protein concentration. Either no yield decreases or low decreases only up to 10% were noted. Because of an increased tendency to erode and in order to improve of the preceding crop's value, creation of a green zone with legumes between the rows is necessary. To prevent competition between cover and catch crops, mulching of catch crops is required.

Introduction

In ecologically cultivated fields, winter wheat is typically planted with narrow row spacing. However, because of the limited nitrogen supply, the resulting baking qualities do not meet consumers' and processors' demands. This problem comes to a head in stockless ecofarming because of the additional deficiency of forage legumes as a good previous crop, as well as the non-availability of nitrogenous fertilizer from livestock. Both practical experience and initial scientific insights have shown that this problem can be counteracted by increasing the row spacing (GERMEIER 2000).

Materials and methods

During the crop growing periods 1999/2000 and 2000/2001, exact field tests were conducted at four ecologically farmed locations in three different German federal states (fully randomized block design with four replicates). In two control variants, the wheat was planted in rows respectively spaced 12.5 cm (normal procedure) and 50 cm apart. Both variants were kept free of weeds mechanically.

Each of the effects of the wide row system without undersown crops was compared with the normal planting procedure. Of significant interest, however, were analyses regarding the impact of clover catch crops cultivated within the 50-cm rows, sown on three different dates (autumn, early spring, late spring). In addition, the effect of catch crop regulation in spring with the help of a specially developed row-mulching machine

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was investigated. Besides the effects on the yield and quality of winter wheat, environmental effects and the cost-effectiveness of the method also were examined.

Results

Yields of winter wheat were not significantly influenced by the variants of the wide row cultivation system analyzed during the 2000 crop year (Table 1). More advantageous conditions for winter wheat cultivation predominated in 2001. Under conditions of wide row cultivation, the harvest in 2001 was insignificantly diminished (by up to 11%) compared with the normal cultivation method. Autumn catch crops in the wide-row system (mulched and non-mulched) caused significantly lower winter wheat yields compared with the normal cultivation method (a strong competition between cover and catch crops could be the reason). Compared with the variant with 12.5-cm between the rows, the mulched spring catch crops of 2001 had the smallest yield losses, which were statistically significant.

Tab. 1: Grain harvest of winter wheat (Bussard type) in conjunction with row width, catch crop and mulching during the analyzed years 2000 and 2001 (results averaged from the four examined locations, n=128)

Variants**		2000 dt/ha		2001 dt/ha	
Control groups	12,5 cm	33.7	a*	46,7	A
	50 cm	35.7	a	41.5	Ab
Row width 50 cm without mulching	US I	34.7	a	37.5	B
	US II	35.2	a	42.3	Ab
	US III	35.8	a	41.3	Ab
Row width 50 cm with mulching	US I	33.3	a	37.5	B
	US II	33.1	a	43.1	Ab
	US III	34.8	a	44.6	Ab
	$\bar{x}$	34.5		41.8	

* Different letters label significant differences, Tukey test □ 0,05

** Variants:
12.5 cm common row spacing
50.0 cm wide row spacing
US I sowing of catch crops in autumn
US II sowing of catch crops in early spring
US III sowing of catch crops in late spring

Row spacing, catch crops, and mulching technique had clear effects on the baking quality of Bussard winter wheat (Table 2). Merely increasing the row spacing from 12.5 cm to 50 cm resulted in a significant increase of sedimentation value, as well as a tendency towards an increase in gluten and crude protein concentrations.

To guarantee the sustainability of production, recommendations for the implementation of the wide row system must also include consideration of environmental effects. For example, soil in the examined variants showed a variably strong disposition to erosion (Table 3). Simply increasing the row spacing from 12.5 cm to 50 cm significantly increased erosion by ca. 30%. By sowing catch crops in early spring, this negative effect was offset for the most part. Autumn catch crops had the strongest erosion-reducing effect. However, because of the observed decrease in yields in 2001 and the insignificant quality effects in comparison to the control variant with 12.5-cm row spacing, this variant probably cannot be considered for dependable production of baking wheat in ecological cultivation.

Tab. 2: Baking quality parameters of winter wheat (Bussard type) in relation to row width, catch crop, and mulching in 2000 and 2001 (results averaged from the four examined locations, n=256)

Variants**		Crude protein concentration (%) (N x 5,7)		Gluten concentration (%)		Sedimentation value (ml)	
Control groups	12,5 cm	10.6	a*	25.0	a	32.2	a
	50 cm	11.3	ab	27.2	ab	38.0	b
Row width 50 cm without mulching	US I	11.1	ab	26.8	ab	35.7	ab
	US II	11.1	ab	26.7	ab	36.4	ab
	US III	11.3	ab	27.0	ab	37.8	ab
Row width 50 cm with mulching	US I	11.1	ab	25.8	ab	35.4	ab
	US II	11.3	ab	27.8	b	38.4	b
	US III	11.5	b	27.9	b	38.5	b
	$\overline{x}$	11.2		26.7		36.6	

Footnote: see fig. 1

Tab. 3: Erosion (t/ha) in relation to row width and catch crops under laboratory conditions (measured in overgrown soil before sprouting, samples taken from the Wetterau location, vegetation year 2001)

Variants**		Light rain 10 min		Light rain 10 min		Heavy rain 2 min		Heavy rain 2 min		Total	
Control groups	12.5 cm	2.1	a *	1.7	a	6.8	a	9.3	a	20	a
	50 cm	1.2	B	1.9	a	12	b	11	b	26	b
Row width 50 cm with mulching	US I	0.0	C	0.6	c	0.8	c	1.7	c	3.1	c
	US II	1.6	B	2.3	b	9.0	ab	9.0	ab	22	a b
$\overline{x}$		1.2		1.6		7.2		7.7		18	

Footnote: see fig. 1

Discussion

Compared with the control variant with rows spaced at 12.5 cm, the quantity of catch crops produced in the 50-cm spaced rows did not result in a significant increase in quality, as long as these catch crops were not mulched. In comparison with the control variant with rows spaced at 50-cm, the non-mulched catch crops again showed a tendency towards lower indirect quality parameters. This relates to the existence of a competitive correlation between grain cover crops and undersown clover crops at the expense of baking quality. Mulching the catch crops sown in spring apparently eliminated this competition, which, with one exception, was evident in the significantly higher quality parameters than in the control variant with 12.5-cm row spacing.

Conclusions

A detailed description and commentary on the field experimental analyses can be found in BECKER and LEITHOLD (2003) and BECKER (2007). Increasing the distance between rows of winter wheat from 12.5 cm to 50 cm proved advantageous for the indirect quality parameters sedimentation value and gluten and crude protein concentration. Either no yield decreases or low decreases of up to 10% were noted. As a whole, the investigations led to the conclusion that by growing winter wheat in rows 50 cm apart instead of 12.5 cm, a level of quality can be attained in ecological cultivation that meets the demands of high baking quality. The use of E-wheat types remains a prerequisite for meeting this objective, as well as good nitrogen supply from the previous crop. Because of an increased tendency to erode and in order to improve the preceding crop's value, creation of a green zone with legumes between the rows is necessary. To prevent competitive relationships between cover and catch crops, mulching is required. If no mulching is done, this will lead to losses in quality. The following combination was best able to meet the demands of crop yields, quality, environmental benefit, and preceding crop's value: 50-cm row spacing, undersowing early enough in spring after raking and/or hoeing, and mulching of the catch crop. The specially developed and tested mulch machines can be considered well tried and proven. Reducing the sowing density by up to 50% compared with normal cultivation was not disadvantageous for the crop or quality. The microeconomic analyses have shown that, provided price premiums are given for quality wheat, the winter wheat's contribution to overall profit increased by cultivating it with the wide-row system (NIEBERG et al. 2003). With shared use of the expensive row mulching machine by cooperating farms, the cost effectiveness of the procedure is increased further. Implementation of the cultivation procedure is particularly advantageous when it results in positive effects on the other production methods used (by the effects of undersown intercrops) and adoption is possible for the overall enterprise.

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Agronomic and environmental factors explaining Grain Protein Content variability in organic winter wheat

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Key words: organic winter wheat, Grain Protein Content, limiting factors, diagnosis

Abstract

A regional agronomic diagnosis was implemented to identify factors responsible for low values of Grain Protein Content (GPC) in a network of 35 organic winter wheat fields in South-Eastern France. The influence of water nutrition, radiation and temperature, weed density at flowering, nitrogen (N) status of crop at flowering and variety type were studied. Two statistical methods were used successively: classical linear regression and a mixing model approach based on a weighted sum of all possible linear combinations of explanatory variables. GPC was significantly related to variety type, crop N status and weed density. An analysis of variance showed that weed density was related to soil type and nitrogen supply.

Introduction

French organic wheat production is characterized by low and variable Grain Protein Content (GPC). For instance, in South-Eastern France, the GPC ranged from 7.6 to 16.2% grain dry matter (DM). Moreover, 39% of the fields presented a GPC under the threshold for breadmaking (10.5% grain DM) (David et al., 2007). This results in a decline in prices as well as disqualification or discounting of grain batches when GPC does not reach this threshold. Taylor et al. (2001) and David et al. (2005) have shown that low and variable organic wheat yields are explained by several limiting factors: nitrogen (N) deficiency, water shortage, weeds, pest and disease pressure or compacted soil structure. The purpose of this study was (i) to assess whether these limiting factors can explain GPC variability across site-years, using two statistical methods and (ii) to determine the characteristics of the cropping systems in which limiting factors arise.

Materials and methods

We studied a field network within the Rhône-Alpes region (South-Eastern France), the French region with the highest amount of organic cereal collected. A two-step regional agronomic diagnosis method was implemented (Doré et al., 1997) to identify: (i) the agronomic and environmental factors for GPC variability and then (ii) the characteristics of cropping systems associated with these limiting factors.

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Field network

A network of 35 fields belonging to 23 farmers and involving 9 varieties was studied over 6 years (between 1993 and 2006). Fields displayed a wide range of environmental conditions (soil type, temperature, radiation, and water availability) and cropping systems (crop rotation and fertilization management). Crop management varied according to variety type (VT), classified according to baking quality grade: superior (BPS) or improved (BAF), previous crop (PC: cereals, oilseed, legumes or other crops), sowing date (SD: before or after the 10^{th} of November), nitrogen supply (NS: amount of N applied in kg ha^{-1}) and weed control (WC: number of weeding operations).

Measurements and analytical procedures

The soil texture (ST: determined by granulometric analysis) and organic matter content (OM) were determined by sampling 10 soil cores to a depth of 30 cm. Daily weather data (mean temperature, rainfall, radiation and evapotranspiration) were recorded nearby each field. At maturity, GPC was determined from four samples per field (0.25 m² each). Four indicators of limiting factors were measured. Water shortage from flowering to maturity (WS) was estimated from a dynamic water balance to evaluate the incidence of water availability on nitrogen and biomass accumulation in the grains (Gate, 1995). Photothermal quotient (PQ) (ratio of mean daily solar radiation by mean temperature) was calculated for the 30-day period prior to flowering knowing its effect on kernel number (Fischer, 1985). Weed density at flowering (WD) was also considered, knowing its negative effect on grain yield (Cousens, 1985; David et al., 2005). Finally, the nitrogen nutrition index, which is the ratio between the actual aerial and the critical N content (Justes et al.,1997), was calculated at flowering (NNI), knowing its effect on GPC (Justes et al., 1997) and grain yield.

Statistical analysis

Statistical analyses were performed using the statistical program R (version 2.5.1, 2007) (Ihaka and Gentlemen, 1996). First, K being the number of explanatory variables (here, VT, NNI, WD, WS and PQ), 2^K possible models, relating GPC to these variables, were fitted to the data by classical linear regressions. Then, the 32 fitted models were weighted by AIC (Akaike's criteria) and summed, leading to a new model mixing all the possible linear models according to their quality of fit (Burnham and Anderson, 2002). Finally, an analysis of variance was performed to identify the crop management techniques and the environmental conditions associated with the limiting factors selected in the linear models.

Results

GPC ranged between 7.8 and 13.9% grain DM within the given field network and the limiting factors indicators displayed contrasted values (Table 1). The values of the different indicators were not significantly correlated (results not shown).

Tab. 1: Ranges of GPC and explicative variables within the field network.

	GPC (% DM)	Variety type [VT]	Crop nitrogen status [NNI]	Weed density [WD] (plants m^{-2})	Water shortage [WS] (mm)	Photothermal quotient [PQ] ($kJ°C^{-1}$)
Min Value	7.8	BAF or BPS	0.27	0	193	0.6
Max Value	13.9		0.71	567	0	1.6

Identification of limiting factors

A linear regression with all the indicators was fitted (Table 2) (R^2=0.68 and RMSE=0.851). Variety type had a very significant effect on GPC: BPS wheat types had lower GPC than BAF wheat types. Significant effects were also found for the crop N status and weed density (Table 2), but not for photothermal quotient and water shortage.

Tab. 2: Results of the linear regression explaining GPC with all 5 explicative indicators.

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	7.919	1.177	6.727	2.21e-07
VT (BPS)	-2.099	0.346	-6.067	1.33e-06
NNI	4.711	1.484	3.175	0.00354
WD	0.006	0.002	3.055	0.00480
PQ	0.667	0.629	1.065	0.29571
WS	0.002	0.003	0.676	0.50432

The 32 tested models were ranked according to their AIC values. The five best ones (with the lowest AIC) were found to involve VT, NNI and WD systematically (Table 3) while PQ and WS were involved in two of these models (Table 3).

Tab. 3: AIC, R² adjusted, R² and RMSE (Root Mean Square Error) of the 5 best models

Tested model	AIC	Weight	R²	RMSE
$GPC = a_0 + a_1VT + a_2NNI + a_3WD$	99.9	0.388	0.66	0.874
$GPC = a_0 + a_1VT + a_2NNI + a_3WD + a_4PQ$	100.6	0.268	0.67	0.858
$GPC = a_0 + a_1VT + a_2NNI + a_3WD + a_4WS$	101.4	0.180	0.66	0.868
$GPC = a_0 + a_1VT + a_2NNI + a_3WD + a_4PQ + a_5WS$	102.1	0.130	0.68	0.851
$GPC = a_0 + a_1VT + a_2WD$	107.4	0.009	0.55	1.001

Mixing model

The mixing model provided a good quality of fit (R^2=0.67 and RMSE=0.860). Its equation is: GPC=8.62-2.10*VT-0.0005*WS+0.005*WD+4.49*NNI+0.27*PQ. The probability that the explanatory variables have an effect on GPC is, for a given variable, equal to the sum of the weights of the models, among the 32 fitted models, including the variable of interest. These probabilities are equal to 1.00, 0.978, and 0.984 for VT, NNI and WD respectively. They are much lower for WS and PQ, 0.320 and 0.413, respectively, but are not negligible. Thus, an effect of WS and PQ on GPC cannot be excluded, though the tests were not significant for these two variables.

Effects of crop management on limiting factors

David et al. (2005) have evidenced significant correlation between NNI and preceding crop. Consequently, the incidence of PC, NS and OM in soil on NNI at flowering was tested. The analysis of variance of our data showed no significant effect of these variables. Effects on weed density at flowering of PC, NS, WC, SD and ST were tested. Analysis of variance showed effect of NS (at 10%) and ST (at 1%) on WD.

Discussion

Variety type, which is a crop descriptor, had a strong effect on GPC. Negative effect of BPS could be explained by the fact that BAF varieties were bred in order to increase GPC. Nitrogen nutrition index at flowering and weed density at flowering had a positive effect on GPC. Positive effect of NNI at flowering on GPC is in accordance with the findings of Justes et al. (1997). David et al. (2005) showed that weed density had a negative effect on kernel number. Moreover, a decrease in kernel number generally leads to nitrogen concentration in grains, thereby increasing GPC. Positive effect of weed density on GPC in our case is thus in line with those previous results. The results obtained by the mixing model approach confirmed the strong effects of NNI and VT and led to a slightly better quality of fit (RMSE=0.860) compared to linear regression (RMSE=0.851). The interest of this approach is that all the explanatory variables are included in the final model. Low parameter estimates were given to the variables which did not have a strong effect on GPC (i.e. WS and PQ). In the near future, we will evaluate the ability of this approach to accurately predict GPC values. No effect of crop management on NNI at flowering was found. It could be explained by variable nitrogen efficiency: N supply (total amount of N applied by the farmers) did not completely match available N for the crop. Effect of ST on WD is consistent with previous results (David et al., 2005). Positive effect of NS on WD could be explained by an improved nitrogen uptake by weeds when nitrogen supply is higher.

Conclusions

This regional agronomic diagnosis clearly demonstrated the effect of variety type, nitrogen nutrition index, and weed density at flowering on GPC and it confirmed the benefits of using mixing model methods in agronomy. The identification of the characteristics of the cropping system that most influence GPC will help people involved in drafting technical adaptations to increase and stabilize GPC in organic winter wheat.

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Organic winter wheat: optimising planting

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Key words: wheat, agronomy, interactions, composite cross populations

Abstract

Data from the second year of experiments at three sites (Wakelyns in SE and Sheepdrove in SW England; and Chapel Farm in SE Scotland) to investigate the effects of interactions among a range of agronomic practices (row spacing, seed density, weeding and undersowing with clover) on winter wheat performance are presented, and compared with first year results. Trends seen at all years and sites indicate that narrow row drill arrangements with high seed rates result in the highest yields. This combination also performed well for emergence and establishment. The effect of drill arrangement was significant (P<0.05) at two of the three experimental sites with establishment of 282 and 232 plants m-2 at Sheepdrove and Chapel farm respectively. There were significant interactions between row spacing and seed density at all three sites. A new composite cross population integrated into the experiment has performed well for a number of traits including canopy cover and grain yield.

Introduction

Organic farming has been, and should be, regarded as a form of ecological farming (Weiner, 2003), making optimal use of interactions among plants, soil and other factors. However, previous work in this area has often taken a reductionist approach to farming systems, focusing on the importance of single factors (Gooding *et al*., 2002). It is essential, however, that as many relevant factors of the system as practicable are analysed together, in order to understand a range of potentially complex interactions (Gooding and Davies, 1997). The main objective of this study was to undertake a multifactorial analysis of different wheat genotypes, with or without clover bi-cropping, planted at different seed rates in a range of different spatial patterns under contrasting site conditions.

Materials and methods

The second year of trials took place at three sites (Wakelyns Agroforestry, Suffolk, Sheepdrove Organic Farm, Berkshire and Chapel Farm in East Lothian in 2006/07). Each site contained a randomised, replicated split-plot design integrating three winter wheat genotypes: Hereward (a benchmark Nabim Group 1 variety), Aristos (bred for

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low input systems) and a 'Yield-Quality Composite Cross Population' ('YQ CCP', output from The Organic Research Centre's Wheat Breeding trial (Wolfe *et al.*, this conference); two seed rates (low, and high, 150 kg ha^{-1} and 250 kg ha^{-1}); three spatial arrangements (wide row (20 cm), narrow row (10 cm) and strips (a seeded band 20 cm wide with 30 cm centres, at Wakelyns and Sheepdrove only); with or without white clover mixture (undersown at 7 kg ha^{-1}) and with or without weeding (tine harrow on half of the wide row plots, at Wakelyns and Chapel only). Standard agronomic assessments on crop, weed and clover growth were taken throughout the growing season and post harvest. Analysis of variance was used to evaluate the main component effects and interactions. Variables in the second year of the experiment were amended from the first year in consultation with farmers, advisers and the project consortium. Additional factors in the second year: Chapel as an extra site; YQ CCP as an extra genotype and weeding.

Results

This paper discusses a selection of results from the second year (2006/07) of experiments. They are compared with results of the first year of experiments, details of which can be found in Haigh *et al.* (2006).

Drill arrangement and seed rates

The combination of narrow rows and high seed rates tended to produce the highest yields in both years. Narrow rows produced the highest yields at all sites in both years, at SAC in 2006/07 this was significant (P= 0.022; Figure 1); in the previous year this was significant at both sites (Wakelyns and Sheepdrove, P<0.001). Highest yields were attained using high seed rates in 2006/07 at Wakelyns and Sheepdrove, at Sheepdrove this trend was significant (P= 0.015; Figure 1). In the previous year this trend had occurred at both sites, and was significant at Sheepdrove (P<0.001).

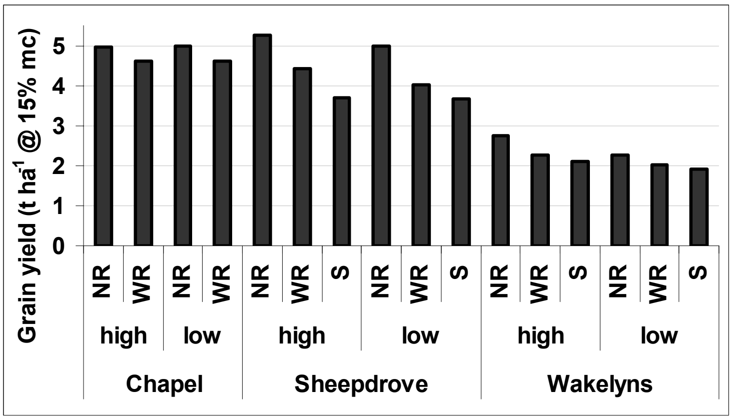

Figure 1: Mean grain yield (t ha^{-1} @ 15 % moisture content) at each site (Chapel, Sheepdrove and Wakelyns) for high and low seed rates (150 kg ha^{-1} and 250 kg ha^{-1}) under narrow (NR), wide (WR) or strip drill arrangements (S) in 2006/07. At Chapel NR yielded significantly more than WR (P= 0.022, l.s.d.= 0.1911); at

Sheepdrove high seed rates produced significantly higher yields than low seed rates (P= 0.015, l.s.d.= 0.2253).

The highest emergence was under high seed rates: Wakelyns= 298 versus 226 plants m-1; Sheepdrove= 310 versus 200 plants m-1 (P<0.001 at both sites), and tended to be in the rank narrow rows > wide rows > strips. Establishment was highest with narrow rows and high seed rates at all sites. The effect of drill arrangement was significant at both Sheepdrove (NR= 282 plants m-1, S= 192 plants m-1, WR= 249 plants m-1, P= 0.025, l.s.d.= 55) and Chapel (NR= 232 plants m-1, WR= 177 plants m-1, P= 0.041, l.s.d.= 50). The interaction between drill arrangement and seed rate was also significant at Chapel where narrow rows and high seed rates produced higher establishment (261 plants m-1) than wide rows and low seed rates (168 plants m-1, l.s.d. = 37, P= 0.038). These results were similar to the previous season where narrow rows also performed well for emergence and establishment. Narrow rows also performed well for canopy cover; they tended to have the highest leaf area index. At Sheepdrove this was significant throughout the season (early: NR= 1.66, WR= 1.55, S= 1.02, l.s.d.= 0.2303, P= 0.003; mid: NR= 2.58, WR= 2.45, S= 2.11, l.s.d.= 0.3332, P= 0.04; and late: NR= 2.80, WR= 2.42, S= 2.25, l.s.d.= 0.3611, P= 0.031). Although weed pressure differed at each site, again narrow rows and high seed rate plots tended to have the lowest weed cover. This trend was seen across sites; it was significant at Wakelyns where narrow rows had fewer weeds than other drill arrangements, early in the season (NR= -10.79 %, WR= 0.16 %, S= 0.61 % weed cover relative to un-cropped ground), l.s.d.= 5.162, P= 0.006).

Varieties

In the 2006/07 season the YQ CCP yield was significantly greater than either Hereward or Aristos at Wakelyns (YQ CCP= 2.60 t ha^{-1}; Aristos= 2.25 t ha^{-1}; Hereward= 2.16 t ha^{-1}, l.s.d.= 0.3027, P= 0.013). Although the YQ CCP was not present in this experiment in the previous season, this result is consistent with another variety trial at Wakelyns, where the YQ CCP yielded 104 % of Hereward. In the previous season Aristos was the highest yielding variety at Wakelyns (Aristos= 7.27 t ha^{-1}, Hereward= 6.83 t ha^{-1}, l.s.d.= 0.2513, P<0.001). At Chapel, varieties yielded significantly differently in the rank Hereward (5.34 t ha^{-1}) > Aristos (4.92 t ha^{-1}) > YQ CCP (4.23 t ha^{-1}, l.s.d.= 0.2684, P<0.001). The YQ CCP performed well for other aspects; it tended to have the highest canopy cover over the season at all sites. (often significant). At Sheepdrove, the YQ CCP had significantly higher early (P<0.001), mid (P= 0.021 and late (P= 0.024) canopy cover than other genotypes (Table 1).

Tab. 1: Mean canopy cover (leaf area index) for the three genotypes at three sites on three assessment occasions, 2006/07.

		Mean leaf area index			
	Site	**YQ**	**Ar**	**He**	**l.s.d.**
Early canopy cover	**Sheepdrove**	1.59	1.27	1.37	0.145
	Chapel	2.23	2.08	1.87	0.251
	Wakelyns	1.41	1.18	1.28	0.168
Mid canopy cover	**Sheepdrove**	2.57	2.34	2.23	0.244
	Chapel	2.73	2.56	2.25	0.311
	Wakelyns	2.45	2.18	2.35	0.240
Late	**Sheepdrove**	2.65	2.42	2.39	0.206

canopy	**Chapel**	3.12	2.86	2.67	0.286
cover	**Wakelyns**	3.30	3.31	3.42	0.247

At Chapel the YQ CCP had higher early canopy cover than Aristos (P= 0.02), for mid canopy cover both YQ CCP and Aristos were higher than Hereward (P= 0.01) and late in the season, YQ CCP had significantly higher late canopy cover than Hereward at Chapel (P= 0.01). YQ CCP canopy cover was higher at Wakelyns only at the early assessment (P= 0.029; Table 1). The YQ CCP also performed well for weed suppression; varieties with least weed cover tended to be in the rank YQ CCP > Aristos > Hereward. Although this was not always significant, YQ CCP did have significantly fewer weeds early in the season at Chapel than other varieties (YQ CCP= -1.49 %, Aristos= -1.21 %, Hereward= -1.06 % weed cover relative to un-cropped ground, l.s.d.= 0.339, P= 0.041); and Hereward had significantly more weeds than other varieties later in the season (YQ CCP= -14.64 %, Aristos= -14.06 %, Hereward= -13.37 %, weed cover relative to un-cropped ground, l.s.d.= 0.882, P= 0.038).

Discussion

The beneficial effects of narrow rows and high seed rates were seen from the beginning of the year, in both crop emergence and establishment. This combination of factors also tended to produce high canopy cover and fewer weeds, and ultimately led to the highest yields. In order to maximise yields, a high number of plants is required, hence high seed rates produce highest yields. However, in order for each plant to perform to its best it also needs to experience as little competition (for light, water, and nutrients) from other crop plants as possible, therefore even plant spacing (best achieved in narrow rows) is essential to realising high yields. The drill arrangement with the optimum plant spacing (fewest numbers of neighbouring plants) was narrow rows, followed by strips and then wide rows.

Although the YQ CCP yielded relatively poorly at Chapel this year, it can potentially adapt to local conditions so that re-sown seed from this site should perform better in next year's experiment.

Conclusions

Narrow rows and high seed rates tended to produce the highest yields. The YQ CCP is performing well and may adapt further to the sites where it is grown.

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Improving nutrient uptake in wheat through cultivar specific interaction with *Azospirillum*

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Key words: nitrogen, plant breeding, organic farming, diazotrophs

Abstract

Obtaining sufficient plant available nitrogen in organic dryland wheat cropping systems is difficult. This study was conducted to determine whether inoculation with Azospirillum could improve nitrogen uptake and increase crop yield, and whether there are differences among wheat cultivars in the ability to benefit from inoculation of these diazotrophic bacteria. Seed from twenty historic and modern wheat cultivars were either left untreated, or treated with a commercial inoculant of Azospirillum, and planted at two locations under certified organic management. In one location with lower fertility, inoculation significantly increased yield and protein, and clear differences existed among individual cultivars in response to the inoculant. In another location with higher fertility, none of the cultivars responded as favorably to the inoculant, and yield in some cultivars was reduced. Plant breeders should be able to select for beneficial cultivar interactions with Azospirillum to increase wheat yield and protein levels. Additional research is needed to determine the impact of site-specific soil conditions on the effectiveness of Azospirillum in organic systems.

Introduction

In low-input organic dryland grain cropping systems, obtaining sufficient plant available nitrogen (N) can be problematic. Organic producers often utilize manure or compost to meet N needs, but in many areas the cost of transportation and application make bulky organic fertilizers uneconomical. Low rainfall also limits the ability of some growers to utilize leguminous green manure crops. One alternative to help supplement N is through exploitation of diverse diazotrophic bacteria capable of biological nitrogen fixation (BNF). Associative BNF can contribute 10-50% of the total N requirement of wheat (Solimon et al., 1995; Kennedy and Islam, 2001). In addition to BNF, these bacteria may increase plant growth through production of phytohormones, phosphorous release, increased nutrient uptake, enhanced stress resistance, biocontrol of both major and minor plant pathogens and improved water status (Creus et al, 2004). However, these plant-microbial interactions are dependent on plant genotype (Iniguez et al., 2004) and site-specific soil conditions (de Oliviera et al., 2006).

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Historically, plant breeders have not selected directly for interaction with beneficial soil bacteria, yet in Brazil, sugarcane breeders selecting for high yield under low-input conditions inadvertently selected for interaction with native diazotrophic bacteria (Baldani et al., 2002). Prior to the advent of chemical fertilizers that have high plant available nitrogen, breeding programs of other graminaceous crops like wheat, may also have indirectly selected for this association. However, after decades of cultivar selection under conditions that utilize chemical fertilizers, modern cultivars may not interact efficiently with these bacteria, and relevant levels of native diazotrophic bacteria may no longer be present in the soil.

To improve nutrient uptake and yield in low-input organic wheat systems, we tested the efficacy of a commercial inoculant of *Azospirillum,* a diazotrophic bacteria that has been shown to positively interact with wheat. Twenty historic and modern winter wheat cultivars were evaluated for the ability to interact with, and benefit from inoculation, and to identify cultivars for use in organic production systems.

Materials and methods

In autumn 2006, field trials were established in two certified organic fields with moderate rainfall near Pullman, WA. Each trial contained five historic and five modern hard red cultivars, and five historic and five modern soft white cultivars, each replicated four times. Each trial was arranged in a split block design, with seed from all cultivars in one block receiving a commercial inoculant of Azospirillum brasiliense (EMD Crop Bioscience) according to the manufacturer's recommendation (9.8 ml kg^{-1}), and cultivars in the other block left untreated. A previous winter pea plowdown provided approximately 40 kg ha^{-1} of N. Weed control was accomplished by hand weeding throughout the growing season. Plant emergence, leaf greenness using a SPAD chlorophyll meter, plant height, yield and protein were recorded. In each of the four blocks within each split block, ten soil samples were randomly collected to a depth of 10-cm and pooled for analysis. Soil samples were analyzed for total carbon (C) and nitrogen (N), inorganic N, and potentially mineralizable N, and organic matter (OM) was estimated. Field plot locations were recorded permanently using GPS coordinates to track survival of the introduced bacteria in the soil over time.

Results

Seed treatment with a commercial inoculant of Azospirillum had little overall impact on seedling emergence, leaf greenness, or plant height in either location, but did have an impact on crop yield and protein. In location A, average crop yield was increased among all cultivars by 538 kg ha^{-1}; however, yield increase ranged from 134 to 1,209 kg ha^{-1} among individual cultivars, and was significantly increased in only five cultivars (Figure 1). In location B, yield data was compromised due to harvest difficulties resulting from the slope of the land, but in general, the cultivars did not respond as favorably to the inoculant, and yield was decreased in some cultivars (data not shown). In location B, average crop yields among all cultivars were 638 kg ha^{-1} greater than average yields in nursery A. Only two historic hard red cultivars responded favorably to the inoculant in both locations, but yield increases were not significant.

In both locations, protein levels were increased in response to the inoculant. Overall protein levels were greater in location B, but increases in response to the inoculant were greater in location A. In location A, six cultivars had significantly increased protein levels (data not shown). Modern cultivars, Masami and Bauermeister had both significantly increased yield and protein in location A. In location B, only two cultivars had significantly increased protein levels, and correspondingly, these two cultivars had significantly reduced yield in response to inoculation. Only one cultivar, Buchanan, had significantly increased protein levels in both locations. Total C and N, inorganic N, and OM were lower in nursery A than in nursery B (Table 1).

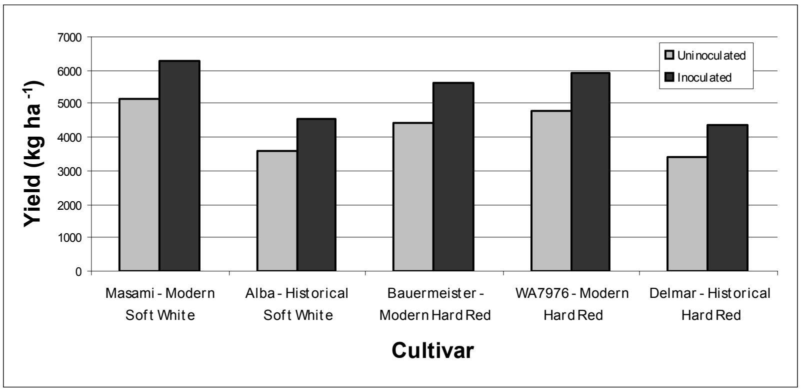

Figure 1: Wheat cultivars with significantly increased yield as a result of Azospirillum inoculation in location A (P<0.05).

Tab. 1: Soil nutrient levels in *Azospirillum* inoculation trials

	Total C	Total N	Inorganic N	Organic Matter
Location	**(mg kg^{-1})**			**(%)**
A	13,700	980	9.31	2.37
B	20,200	1460	14.35	3.49

Discussion

Treatment of wheat seeds with a commercial inoculant of *Azospirillum* increased crop yield and protein in organically managed systems, but the interaction was dependent on plant genotype. Five of the twenty wheat cultivars inoculated with *Azospirillum* had significantly increased crop yield, suggesting that wheat breeders can select for this interaction. The ability to benefit from *Azospirillum* inoculation was present in some modern cultivars, indicating that this trait can co-exist with other beneficial plant traits like high yield and disease tolerance that have been traditionally selected for in modern breeding programs. Inoculation also resulted in increased protein levels in some cultivars, suggesting that this interaction can be used to select wheat cultivars for use in the hard red market class, where high protein levels are required. Site-specific soil conditions also had an impact on wheat yield and protein in response to inoculation. In our study, greater soil fertility levels were correlated with an insignificant, or deleterious response in some cultivars to inoculation with *Azospirillum*. This is consistent with the findings of Martinez de Olivera et al. (2006) who found sugarcane productivity to be reduced as a result of inoculation with diazotrophic bacteria in a high fertility soil. However, these findings contradict company reports on the activity of the *Azospirillum* inoculant under conventional wheat management. More research is needed to determine how site-specific soil conditions affect interaction of graminaceous crops with diazotrophic bacteria. To better meet our objectives, we expanded our trials in autumn 2007. Ten advanced lines from our organic breeding program were included and the trials were planted in five different locations that include regions of low and intermediate rainfall, and organic and conventional management. Soil samples from all 2006 and 2007 planted sites will be evaluated for additional chemical and biological factors to help determine how site-specific soil conditions influence the interaction of wheat and *Azospirillum*. A subset of the cultivars used in our field studies were planted with and without inoculation in greenhouse trials using zero fertilizer, or either organic or chemical fertilizer at both a low and high rate. Root abundance of *Azospirillum* and mycorrhizae, and nitrogen fixation by *Azospirillum* among individual cultivars will be determined. Abundance and diversity of native diazotroph communities will be evaluated in soils from across Washington State.

Conclusions

Initial results from the first year of this study suggest that inoculation of wheat with *Azospirillum* can improve nutrient uptake and increase crop yield and protein under organic management, but this is dependent upon genotype and site-specific soil conditions. Wheat breeders may be able to select for cultivars that benefit from association with these bacteria, but additional research is needed to validate the findings of cultivars differences, and determine the impact of site-specific soil conditions before recommending this to organic farmers as a management tool.

Acknowledgments

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Sustainability assessment of wheat production using Emergy

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Key words: Organic and conventional production, soil type, wheat, emergy, sustainability assessment

Abstract

Sustainability of crop production has to be given high priority when global biomass resources are limited. Here emergy evaluation is applied in order to assess sustainability of crop production exemplified by winter wheat. Emergy evaluation takes into account all inputs involved in a production system (i.e. renewable and non-renewable, local and imported) and transforms them into a common measure of direct and indirect solar energy requirement. The evaluation of winter wheat production is conducted by comparing conventional and organic management on two soil types using Danish reference conditions. The resource use efficiency of wheat production per kg biomass is higher using conventional management practices. This is due to high yield based on large use of non-renewable resources. The environmental loading ratio from organic management practices is about a third of the conventional implying that the organic management can be considered more sustainable.

Introduction

Increasing oil prices and foreseeable limitations of fossil resources has put emphasis on crops as a resource of raw materials for fuels and fibres in addition to their importance for food and feed. Also the many functions of crops in ecosystem services such as securing water reservoirs, biodiversity and landscape has been reconsidered. The crop resource is, however, limited since the inputs, which are needed for its production, are limited, e.g., fertiliser (organic or non-organic), fuel for machinery, human labour, as well as available land. In order to address the sustainability of crop production, assessments of material and energy flows are needed.

The concept of sustainability has many definitions all based on ensuring resources for future generations. Many sustainability assessments consider balances of energy and materials flows without qualifying to what extend the inputs are from renewable or non-renewable resources. The emergy evaluation methodology (Odum, 1996) emphasizes how to exploit renewable resources more efficiently such that the costly (with respect to resource limitations) non-renewables may last longer. The basis of emergy evaluation is the conversion of all process inputs, including energy from climatic resources like precipitation and global radiation, energy inherent in materials such as machinery and in services like human labour, into total amount of solar energy by means of a conversion factor called transformity. In this way, all flows get the same common unit for the analysis.

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Emergy has been used to assess sustainability of crop production in relation to bioenergy production (Bastianoni and Marchettini 1996), for comparison of different land uses (Lefroy and Rydberg, 2003) and to compare organic and conventional farming (e.g. Ortega *et al.* 2005). Here we describe the method and demonstrate its usefulness with four types of winter wheat production in Denmark: organic and conventional management on two locations with different soil types and climate.

Materials and methods

The present emergy assessment compares winter wheat production conducted under conventional and organic reference management practises on two Danish locations with slightly different climatic conditions; site I: sandy soil in south of Jutland and site II: sandy loam soil in east of Zealand. Data for inputs, field operations and yields were mainly obtained from farmers' advisory manuals (Dansk Landbrugsrådgivning 2003 and 2006), norms for direct and indirect energy consumption from Dalgaard *et al.* (2001), average actual evapotranspiration at similar sites from Barlebo *et al.* (2007) and global radiation from the Danish Meteorological Institute.

Emergy represents the solar energy used up directly or indirectly to make a product or to support a process; it is measured in sej (solar emergy joule). The basis of emergy evaluation is the conversion of all process inputs into emergy by means of the conversion factor transformity expressed in sej J^{-1} (emergy per Joule). When comparing two products from different processes, the product having the highest transformity requires most emergy (direct or indirect solar energy) for its production and is thus more costly. By definition, transformity of solar energy is equal to 1 sej J^{-1}. List of transformities are found in Emergy folios (2000-2002).

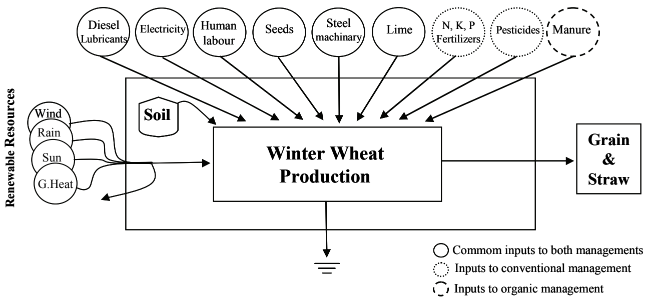

Figure 1: Energy System Diagram of organic and conventional winter wheat production

Flows of energy and matter for wheat production in Denmark were described by an Energy System Diagram (Figure 1) showing all resources contributing being i) renewables (R) such as sun, rain (only the amount evapotranspirated by crop), geothermal heat and wind, ii) local (within the system) non-renewables (N) such as soil, and iii) imported (from outside the system) non-renewables (F) such as fossil fuels, fertilizers, seeds and chemicals. Also the emergy based indicator Environmental Loading Ratio (ELR) was considered. This is the ratio of all non-renewable emergy flows both from inside and outside the system (N + F) to the renewable emergy flows (R). The ELR is generally high for systems with a high level of technology and/or with high environmental pressure.

Results and discussion

For each system considered, a table with energy and material flows, transformities and resulting emergy flows was calculated for wheat grain and straw yield; here, only the summary of the calculations is shown (Table 1).

The crop yield increased about 2-fold between the four scenarios from the organic production on the sandy soil to the conventional on the sandy loam soil. The total annual emergy flow (e.g. total solar energy used up) per hectare had the highest value in the conventional management at both sites, implying that this production lead to a greater use of resources per hectare. In all scenarios, three inputs contributed substantially to the emergy flow: i) fertiliser application (manure approx $3x10^{15}$ sej ha^{-1} y^{-1} and synthetic fertiliser approx $4\text{-}5x10^{15}$ sej $ha^{-1}y^{-1}$ mainly from N fertiliser), ii) lime application (approx $0.8x10^{15}$ sej $ha^{-1}y^{-1}$) and iii) evapotranspiration (approx $0.7x10^{15}$ sej $ha^{-1}y^{-1}$). The difference between conventional and organic systems was mainly due to synthetic versus organic fertiliser use. The two sites differed by higher input of synthetic fertiliser at site II compared to site I and higher evapotranspiration at site I compared to site II (480 and 420 mm y^{-1}, respectively).

Tab. 1: Summary of Emergy assessment of winter wheat grain and straw production for organic and conventional management at different sites

	Sandy soil, site I		Sandy loamy soil, site II	
	Organic	Conventional	Organic	Conventional
Total dry matter (t ha^{-1} y^{-1})	5.6	8.0	8.2	12.4
Total emergy flow (sej ha^{-1} y^{-1})	$5.6x10^{15}$	$6.6x10^{15}$	$5.4x10^{15}$	$6.9x10^{15}$
Transformity wheat crop (sej J^{-1})	$7.1x10^{4}$	$5.8x10^{4}$	$4.6x10^{4}$	$3.9x10^{4}$
Environmental Loading Ratio	2.3	7.3	2.4	8.5

The transformity values indicate the use of solar energy related to the energy of the final product. These values decrease from organic production on sandy soil to conventional production on sandy loam soil corresponding inversely to the increase in yield. This implies that the efficiency of the production system per unit biomass is higher using conventional management practises. However, this efficiency is caused by the much larger use of non-renewable resources as seen from the Environmental Loading Ratio (ELR); ELR is more than 3 times higher as compared to organic management practices. This implies that under these growing conditions the organic management needs much less non-renewable inputs.

So far, the analysis has considered the total crop biomass (grain + straw); traditionally, only grain is considered. If this was the case in the present study, all emergy flows would be accounted for in the production of the grain giving somewhat higher values. The highest efficiency per kg (or Joule) as seen from the transformity for grain would again be for conventional production on sandy loam soil ($6.1x10^{4}$ sej J^{-1}), and the average value over all systems would be $8.6x10^{4}$ sej J^{-1}. The latter value is a little lower than the average transformity value for winter wheat production in Italy ($15.9x10^{4}$ sej J^{-1}, Ulgiati et *al*., 1994) and nearly similar to the Siena Province value ($11.3x10^{4}$ sej J^{-1}, Bastianoni et *al*., 2001). Such differences may be due to a more efficient production in Denmark primarily caused by a higher grain yield potential. Unfortunately, no other published transformity values could be found for comparison. Wheat straw is, however, also a valuable raw material: i) if we consider the straw as residual biomass usable as feedback in the wheat production systems (e.g. to generate electricity for grain drying), the transformity of product output (wheat grain) would decrease; ii) if the straw is left in the fields as a carbon source we would have an increase in soil fertility and a feedback potentially improving subsequent crop production. A detailed analysis of the role of straw as raw material for energy purposes and/or bio-fertilizers is under preparation.

Conclusions

This emergy evaluation of winter wheat production conducted under Danish reference growing conditions concluded that organic production (sandy loamy soil) was the most favorable growing system due to the lowest ELR value. However, the best efficiency of the resource use per kg biomass (lowest transformity value) was obtained on the rather fertile sandy loamy soils on east Zealand and highest for the conventional management due to high yield based on large use of non-renewable resources. We see emergy assessment as a tool to emphasize the use of natural and especially renewable resources, and an accounting method where environmental costs are evaluated using a common scale for all energy and materials flows, i.e., the direct and indirect solar energy used up to obtain a product.

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Organic crops

Impact of agronomic measures on yield and quality of organic potatoes (*Solanum tuberosum* L.) for industrial processing

Haase, T.[1], Haase, N.U.[2] & Heß, J.[3]

Key words: Nitrogen; Potassium; Preceding Crop; Pre-sprouting; Cultivar

Abstract

Three field experiments were conducted during 2002 and 2004 on two sites in Germany in order to examine the impact of preceding crop, pre-sprouting, N- and K-fertilization and cultivar on total tuber fresh yields, tuber DM, glucose and fructose concentration, as well as the colour of crisps and the quality score of French fries at harvest and after storage. Generally, total tuber yields depended very much on the growing season. However, highest yields were obtained when horn grits were applied along with potassium sulphate. Increasing yields after cattle manure fertilization could be attributed to K rather than N. Combined N and K fertilization may cause DM concentration to fall short of the required minimum for crisps. Pre-sprouting and storage increased tuber DM concentration considerably. Cultivars belonging to the very early and early maturity type showed the largest relative increase of reducing sugars due to storage.

On the whole, results suggest that the effect of agronomic measures such as fertilization, preceding crop and seed-tuber preparation may be rather small and the response of internal tuber quality and quality of fried products difficult to predict. The quality standards for tuber raw stock can be accomplished best when adequate cultivars suitable for storage are chosen.

Introduction

Organic cultivation of potatoes for industrial processing into French fries or crisps may be a new source of income for organic farmers in European countries. For potato processing, high proportions of larger tubers are required for French fries and also for crisps. In addition, there are ranges and thresholds for tuber dry matter (DM), as well as for the concentration of reducing sugars (glucose and fructose) of tubers. Tubers should not only meet these standards shortly after harvest, but also after storage. Tuber size is mainly determined by nitrogen (N), and tuber yield response is mainly dependent on the rate at which N is released from preceding crops or organic amendments such as animal manures. Little is known about the potential interactions between N supply and crop growth as a function of seed-tuber preparation and cultivar. In organic farming, where N is usually very limited, the correlation between available potassium (K) - applied as mineral K or with cattle manure - and potato crop response may be low.

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Materials and methods

Three field experiments were conducted over two and three years, on two organically managed sites (DFH: 51°4, 9°4', BEL: 52°2', 8°08') in Germany in split-plot designs (Exps 1 and 2) and in a RCB design (Exp. 3) on loamy sand (Exp. 1) and silt loam (Exps 2 and 3) with factors fertilization (cattle manure, potassium sulphate, horn grits, both combined, and a control)) and cultivar (Agria and Marlen) in Exp. 1, preceding crop (oats, peas, grass-clover, winter wheat), pre-sprouting (yes or no), cultivar (Agria and Marlen) and harvest date (two early and one final) in Exp. 2, and cultivar (see results) in Exp. 3. Details on site and weather conditions, agronomic measures and statistical analysis are presented in Haase et al. (2007 a-b). Parameters discussed in this paper are total tuber fresh matter (FM) yields, tuber DM, glucose and fructose concentration, as well as the colour of crisps and the quality score of French fries.

Results

In Exp. 1, tuber fresh matter (FM) yield was consistently and significantly increased ($p<0.0001$) by any fertilizer treatment as compared with the control. Combined potassium sulphate and horn grits application (PSHG) gave the strongest yield response (+6.1 t ha^{-1}), while cattle manure (CM) and PS or HG alone did not differ significantly from each other (Fig. 1a). While in 2002, cv. Marlen yielded significantly higher than cv. Agria, the opposite was true in 2004. In 2003, total FM tuber yield (mean of both cultivars) was 31.3 t ha^{-1} (Fig. 1b).

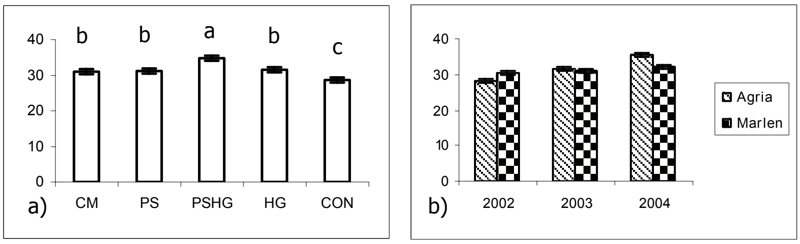

Figure 1: Fresh matter tuber yields (t ha^{-1}) as affected by (a) fertilization and (b) cultivar during 2002, 2003 and 2004 (means ± standard error)

In Exp. 2, cv. Marlen in 2003 had higher tuber FM yields than cv. Agria in most cases at the two early harvests, while Agria gave higher yields at the later harvest (Table 1). In 2004, the positive response of tuber FM yield to pre-sprouting (PS) lasted throughout the season, but could not be established at final harvest in 2003 (Table 1).

Tab. 1: Fresh matter tuber yields (t ha^{-1}) as affected by pre-sprouting for two cultivars at subsequent harvests during 2003 and 2004

cv.	PS	2003			2004		
		15 Jul	28 Jul	17 Sep	28 Jul	13 Aug	9 Sep
Agria	yes	22.6	31.5	39.9	29.9	31.1	30.0
	no	19.6	28.2	39.0	26.6	27.6	28.1
Marlen	yes	23.9	32.5	36.1	27.8	29.8	30.7
	no	21.5	30.7	35.2	25.6	27.4	27.4
S. E. of mean		0.53			0.59		

At harvest in September 2004, yield increase by pre-sprouting still amounted to +2.6 t ha^{-1} (+2.8 t ha^{-1} at the end of July) (Table 1). A similar response to pre-sprouting depending on year and date of harvest was established for size-graded (marketable) yields (data not shown). Dry matter (DM) concentration of tubers was significantly affected by fertilization (Exp. 1; Table 2a), cultivar (Exps 1-3) and pre-sprouting of tubers (Exp. 2; Table 2b). Moreover, significant interactions of these treatments with the year were established. Storage increased DM concentration significantly (Exp. 1; Table 2c), in two of three experiments.

Tab. 2: Tuber dry matter concentration (%) as affected by (a) fertilization and cultivar, (b) pre-sprouting and year and (c) storage (means ± standard error)

	cv.			Pre-sprouting	
Fertilizer type (a)	Agria	Marlen	(b)	Yes	No
CM	21.2	22.5	2003	27.6	27.5
PS	21.2	22.7	2004	25.6	24.1
PSHG	20.1	22.0	S.E. of mean	0.11	
HG	20.6	23.0	(c)	At harvest	After storage
CON	21.9	23.5		21.7	22.1
S.E. of mean	0.17		S.E. of mean	0.08	

No effect of fertilization (Exp. 1) and no consistent effect of preceding crop or pre-sprouting (Exp. 2) on reducing sugar concentration (RSC) could be established, but significant ($p<0.0001$) interactions for storage*year were found in all experiments.

Tab. 3: Tuber reducing sugar concentrations (g kg^{-1} FW), crisp L-values and French fry quality scores (in italics), respectively (both in brackets) as affected by storage and cultivar during 2003 and 2004 (means ± standard error)

		2003		2004	
Exp.	cv.	At harvest	After storage	At harvest	After storage
1	Marlen	6 (70.5)	16 (70.3)	15 (71.6)	66 (64.2)
2		10 (69.6)	17 (70.1)	27 (70.6)	104 (65.8)
3		1 (70.5)	2 (70.5)	2 (71.0)	15 (62.8)
3	Carmona	2 (70.1)	24 (62.8)	6 (69.1)	64 (50.8)
3	Delikat	4 (67.7)	44 (58.1)	18 (62.7)	113 (44.7)
3	Saturna	1 (69.3)	4 (69.2)	5 (71.2)	19 (62.2)
1	Agria	5 (*3.9*)	10 (*3.8*)	15 (*3.9*)	70 (*3.5*)
2		16 (*4.4*)	28 (*4.0*)	29 (*3.9*)	136 (*3.5*)
3		1 (*4.5*)	3 (3.8)	2 (*4.1*)	21 (*3.5*)
3	Premiere	11 (*4*.1)	56 (*2.8*)	23 (*3.0*)	90 (*2.2*)
3	Velox	6 (*3.9*)	39 (*2.6*)	21 (*3*.3)	102 (*2.6*)
3	Camilla	2 (*3*.6)	10 (*3.8*)	11 (*2.9*)	72 (*2.4*)
3	Freya	2 (*4.1*)	3 (*3.6*)	3 (*3.8*)	24 (*3.2*)
3	Marena	2 (*4*.1)	3 (*4.0*)	2 (*3.7*)	11 (*3.5*)

For the 2003 crop, RSC increased during storage (Exp. 1-3), but was still very low after four months of storage (8°C). In 2004, the RSC at harvest was comparatively higher than in 2003, and increased during storage appreciably (Table 3). The response of French fry quality score (mean of weighted characteristics colour [2x], texture [3x] and taste/odour [5x]) was mostly affected by storage (Exp. 1-3) and, additionally, interactions for cultivar*storage (Exp. 3) occurred. For crisp quality, significant interactions for storage*year ($p<0.0001$) were established. Lighter crisps (higher L-values) were assessed after winter wheat than after the two leguminous crops (data not shown), while after oats L-values were lower than after grass-clover.

Discussion

The positive response of tuber FM yield to cattle manure application in one of three years could be traced back to the increased supply of K, and – possibly a more balanced nutrition with regard to N and K. This suggestion is further strengthened by the profound effect of combined K and N fertilization(PSHG) on FM tuber yield compared with sole application of N (HG) and K (PS) (Fig. 1a). Results show clearly that performance of cultivars may vary considerably between the years (Fig. 1b) and seems to depend on the length of the growing season which - in organic potato cropping – is often shortened by late blight (*Phytophthora infestans*). Pre-sprouting could be shown to promote early tuber yield formation and DM accumulation and thereby reduce the risk induced by *P. infestans,* like in 2004. Results show that tubers from organic potato cropping may be expected to have sufficiently high tuber DM concentrations for processing into French fries (>19%). However, DM concentrations of tubers may fall short of the minimum of 22% required for crisps when a combined N and K fertilizer is applied. Results give evidence that the development of reducing sugars cannot necessarily be foreseen from the initial reducing sugar level at harvest. Moreover, sugar accumulation during storage seems to be mainly cultivar-specific. The marked increase due to storage for very early and early cultivars suggests that reducing sugars accumulation may strongly depend on maturity type. Throughout the experiments, results confirmed that the individual growing season has a tremendous impact on both, the initial level of reducing sugars and the increase of reducing sugars during storage. The medium-early cv. Agria and medium-late Marena proved to be well suited for cultivation of organic potatoes for French fries. Even in the season with marked quality losses due to storage, the quality score did not fall below the threshold of 3.5. There was no consistent response of crisp colour to an increased N supply brought forth by leguminous preceding crops or fertilization with horn grits. Even though L-values were significantly reduced by grass clover and peas, preceding crops do not seem to have any relevance to marketability of crisps. Overall, the results indicate that final product quality is much more influenced by growing season, storage and cultivar than by fertilization, preceding crop, or pre-sprouting.

Acknowledgments

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Effect of Compost versus Animal Manure Fertilization on Crop Development, Yield and Nitrogen Residue in the Organic Cultivation of Potatoes

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Key words: fertilization trial, compost, potato yield, N-residue, organic

Abstract

Organic farmers in Flanders use manure from extensive conventional livestock systems due to a lack of animal manure from organic producers. The research question was if on-farm prepared compost mainly consisting of vegetal residues can be a good alternative. A long-term fertilization trial with a 4-year crop rotation of maize - potatoes - spring barley - red clover is carried out on two fields with a time difference of one year. The fertilization treatments are on-farm prepared compost, applied as a single dose and a double dose, farmyard manure, slurry and slurry combined with composted municipal waste. This paper concerns the experimental results of the potato crop in 2006 and 2007. The nitrate content of the plant juice was monitored and the potato yield and nitrate content in the soil profile at the end of the growing season were determined. In 2006 the potato yields were significantly higher for both farm compost treatments while the nitrate residues in soil were significantly lower. The early, high and constant leaf blight disease pressure in 2007 resulted in lower yields and less marked treatment effects. This investigation demonstrated that application of mature compost can result in a faster development of the potato crop in the first weeks of the growing season, which is important for sufficient yields in organic potato growing.

Introduction

Organic farmers in Flanders use manure from extensive conventional livestock systems due to a lack of animal manure from organic producers. We questioned whether on-farm prepared compost mainly consisting of vegetal residues can be a good alternative.

It was hypothesised that the type and application method of the organic fertilizer input affect the yield and quality of the potato crop. In a field experiment carried out in 2001 in North Yorkshire with an identical level of N-input, cattle manure-based compost increased potato yield significantly compared with chicken manure fertilizer pellets (Leifert, 2005).

Differences in the organic fertilization regimes can lead to large differences in the environmental effects of organic farming (Thorup-Kristensen, 2007). Potato crops are very sensitive to losses of soil mineral nitrogen by post-harvest leaching. It was questioned whether the type of organic fertilizer input would affect the nitrate N-residue in the 0-90 cm soil profile.

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Materials and methods

On two fields a long-term fertilization trial is executed. The crop of the conversion period was a fallow of grass-clover. The adopted crop rotation is a 4-year cycle of maize - potatoes - spring barley - red clover. The experiment has been repeated on two fields in two consecutive years (starting in 2005 and 2006 resp.).

Two treatments concern on-farm prepared compost: a single dose (FC) and a double dose (2xFC). Other treatments were farmyard manure (FYM), slurry (S) and slurry combined with compost of municipal waste (S+MWC). The organic matter input by fertilization is equalized for the treatments FC, FYM and S+MWC, 6,5 t organic matter per ha in 2006 and 6 t per ha in 2007. Considering organic matter input 30 t FYM was equivalent to 50 t and 65 t FC in 2006 and 2007 respectively. The total nitrogen input with FC was 160 kg per ha in 2006 and 185 kg per ha in 2007 and the dose of 30 t FYM resulted in a total nitrogen input of 150 kg per ha in 2006 and 125 kg per ha in 2007. The nitrogen input with 20 t slurry was about 100 kg per ha. Municipal waste compost resulted in an additional nitrogen input of 140 and 175 kg per ha in 2006 and 2007 respectively. Compost application is combined with reduced tillage techniques, so that compost is incorporated to a shallow depth. Both types of manure, farmyard manure and slurry, were incorporated by ploughing to a depth of 30 cm. Each treatment counts 4 replicates, consisting of 15 m by 25 m plots.

The nitrate content (ppm) of the plant juice of the FC and FYM treatments was monitored (n=1) in 2006. Samples of petioles were taken weekly from the beginning of June until mid-August 2006. Nitrate concentration was determined in the plant juice, using a Horiba ion-selective measurement device. The potato yield was determined (n=4) by harvesting two adjacent rows of 6 m (plots of 9 m^2). The nitrate N-content of three soil layers (0-30, 30-60 en 60-90 cm) was determined (n=4) after extraction with a 1N KCl solution at the end of the growing season. Potato yield and nitrate N-residue (0-90 cm) of the different fertilization treatments were compared with each other using a variance analysis (One-Way Anova, Scheffé multiple comparison of means).

Results

Large differences in initial development of the potato crop were observed between the treatments with farm compost and those with animal manure. By the middle of June 2006 the crops from the farm compost treatments were better developed. The leaf color was lighter for the potatoes of the compost treatments than for the potatoes fertilized with animal manure and the mean plant juice nitrate concentrations, over the measurement period, were three times lower for the FC (807 ppm) compared to the FYM treatment (2473 ppm).

The potato crop in 2007 was planted earlier and similar differences in initial development were observed between the treatments with farm compost and those with animal manure.

In 2006 significant yield differences were observed between treatments (Figure 1). Multiple comparison of the yield in function of the fertilization (via Scheffé) showed that in 2006 the yield for the compost treatments was significantly ($p<0.05$) higher than the yield for the three other treatments. For 2007 multiple comparison of the yield (via Scheffé) revealed no significant differences in yield (Figure 1).

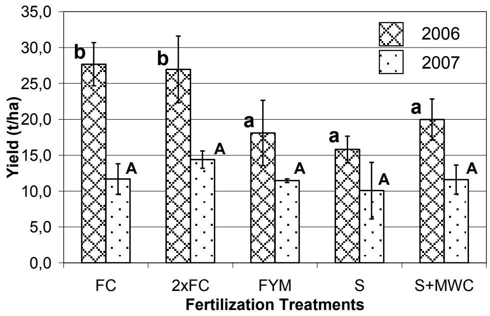

Figure 1: Potato yields 2006 & 2007 (t/ha >35mm)

Error flag indicates +/- standard deviation;
Means that are not significantly different are denoted with the same letter;
Fertilization treatments FC: single dose farm prepared compost, 2xFC double dose farm prepared compost, FYM: farmyard manure, S: slurry, S+MWC: slurry plus municipal waste compost

In autumn, October 3, 2006 the N-residue (kg NO_3^--N per ha, 0-90 cm soil depth) was determined for the different treatments (table 1, n=4). For all treatments the residue was lower than the standard of 90 kg N/ha. Significant differences ($p<0.01$) between the treatments were found in 2006 using ANOVA. Fertilization with compost (for both compost treatments) resulted in significantly lower amounts of nitrate than in the three other treatments where animal manure was applied. In October 31, 2007 no significant differences in N-residue were found between treatments (table 1, n=4).

Tab. 1: N-residue in 2006 & 2007 after the potato crop

	kg NO_3^--N per ha, 0-90cm	
	2006	2007
FC	47 [a]	79 [A]
2xFC	49 [a]	79 [A]
FYM	77 [b]	101 [A]
S	67 [b]	90 [A]
S+MWC	75 [b]	87 [A]

Means that are not significantly different are denoted with the same letter;
Fertilization treatments FC: single dose farm prepared compost, 2xFC double dose farm prepared compost, FYM: farmyard manure, S: slurry, S+MWC: slurry plus municipal waste compost

Discussion

The higher potato yield for the compost treatments in 2006 was a consequence of the earlier start and ripening of the potato crop. When *Phytophtora infestans* became detrimental for the potatoes, the plants on the compost treatments were already ripening while the potato plants on the manure treatments were greener and their growth was interrupted by the disease. The reason for lower yields and less marked treatment effects in 2007 was probably the early, high and constant leaf blight disease pressure in that year. In 2006 leaf blight appeared late. Accelerating development by agronomic practices is an important strategy for organic growers in order to obtain sufficient yields and an acceptable tuber size grading. For the earliness of the crop a fast crop development, early tuber formation and fast tuber growth are important (Tiemens-Hulscher, 2007). The leaf development after emergence is strongly influenced by the nitrogen availability in the first weeks after emergence (Vos, 1995). Mature compost is already transformed organic matter and is a product with a limited but guaranteed nitrogen supply. This can explain the early start of the potato crop on the compost treatments. In the case of the animal manure treatments the squat growth and the high nitrate concentration in the leaves, together with the dark colour indicates that plants could not respond to the nutrient availability by growth because of a soil-related stress factor. Root development was possibly hindered by the decomposition of fresh organic matter from the organic fertilization. The lower N-residues in 2006 for both farm compost treatments compared to those for treatments with cattle manure in combination with the higher potato yields for compost treatments indicate that compost application in potato cultivation has potential for obtaining a successful crop and lowering potential nitrate losses following harvest. In 2007 the lower yields resulted in a lower N-uptake and in higher N-residues. Less marked treatment effects on yield coincide with less marked treatment effects on N-residue.

Conclusion

Application of compost can result in a faster initial development of the potato crop. This is important in organic farming when leaf blight rapidly becomes fatal for the crop because of limited crop protection measures. In 2006 the organic fertilizer type had a significant influence on the yield response. This confirms the hypothesis that the form of the organic fertilizer input may affect yield even though blight infection may not be affected. The fact that significantly lower nitrate residues were found in 2006 in the compost treatments indicates that the type of the organic fertilizer input influences potential nitrogen losses. Plant juice nitrate concentration measurement may be used to indicate the speed of the initial development of the potato crop.

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Effects of Farm Type and Different Intensities of Soil Tillage on Cash Crop Yields and Soil Organic Matter

Schulz, F.[1], Brock, Chr.[2] & Leithold, G.[3]

Key words: crop rotation, tillage, long-term field experiment

Abstract

An organic long-term field experiment has been carried out at the experimental station Gladbacherhof (Giessen University, Germany) since 1998 to survey the performance of agronomical, economical and ecological indicators dependant on farm type and tillage intensity. This article presents results on cash crop yields and changes in humus contents in the first two rotations of the experiment. It can be concluded that organic stockless farming without ley affects cash crop yields and demands special attention with regard to a sustainable humus management. Stockless farming with rotational ley on the other hand up to now showed a satisfactory performance when compared to a mixed farm type with livestock. As for the yields, reduced tillage systems could cope with the regularly ploughed reference system if at least a shallow turning of the soil was carried out. An increase of humus contents was not induced by reduced tillage systems.

Introduction

In the context of specialization and intensification processes taking place even in organic farming, an increase of organic stockless farm types can be observed. However, it has been suggested that organic stockless farming faces particular challenges with regard to nutrient supply as well as sustainable management of humus resources. A careful assessment of the economical and ecological performance of such systems is therefore necessary in order to promote sustainable management. Further, the reduction of tillage intensity has often been considered as desirable in organic farming. The reasons for this are manifold. Lately the issue has been given special attention in the context of climate change and carbon sequestration in agricultural soils. Still it has to be investigated whether reduced tillage systems in organic farming can cope with the requirements of nutrient availability and weed control (Drinkwater et al. 2000).

These issues are being investigated in a long-term field experiment at the experimental farm Gladbacherhof of Giessen University (Germany), started in 1998. This article presents the results on the changes in cash crop yields and soil organic matter (humus) in the first ten years of the experiment in order to discuss the agronomical as well as ecological impact of farm type and tillage intensity with regard to selected indicators.

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Materials and methods

The long-term field experiment Gladbacherhof is located at Villmar (Hesse, Germany) on the north-western spur of the Taunus hill landscape (altitude 170 masl., mean annual temperature 9.5°C, mean annual precip. 649mm, orthic luvisol, silt with high clay content). In 1998, the experiment was set up in split plot design with four replications. Main factor is farm type, second factor is tillage intensity. Three farm types are displayed in the experiment comprising different crop rotations and fertilization (tab.1).

Tab. 1: Design of crop rotations and fertilization for farm types in the long-term trial Gladbacherhof (Hesse, Germany) from 1998 to 2009

field number in crop rotation	year	Farm type		
		a1 (mixed farm, 0.7 LU cattle stocking)	a2 (stockless farming with ley)	a3 (stockless farming without ley)
1	1998,2004	alfalfa-grass	cereal + US	cereal + CC
2	1999,2005	alfalfa-grass	ley (alfalfa-grass)	faba beans
3	2000,2006	w. wheat + CC	w. wheat + CC	w. wheat + CC
4	2001,2007	## potatoes	potatoes	potatoes
5	2002,(2008)	oats/peas* + US	peas	peas
6	2003,(2009)	#w. rye + US	w. rye + CC	w. rye + CC

* Oats/peas in 2002, winter wheat in 2008, #20 t farmyard manure, ## 30 t farmyard manure, CC=catch crop (non-legume/legume mix), US=underseed alfalfa-grass

Furthermore, four levels of tillage intensity are included with the following tillage systems:

b1: regular tillage with plough (30 cm)

b2: two-layer plough (soil turning in 0-15 cm, soil break up 15-30 cm)

b3: until 2003: as b2 but without tillage in autumn before spring crops
from 2004: max. cultivation depth 15 cm, various standard tillage equipment

b4: cultivator & rotary harrow, max. cultivation depth 30 cm, no turning of soil

Results

Winter wheat yields showed a difference between farm types already in the first rotation period (Schmidt et al. 2006), indicating an advantage of the stockless farm type with rotational ley (a2) and the mixed farm type (a1), when compared to the stockless farm type without ley (a3). In the second rotation period, winter wheat yields in a1 decreased nearly down to the level of yields in a3 (fig.1). Wheat yields in a2 in 2006 were even higher than in 2000, thus exceeding the yields of the other two farm types significantly.

As compared to the deeply ploughed system (b1), the reduction of tillage intensity significantly affected winter wheat yields. In the second rotation period a significant difference between the tillage systems was evident with considerably lower yields in b4 than in all other three variants.

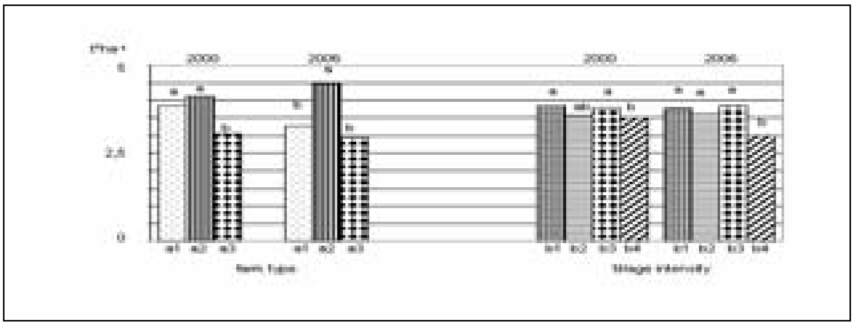

Figure 1: Winter wheat yields ($t*ha^{-1}$) dependant on farm type (left) and tillage intensity (right) in the first two rotation periods of the long-term experiment Gladbacherhof. Differing letters denote significant distinctions (P≤0.05).

No significant differentiation of potato yields according to farm type or tillage intensity could be observed (without figure). Statistically firm interactions between farm type and tillage intensity could not be observed for any of the crops.

Tab. 2: C_{org}[1)] and N_t[1)] contents in topsoil (0-30 cm) and C/N ratio dependant on farm type and tillage intensity in the long-term experiment Gladbacherhof in 2007 after nine trial years.

farm type	C_{org} mg $(100g)^{-1}$	N_t mg $(100g)^{-1}$	C_{org}/N_t	tillage intensity	C_{org} mg $(100g)^{-1}$	N_t mg $(100g)^{-1}$	C_{org}/N_t
a1	1323 a	147 a	9.0 a	b1	1285 a	143 a	9.0 a
a2	1264 ab	139 b	9.1 a	b2	1250 a	139 ab	9.0 a
a3	1201 b	131 c	9.2 a	b3	1241 a	133 b	9.4 a
				b4	1274 a	141 a	9.0 a

C_{org} and N_t values have been corrected with reference to initial values in 1998. Within a column differing letters denote significant distinctions (P≤0.05).

After nine years, C_{org} and N_t contents again were lower in the stockless farm type without ley (a3) than in the mixed farm type (a1) (tab.2). Concerning the higher C_{org} and N_t values in a1, the short-term effect of farmyard manure application (tab.1) must be taken into account. A significant differentiation of C and N contents by tillage intensity on the other hand could not be confirmed (tab. 2). This holds true even if bulk density is considered (Krawutschke 2007).

Discussion

The positive precrop effect of alfalfa-grass obviously is stronger for ley with the mulched plant material remaining on the plot than for fodder cropping (Loges et al. 1999). This situation was reflected in the experiment despite of a considerably higher yield level of the alfalfa-grass precrop in a1 compared to a2 before 2000. As for potato yields, it can be assumed that the pre-precrop effect of mulched alfalfa-grass in a2 is at least compensated by farmyard manure application in a1. The lower yield level for winter wheat in a3 reflects the low N supply in this farm type (Schmidt et al. 2006).

A negative impact of tillage intensity reduction on cash crop yields is evident for the lowest intensity level (b4). There is some evidence that losses caused by lower yields in no-till systems in organic farming may not easily be compensated by the lower energy consumption (Kainz et al. 2005).

The impact of farm types on humus contents in the experiment supports the assumption that farmyard manure application and perennial legume cropping have a decisive impact on humus content dynamics (e.g. Leithold et al. 2007). Since manure application adds to legume cropping in a1, the higher humus content produced by this farm type compared to a2 and a3 is likely to become even more apparent in the long run. Reduced tillage intensity did not raise humus contents in the Gladbacherhof experiment. Similar results have recently been published (e.g. Baker et al. 2007), contradicting an assumed carbon sequestration potential of tillage intensity reduction. Still it is necessary to further investigate the potential for saving fossil energy (fuel).

Conclusions

After 10 years of differentiated management in the long-term experiment Gladbacherhof it can be concluded that perennial legume cropping has to be considered beneficial in agronomical terms as well as with regard to humus reproduction. Stockless farming without ley in the rotation obviously cannot easily cope with nutrient supply, even with optimized inclusion of catch crops.

Reduced tillage intensity in the trial affected SOM allocation in the soil profile but did not raise humus contents. On the other hand, a similar yield level as in the reference system could be reached with reduced tillage intensity in the experiment, if at least shallow ploughing was not categorically excluded.

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Searching for an alternative oil crop for organic farming systems in temperate climates

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Key words: safflower, accessions, selection, seed yield, oil content

Abstract

Safflower is an oil crop widely grown in semiarid and arid regions whose oil is valuable because of its high concentration of polyunsaturated fatty acids. The aim of this contribution is to give an overview of the methods for identifying potential genotypes suitable for cultivation in temperate climates. From 2002 to 2005 a great many safflower accessions from a worldwide safflower collection were screened at several locations in Germany and Switzerland. More than 75 % of the accessions tested failed under the humid conditions of the first year because they did not set seed. During 2004 and 2005, seed yield per row and oil content from 486 tested accessions varied between 0 and 428 g and between 0 and 21 %, respectively. Twenty selected accessions showed seed yields between 1.4 and 2.1 t ha^{-1} and oil contents ranging between 21 and 23 %. Although yield potential of given accessions was strongly dependent upon climatic factors, well adapted safflower accessions for more humid conditions were identified. For future research there are several agronomic challenges to be solved for cultivating safflower in organic farming systems, such as increasing oil content and optimizing weed and disease control.

Introduction

Safflower (*Carthamus tinctorius* L.), a member of the family of the Asteraceae, is one of the oldest cultivated crops. It often is grown on a small scale for personal use and thus remains a minor crop, with world seed production around 800 000 t per year (Gyulai, 1996). Commercial oil production from safflower seeds has been conducted for about 50 years, first for the paint industry and now mainly for its edible oil (Li and Mündel, 1996). Safflower is grown in more than 60 countries, but mainly in India, USA, Mexico, Ethiopia, Argentina and Australia (Li and Mündel, 1996). Safflower has very valuable oil for human nutrition, because of high contents of polyunsaturated fatty acids, especially linoleic acid (Honermeier, 2006). Apart from the use as an edible oil, safflower is a crop for multiple purposes. Dyes extracted from florets can be used as natural food colours or to tint natural cosmetics. Florets as well as seeds are used for cosmetic products and medicinal purposes in traditional Chinese medicine. Seeds are also used as birdseed (Li and Mündel 1996). Although, safflower can be grown across a wide range of latitudes (from 60°N to 45°S) and its product has many uses, cultivation in Germany currently is negligible (Honermeier, 2006). Because of its applicability in the human health sector as well as its usability for natural cosmetics

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and natural medical products, safflower seems to be a very favourable crop for organic plant production in Central Europe. However, there currently is a lack of knowledge on potential genotypes suitable to be grown under temperate climatic conditions, as well as on agronomic factors to optimize seed yield and oil content and to control weeds and pests. The aim of this study was to search for genotypes adapted to temperate climatic conditions within a great number of accessions from all over the world. A methodical approach is given on the ideotyping already done and the prototyping intended for prospective research.

Materials and methods

In 2002, 741 safflower accessions, obtained from different gene banks, breeders and official institutions from all over the world, were evaluated at the two locations Ihinger Hof (SW Germany) and Göttingen (Central Germany). The field trials were set up in a randomized block design with two replicates. Because of the limited number of seeds, safflower accessions were sown in microplots of one row of 1.2 m length. Row distance between different accessions was 40 cm. From the tested pool, 65 accessions were selected according to an index summarizing disease resistance, seed set, seed yield, etc. These selected accessions were cultivated in 2003 at three locations, Kleinhohenheim, Göttingen and Klettgau (SW Germany), on plots 1.8x3.0 m. In 2004 and 2005, 20 selected accessions were evaluated at four sites in SW Germany and Switzerland in a lattice design with four replicates. Fifty seeds per m^{-2} were drilled in rows with a row spacing of 20-40 cm. Crop management in all trials was done according to organic standards. Weeding was done mechanically at the rosette stage, and if necessary, manually. No fertilizer was applied. Twenty agro-morphological traits were evaluated. Oil content in per cent was estimated using near infrared reflectance spectroscopy (NIRS). In parallel, 468 accessions from 49 countries across 15 geographical regions were evaluated at the location Kleinhohenheim across two seasons. In a simple lattice design with two replicates, 25 seeds from each accession were drilled in a 1.2-m-long row with 75 cm inter-row distance. Statistical analyses were performed with PLABSTAT (Utz, 2002). An overview of the selection process is given in Fig. 1.

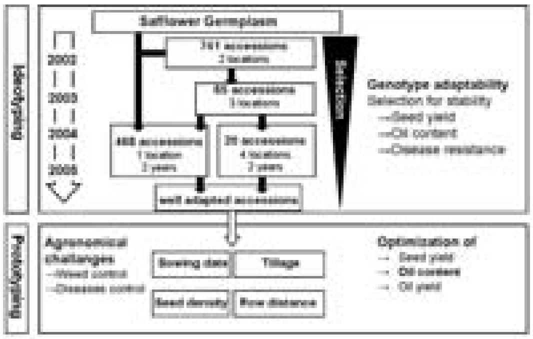

Figure 1: Methodology of searching for safflower genotypes adapted to temperate climates (Ideotyping according to Reinbrecht et al. 2005, Elfadl et al. 2008a,b).

Results and discussion

Although highly significant genotypic effects for all evaluated parameters could be observed in 2002, about 75 % of the tested accessions failed because of high disease attack and thus no seed set (not shown). Most accessions showing satisfying values originated from Europe, especially Central Europe. Figure 2 depicts in a simplified way the broad ranges for seed yield, oil content and sensitivity to head rot infestation of the 468 accessions tested in 2004 and 2005. About 5 % of the evaluated accessions had a mean oil content ranging between 20-25 %, and about 8 % showed a low sensitivity to head rot infestation between 10 and 20 %.

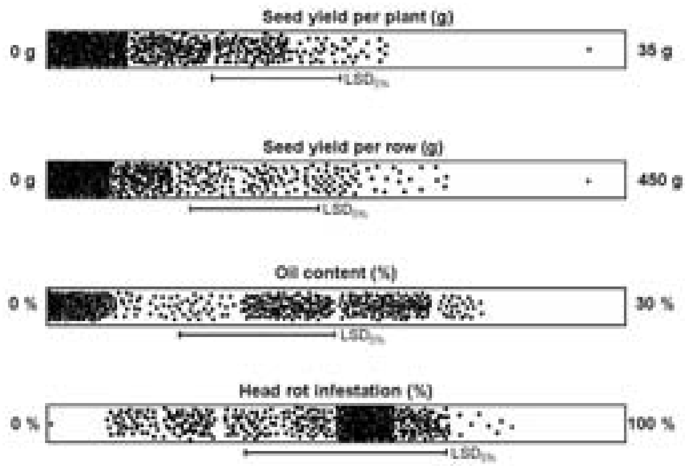

Figure 2: Ranges in seed yield, oil content and head rot infestation of 468 safflower accessions grown in 2004 and 2005 at Kleinhohenheim (means across years and locations). Each dot represents one accession. Simplified illustration according to data of Elfadl et al. (2008a).

Figure 3 shows the average ranges in seed yield, oil content and head rot infestation of the 20 selected accessions evaluated across two growing seasons (2004 and 2005) and four locations. Thirteen of the 20 selected accessions showed average seed yields ranging from 1.7 to 2.0 t ha^{-1}, with five between 2.0 and 2.2 t ha^{-1}. Oil content showed a lower variability, ranging between 21 and 23 %. Head rot infestation ranged between 13 and 28 %. Although the evaluated parameters depended on climatic factors, well-adapted safflower accessions could be identified for more humid conditions that showed satisfactory yield and oil content and low susceptibility to head rot disease. Since cultivation of the two main oil crops in Central Europe, oilseed rape and sunflower, entails several problems under organic farming conditions, such as strong attack by insects, the high demand for nitrogen, and the high susceptibility to fungal diseases, safflower is considered to be a valuable alternative oil crop for organic farming systems under temperate climate conditions.

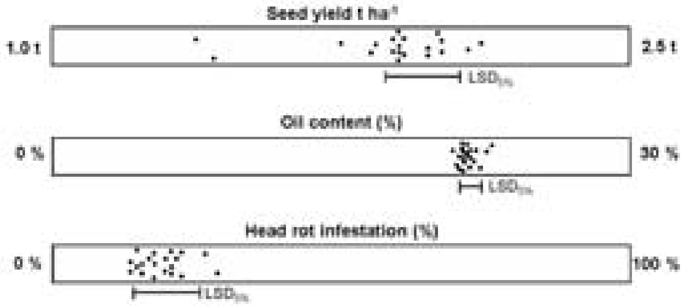

Figure 3: Ranges in seed yield, oil content and head rot infestation of 20 selected safflower accessions tested in 2004 and 2005 at four locations (means across years and locations). Each dot represents one accession. Simplified illustration according to data of Elfadl et al. (2008b).

Conclusions

The studies showed that although weather during the particular growing year had an evident impact on seed yield and oil content, safflower genotypes suitable for organic farming systems in temperate climates could be identified. However, there are still agronomic challenges to be solved, such as weed and disease control, to ensure a successful implementation in organic cropping systems. Additionally, breeding should be encouraged to increase the oil content of safflower to make it competitive with other oilseed crops.

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Effect of Biofertilizers on Agronomic Criteria of Hyssop (Hyssopus officinalis)

Tabrizi, L., Koocheki, A. & Ghorbani, R.[1]

Key words: hyssop, biofertilizer, agronomic criteria, essential oil

Abstract

An experiment was conducted under field conditions to evaluate the effects of pure or combinations of biofertilizers on agronomic and quality criteria of Hyssop (Hyssopus officinalis), a medicinal and aromatic plant from Labiateae family at the Research Station of the Faculty of Agriculture, Ferdowsi University of Mashhad, during 2006 and 2007. A complete randomized block design with three replications was used. Treatments containing Azospirillum/Azotobacter(Nitroxin), Azospirillum/Bacillus subtilis/ Pseudomonas fluorescens (Super Nitro Plus), Glomus intraradices (Mycorrhizal inoculant), Pseudomonas fluorescens, Glomus intraradices / Pseudomonas fluorescens, Azospirillum/ Azotobacter/ Glomus intradica / Pseudomonas fluorescens and a control. The results indicated that in general application of biofertilizers enhanced yield and other plant criteria in this plant. In terms of all plant criteria, the plants performed better with application of Super Nitro Plus and a mixture of Glomus intraradices and Pseudomonas fluorescens.

Introduction

Good soil fertility management ensures adequate nutrient availability to plants and increases yields. High above-ground biomass yield is obviously accompanied by an active root system, which releases an array of organic compounds into the rhizosphere (Mandal *et al.,* 2007). It is well known that a considerable number of bacterial and fungal species possess a functional relationship and constitute a holistic system with plants. They are able to exert beneficial effects on plant growth (Vessey, 2003) and also enhance plant resistance to adverse environmental stresses, such as water and nutrient deficiency and heavy metal contamination (Wu et al., 2005).

Biofertilizers are products containing living cells of different types of microorganisms (Vessey, 2003; Chen, 2006) that have an ability to convert nutritionally important elements from unavailable to available form through biological processes (Vessey, 2003) and are known to help with expansion of the root system and better seed germination. Biofertilizers differ from chemical and organic fertilizers in that they do not directly supply any nutrients to crops and are cultures of special bacteria and fungi. Some microorganisms have positive effects on plant growth promotion, including the plant growth promoting rhizobacteria (PGPR) such as *Azospirillum*, *Azotobacter*, *Pseudomonas fluorescens*, and several gram positive *Bacillus* spp. (Chen, 2006). The diazotrophic rhizobiocoenosis is an important biological process that plays a major role in satisfying the nutritional requirements of the commercial medicinal plants (Deka *et al*., 1992) The strong and rapidly stimulating effect of fungal elicitor on plant secondary metabolism in medicinal plants has attracted considerable attention and research efforts (Zhao et al., 2005).

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Azotobacter and *Azospirillum* are free-living N_2-fixing bacteria that in the rhizospheric zone have the ability to synthesize and secret some biologically active substances that enhance root growth. They also increase germination and vigour in young plants, leading to improved crop stands (Chen, 2006). Various *Pseudomonas* species have shown to be effective in controlling pathogenic fungi and stimulating plant growth by a variety of mechanisms, including production of siderophores, synthesis of antibiotics, production of phytohormones, enhancement of phosphate uptake by the plant, nitrogen fixation, and synthesis of enzymes that regulate plant ethylene levels (Abdul Jaleel et al., 2007). Arbuscular mycorrhizal fungi (AMF) are a major component of rhizosphere microflora in natural ecosystems and have been reported to form obligate symbiotic associations with most angiospermic plants, including several medicinal species (Venkateshwar Rao et al., 2000).The ability of AMF to enhance host plant uptake of relatively immobile nutrients, in particular P, and several micronutrients, has been the most recognized beneficial effect of mycorrhiza. Therefore, mycorrhizas are multifunctional in (agro)ecosystems, potentially improving physical soil quality (through the external hyphae), chemical soil quality (through enhanced nutrient uptake), and biological soil quality (through the soil food web) (Cardoso and Kuyper, 2006).

Hyssop *(Hyssopus officinalis*), which belongs to the family Labiateae, is a perennial, branched semi-shrub and one of the most important pharmaceutical herbs. Since efficient plant nutrition management should ensure both enhanced and sustainable agricultural production and safeguard the environment, the objective of the present investigation was to evaluate the .effects of different biofertilizers on growth and productivity of *H. officinalis*.

Materials and methods

This experiment was conducted over two years (2006-2007) with a complete randomized block design with three replications. Treatments containing N-fixing *Azospirillum/Azotobacter* (Nitroxin), *Azospirillum/Bacillus subtilis/ Pseudomonas fluorescens* (Super Nitro Plus), *Glomus intraradices* (Mycorrhizal inoculant), *Pseudomonas fluorescens* (P solubilizer), *G. intraradices /P. fluorescens*, *Azospirillum/ Azotobacter/G. intraradices /P. fluorescens,* and a control. A few months before the experimental practices were introduced, all plots were given 20 t ha^{-1} of cow manure. In April seeds of hyssop were mixed with different biofertlizers on the basis of 2 l ha^{-1} for Nitroxin, Super Nitro Plus, and *P. fluorescence* and for Mycorrhizal inoculant the seeds were inoculated with a proper amount of powder. Arabic gum was used as surfactant. Seeds were planted in early April in plots of 2×2 m in rows 50 cm apart with 40 cm separation between plants in rows. The field was managed organically, with no application of chemicals including fertilizers and pesticides. In the flowering stage, morphological parameters such as plant height and plant diameter were measured in the samples from 1 m^2 of each plot, then the plants were cut at a height of 10 cm above soil level and dried in a shaded area. Dry weight of aerial parts and essential oil content were determined. The essential oil content of the dry herbage was determined by hydro-distillation for 3 h, using a Clevenger-type apparatus. Since this investigation was to compare the treatments' effects in two years, the analysis was done as a split plot design in time, using SAS statistical software (SAS Institute, 2002).

Results

Table 1 shows that as expected, although there were some differences in plant height among different biofertilizer sources, the differences were not considerable. However, a pronounced difference could be seen between the control and biofertilizers. This was also true for plant diameter, where the trend was almost the same as with plant height. In other words biofertilizers affected plant height and plant diameter in the same manner.

Although dry weight showed no significant difference in response to biofertilizers, the yield in biofertilizered plots were 2-3 times higher than the control. In addition, applications of Super Nitro Plus and a mixture of *G. intraradices* and *P. fluorescens* were more effective in terms of all these plant criteria. A similar trend as with dry matter yield was also observed for essential oil yield. However, no significant effect was observed between control and biofertilizers in terms of percent of essential oil.

Tab. 1: Mean values for agronomic criteria of hyssop grown under different biofertilizers

Treatments	Height (cm)	Diameter (cm)	Dry Weight (gm^{-2})	Essential Oil (%)	Essential Oil Yield (gm^{-2})
B1	54 ab	35 c	566 a	0.7 a	4 a
B2	59 a	44 a	629 a	0.8 a	4 a
B3	52 ab	37 bc	470 a	0.7 a	3 a
B4	52 ab	39 b	558 a	0.7 a	4 a
B5	55 a	39 b	591 a	0.8 a	4 a
B6	53 ab	38 bc	586 a	0.7 a	4 a
Control	48 b	28 d	279 b	0.8 a	2 b

B1: Azospirillum/Azotobacter, B2: Azospirillum/B. subtilis/ P. fluorescens, B3: G. intraradices, B4: P. fluorescens, B5: G. intraradices /P. fluorescens, B6: Azospirillum/ Azotobacter/ G. intraradices /P. fluorescens, Means in each column followed by the same letter are not significantly different ($P<0.05$) using Duncan's Multiple Range Test.

Discussion

Productivity in an ecosystem is influenced by several factors, such as availability of nutrients and water. In the present study, increases in agronomic criteria were observed following inoculation with biofertilizers. This may be due to better utilization of nutrients in the soil through inoculation of efficient microorganisms. A positive effect of biofertilizers on plant height and diameter has been reported in the literature (Migahed *et al*., 2004).

In addition, higher dry matter production by the inoculated plant might be because of the augmented uptake of N and P, which in turn was a consequence of the root proliferation. Also, the increased growth parameters in hyssop might be due to the production of growth hormones by the bacteria. Ratti *et al.* (2001) found that a combination of the arbuscular mycorrhizal fungi (*G. aggregatum)*, the PGPR (*B.*

polymyxa) and *A. brasilense* maximized biomass and P content of the aromatic grass palmarosa (*Cymbopogon martinii*) when grown with an insoluble inorganic phosphate.

In general it appears that, as expected, application of biofertilizers improved yield and other plant criteria; this has also been reported elsewhere (Venkateshwar Rao *et al*., 2000). Therefore, it appears that application of these biofertilizers could be promising in production of medicinal and aromatic plants.

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Comparison of Different Intercropping Arrangements of Cumin (*Cuminum cyminum*) and Lentil (*Lens culinaris*)

Jahani, M., Koocheki, A. & Nassri Mahalati, M.[1]

Keywords: row intercropping, strip intercropping, cumin, lentil, LER.

Abstract

To evaluate the effect of different intercropping pattern of cumin and lentil on plant growth and yield, an experiment was conducted in Agricultural Research Station of Ferdowsi University of Mashhad, Iran in the growing season of the year 2004. Treatments were: A: row intercropping of cumin and lentil B: strip intercropping of cumin and lentil (three cumin rows and three lentil rows) C: strip intercropping of cumin and lentil (four cumin rows and four lentil rows) D: sole crop of cumin (six rows) E: sole crop of lentil (six rows). For this purpose a complete randomized block design with 4 replications was used. Results showed economic and biologic yield of cumin, 1000-seed weight, number of seed per umbel were affected by different intercropping and there was a decreasing trend in these parameters from intercropped to the sole crop. Biological and economic yield and also harvest index for lentil were higher in sole crop compared with intercrop. The highest Land Equvalent Ratio -LER (1.86) was obtained from treatment A (row intercropped) and the least (1.26) was obtained in treatment C (strip intercropped). There was a decreasing trend in LER from row intercropped to strip cropping.

Introduction

Intercropping has been considered as one of the practice for enhancing biodiversity of cropping system and it has been reported to increase sustainable yield production when it is done particularly with combination of medicinal plant and a field crop the beneficial effect may be increased (Guldan, *etal*.1999). In other words intercropping crops such as lentils (nitrogen fixer) with medicinal plants may increase nitrogen availability for the medicinal plants. Also intercropping lentil with other plants has been reported to reduce lodging and thereby facilitating mechanical harvesting of lentils (Bagheri, *etal.* 1998).

Pulses are the second source of food after cereals for humans. Lentil which is a pulse crop is an important crop in Iran with more 260.000 ha. Iran ranks forth in term of lentil acreage (Sabaghpour, et al. 2003). Cumin is an important medicinal cash crop of Iran with 35.811 ha (Kafi, *etal*. 2003). Iran is the major cumin producing country and the main growing area is Khorasan province. Growing nature of cumin and lentil are almost similar in terms of period of growth, time of sowing and scale of biomass production and therefore intercropping of these two plants is facilitated. The purpose of this study was to evaluate intercropping cumin and lentil with different planting pattern in terms of feasibility of intercropping and yield advantages.

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Materials and methods

Our experiment was conducted in 2004 as a Complete Randomized Block with four replications and five treatments including different planting pattern for lentil and cumin:

-Row intercropping of lentil and cumin

-Strip intercropping of lentil and cumin with three rows each

-Strip intercropping of lentil and cumin with four rows each

-Pure stand of lentil and cumin

Seeds were sown in April on rows at a distance of 25 cm. The distance in the rows was 10 cmr for lentils and 5 cm for cumin. At the time of harvest total biomass and yield and yield components were measured. Land Equivalent Ratio, which shows relative area under sole crop to achieve intercrop yields under the same conditions, was calculated as follows:

$$LER= I_a/S_a+I_b/S_b$$

where LER is land equivalent ratio , I= multiple cropping yield, S= sole cropping yield and a, b refer to the component crop.

Statistical analysis of the results was carried out by MSTAT-C software. For the comparison of means Duncan Multiple Range Test (DMRT) was used.

Results

Table 1 and 2 show different plant criteria associated with intercropping pattern. As it is apparent plant height for both cropping was not affected by planting pattern but out of the expectation height of plant particularly for lentil was somehow higher in pure stand.

Biological yield in row intercropping was somehow more than strip intercropping. However, in case of lentil biological yield in pure stand was much higher compared with the other treatments.

Harvest index for both plant species was higher in pure stand. Similar findings have been reported elsewhere (Abbasi, 2005). Economic yield for lentil was also higher in pure stand. This was not the case for cumin and in general yield in intercropped plots was slightly higher than in strip intercropped plots.

Thousand seed weight was higher in intercropped than in other systems. There are reports (Calavan & Weil 1988) which confirm our results.

Tab. 1: Yield structure of lentils under intercropping and strip cropping

Treat-ment	Biological yield (kg/ha)	Har-vest index	Econ. Yield (kg/ha)	Thousand seed weight (g)	Number of pods per plant	Number of seeds per pod	Par-tial LER	Total LER
A	2651^{b}	0.17^{ab}	453^{b}	35.55^{a}	2.12^{a}	1.43^{a}	0.53^{b}	1.9a
B	2272^{c}	0.13^{b}	302.3^{c}	21.32^{b}	1.55^{b}	1.25^{b}	0.36^{c}	1.5b
C	1047^{d}	0.13^{b}	185.1^{d}	20.89^{b}	1.27^{b}	1.1^{b}	0.22^{d}	1.3c
D	3159^{a}	0.2^{a}	858.9^{a}	25.29^{b}	1.36^{b}	1.25^{b}	1	

significant for P<0.05

A-Row intercropping of lentil and cumin, **B**-Strip intercropping of lentil and cumin with three rows each, **C**-Strip intercropping of lentil and cumin with four rows each, **D**-Pure stand of lentil and cumin

Number of pods per plant for lentil and number of umbels per plant for cumin was also higher in intercropped. However for cumin no differences were observed between different planting patterns. This was also to some extent true for number of seeds per pod for lentil and number of seeds per umbel for cumin.

In general partial land equivalent ratio for cumin was higher than for lentil. Total land equivalent ratio for intercropped was higher than for pure. It appears that intercropping of cumin and lentil is advantageous compared with sole cropping.

Tab. 2 Yield structure of cumin under intercropping and strip cropping

Treat-ment	Biological yield (kg/ha)	Har-vest index	Econ. Yield (kg/ha)	Thousand seed weight (g)	Number umbels per plant	Number of seeds per pod	Par-tial LER	Total LER
A	1220^{a}	0.33^{d}	394.2^{a}	1.757^{a}	15.49^{a}	17.74^{a}	1.34^{a}	1.86^{a}
B	803.7^{b}	0.42^{c}	339.9^{b}	1.375^{ab}	18.67^{a}	9.29^{ab}	1.14^{b}	1.5^{b}
C	598.1^{c}	0.51^{b}	308.8b^{c}	1.34^{ab}	16.91^{a}	7.87^{b}	1.04^{bc}	1.26^{c}
D	505.7^{c}	0.58^{a}	298.6^{c}	1.056^{b}	16.15^{a}	8.71^{b}	1	

significant for P<0.05

A-Row intercropping of lentil and cumin, **B**-Strip intercropping of lentil and cumin with three rows each, **C**-Strip intercropping of lentil and cumin with four rows each, **D**-Pure stand of lentil and cumin

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Yield and quality of organic versus conventional potato crop

Mourão, I.[1], Brito, L.M.[1] & Coutinho J.[2]

Key words: Compost, N uptake, nutrient content, potato grades.

Abstract

The improvement of organic fertilization practices is essential to increase organic potato production in the highland region of NW Portugal, with environmental benefits and better returns. For that reason, the response of organic potato was evaluated throughout a randomized block design experiment, with two cultivars (Raja and Virgo) and increasing rates of composted organic pig manure (0, 15, 30 and 45 t ha^{-1}). These cultivars were also grown with mineral N fertilizer (120 kg N ha^{-1}) under conventional practices to compare the results between crop systems, 30, 45, 60, 80 and 125 days after planting.

Crop yield was not improved with increasing rates of compost application because the N mineralization rate of the compost was small and soil organic matter was high (8%). Organically grown cv. Virgo yielded 66.0% of the conventional crop, whereas Raja yielded 46.6%. The N uptake of the organic crop (tubers and foliage) was 37.0 kg ha^{-1} for Raja and 50.5 kg ha^{-1} for Virgo, respectively 21.1% and 27.8% of the N uptake by the same cultivars grown with mineral fertilizer. Although foliage N content was increased for the conventional crops, differences between N content of organic and conventional tubers were not significant, as well as for K, Ca and Mg.

Introduction

In Portugal, 233.5 thousand hectares were under organic farming in 2005, where herbaceous crops represented 85.4%, mainly with pasture (77.6%) and only 1.4 thousand hectares with vegetables or aromatic plants. The remaining area of 34.1 thousand hectares included olives (82.6%) followed by dry fruits (10.3%), fresh fruits (3.8%) and viticulture (3.3%) (IDRHa, 2007). The small area of organic production and the increasing consumption of horticultural organic products in Portugal is a scope for increasing home production. In addition, considering the potential environmental benefit of organic production, the highland regions as in NW Portugal may take this advantage, at the same time as higher agricultural returns could be taken from organic compared to conventional agriculture, leading to a more sustainable rural development.

Yield is frequently limited by nitrogen (N) availability in organic production and soil amendment with organic fertilizers is a current practice for soil nutrient replenishment. However, there is much uncertainty regarding the rate of N mineralization and the time required for organic fertilizers to release sufficient mineral N for crop growth. The objective of the present work was to evaluate organic potato growth, N uptake and

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tuber quality with soil application of composts and to compare organic with conventional production.

Materials and methods

A randomized block design experiment with 3 blocks was performed on a sandy loam soil (pH 4.9 and OM 80.05 g kg^{-1}), at 680 m high, in NW Portugal, with potato (*Solanum tuberosum L.*) organically produced with the application of 0, 15, 30 and 45 t ha^{-1} of composted pig manure with straw from an organic farm (table 1). Two certified cultivars were used, Raja (B1) and Virgo (B2) (Eurobatata), of 35-45 mm grade. Sprout emergence was induced before planting. Planting took place on 4 May 2005, with a plant spacing of 0.75 m x 0.3 m, and tubers were placed at 10 cm depth. Each experimental plot with 22.5 m^2 included 4 plant rows. The crop was sprinkle irrigated at 48 and 75 days after planting and hand weeding was carried out at 43 days after planting. The crop was sprayed against late blight (*Phytophthora infestans*) with copper hydroxide (Kocid DF) on 6, 17 and 24 of June and control of Colorado potato beetles (*Leptinotarsa decemlineata*) was performed with pyrethrum (Pelitre Hort) on 2 and 15 of June. In a nearby farm, with a similar soil type (pH 4.7 and OM 80.0 g kg^{-1}), a conventional potato crop experiment with 3 blocks was carried out, with the same cultivars planted in the same day. This included mineral fertilizer application (120 kg N ha^{-1}). Comparisons with the organic experiment were made by using the t test. All crops were monitored 30, 45, 60, 80 and 125 days after planting, based on 4 plants of each replicate treatment, to quantify the number of stems, fresh and dry (70ºC, 2-4 days) weights of tubers and foliage and N, P, Ca and Mg tuber content at commercial harvest. Mean daily air temperature was 17.4ºC (ranging from 8.1 to 26.2ºC), daily mean soil temperature (10 cm) was 16.7ºC (ranging from 9.5 to 19.7ºC) and rainfall was 257.0 mm during the growing period.

Compost pH was measured with a pH meter in samples extracted with water at 22ºC±3ºC in an extraction ratio of 1:5 (v/v) and the specific EC was measured in the same extract with a conductivity meter. For the organic matter (OM) determination, compost samples were dried at 103ºC, then ashed at 450ºC in a muffle furnace. The N content of the sample was determined using a modified Kjeldahl method based on a sulphuric acid/potassium sulphate digestion and copper selenium catalyst, with a Kjeldahltherm digestion unit and a compact distillation unit. Mineral N of fresh compost samples was extracted with KCl 2M 1:5. Mineral N content of the extracts (NH_4^+-N and NO_3^--N) were determined by molecular absorption spectroscopy in a segmented flow analyser system equipped with dialysers to prevent interferences from colour or suspended solid particles in the extracts. For the C/N ratio calculation, C content in compost was estimated by dividing the OM content by a factor of 1.8.

Tab. 1: Characteristics of the pig manure composted with straw.

DM (%)	pH	EC (dS m^{-1})	OM (g kg^{-1})	C/N	N-NO_3^- (mg kg^{-1})	N-NH_4^+ (mg kg^{-1})	N (g kg^{-1})	P (g kg^{-1})
25.3	7.1	0.41	495.3	14.1	1.4	201.8	19.5	9.9

Results

Throughout the growing period and at harvest (125 days after planting), crop yield was similar for all organic crop treatments and to the crop without organic fertilizer application. Yield of cv. Virgo (27.5 t ha^{-1}) was higher than cv. Raja (20.1 t ha^{-1}). Cultivar Virgo yielded 66.0% and cv. Raja 46.6% in comparison to conventional crops (fig. 1). However, commercial tuber yield (tuber >45 mm) was 29.4% and 46.8% for Virgo and Raja cv. respectively, compared to conventional crops. The total number of tubers was similar for all organic and conventional crop treatments, but the number of commercial tubers was higher in the conventional crops (fig. 1).

Nutrient content for organic crops was 8.9 g N kg^{-1}, 2.0 g P kg^{-1}, 4.2 g Ca kg^{-1} and 0.70 g Mg kg^{-1}. Differences between N, K, Ca and Mg content of organic and conventional potatoes were not significant. N uptake was 37.0 kg ha^{-1} for Raja and 50.5 kg ha^{-1} for Virgo cv, respectively, 21.1% and 27.8% of the N uptake by the same cultivars grown with mineral fertilizer (fig. 2). The N recovery rate for the mineral N application in conventional crops was 54.6% and 36.0%, respectively, for Raja and Virgo cultivars. Dry matter content of tubers was different for both cultivars, respectively, 23.2% and 18.9% for Raja and Virgo cultivars. Conventional potatoes of cv. Raja had significantly lower dry matter (22.1%) compared to organic potatoes (24.3%).

Discussion

Crop yield was not improved with increasing rates of compost application because the N mineralization rate of the compost was small and soil organic matter was high (8%). Compost utilization in soils with very high OM content may be beneficial to maintain soil fertility. However, the compost used in this experiment had a higher ammonium content compared to the nitrate content, indicating that compost was not completely mature and could immobilize soil mineral N, decreasing N availability to the crop. Therefore, compost should be more mature and must be evaluated in soils with a lower OM content.

The organic potato yield in this experiment compared to conventional yield was similar to that reported by Mäder et al. (2002) of 40% and Tamm et al. (2004) of 50 to 80% of conventional yields. Rembialkowska (2005) reported higher P and Mg tuber content in organic compared to conventional potatoes. Here, in agreement with Quenum et al. (2004), differences between these two systems were not significant.

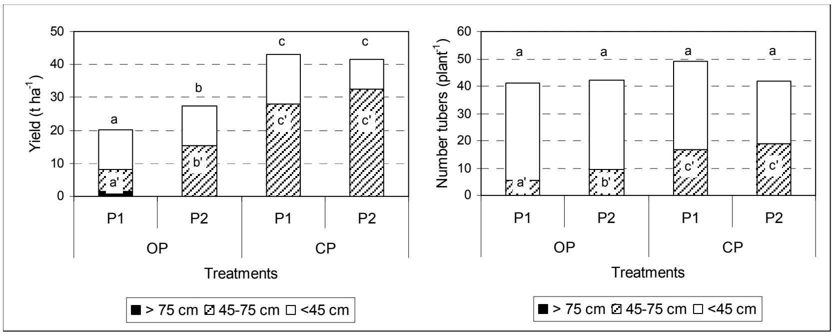

Figure 1: Potato yield (t ha^{-1}) and number of tubers ($planta^{-1}$) per each grade at commercial harvest, for cv. Raja (P1) and cv. Virgo (P2), organically grown (OP) (mean of the 3 compost rates) and for conventional crops with mineral fertilization (CP). Different letters means significant differences between crop treatments.

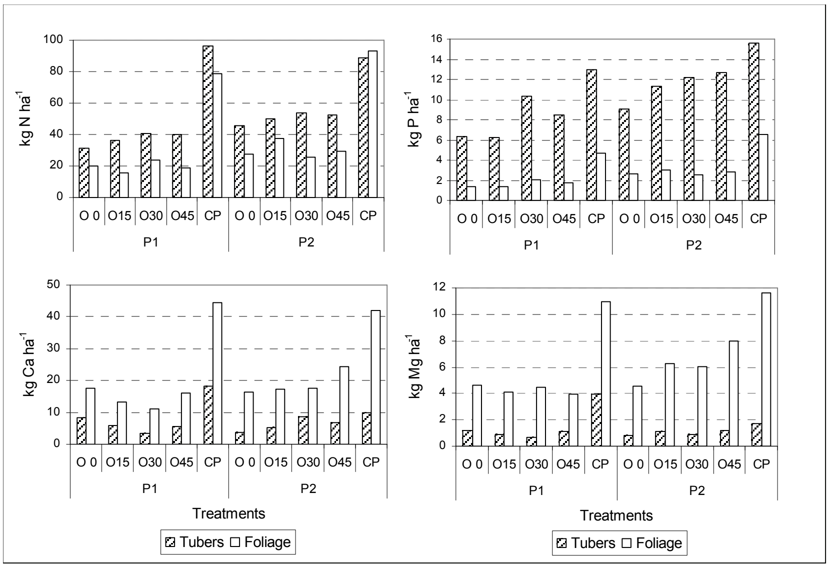

Figure 2: Nutrient extraction (kg nutrient ha^{-1}) by the foliage (80 days after planting) and by tubers at final harvest (125 dap), of nitrogen (N), phosphorus (P), calcium (Ca) and magnesium (Mg), for cv. Raja (P1) and cv. Virgo (P2) and for the 0, 15, 30 e 45 t ha^{-1} compost rates application.

Acknowledgments

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Quality of thyme herb (*Thymus vulgaris* L.) from organic cultivation

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Abstract

In five field experiments the quality of thyme herb and usefulness of Polish cultivar 'Słoneczko' for organic cultivation were tested. The following features were tested: dried herb yield, stem content in dried herb, essential oil content, nitrate content, macro- and microelements content and microbiological purity. Only from Słońsk thyme herb yield was higher compared with the yield from conventional cultivation though it contained high amount of stems. Thyme herb was characterized by higher content of essential oil and increased content of macro- and microelements except calcium. Evaluation of microbiological purity showed that for both types of cultivation herb contamination did not exceed standard for raw materials treated with hot water.

Material and Methods

The main aim of field experiments was the investigation yield and quality of organically produced raw material of thyme. In 2005-2006 the experiments were carried out in five different locations of Poland: Cedry Wielkie (north), Wiry (south-west), Bolewice and Plewiska (central), Słońsk (west). The experiments were established in the randomized complete block design in three repetitions. Each plot had 10 m^2. Thyme cultivar 'Słoneczko' was examined for its usefulness for organic cultivation. Seeds were sown directly to the soil in rate 6 g/plot [1]. At the end of August raw material was collected by hand, from the area of 1,0 m^2 of each plot. The herbs were dried in natural conditions, in a shaded and well ventilated places.

The raw material from the conventional cultivation from Plewiska was used as a control.

The following traits were estimated: total yield of dried herb, content of stems in dried herb, essential oil content, macro- and microelements content, N-nitrate content and the microbiological purity.

The essential oil was hydrodistillated with Dering's apparatus from herb without stems following the methods recommended by Polish Pharmacopoeia VI [3].

To determined macro- and microelement content the plant material was subjected to „wet" mineralization:

1. in sulphosalicylic acid, sodium thiosulphate and selenium mixture in order to determine N-total by distillation method with Parnas-Wagner apparatus,

2. in concentrated sulphuric acid to determine P colorimetrically with ammonium vanadomolybdate and K, Ca, Mg, Fe, Zn, Cu, Mn by the method of atomic absorption (ASS) [4,5].

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N-nitrate content in dried herb was determined by Bremner distillation method in modification done by Starck after extraction in 2 % acetic acid [5].

In Microbiology Laboratory the evaluation of raw material microbiological purity was carried out following Polish Pharmacopoeia VI standards for raw materials treated with hot water (gr. III e) [3]. Number of aerobic bacteria, number of yeasts and moulds and number of *Escherichia coli* were estimated in dried herb. Additionally the number of intestine bacteria from family *Enterobacteriaceae* was evaluated. Investigations were done after 6 and 12 months of storage in darkness and room temperature.

The obtained data were evaluated by analysis of variance. The mean values were compared by the use of Students' t test with the confidence level of 5%.

Results and Discussion

The yield of dried thyme herb varied from 120,1 (Cedry) to 1150,0 g/m^2 (Słońsk) and was significantly different (table 1). Stem content in thyme herbs was also significantly different and oscillated from 34 (Wiry) to 49 % (Słońsk). The yield of herb from Słońsk contained a lot of stems and was higher than that from conventional cultivation. Following the breeder's characteristic of thyme cultivar 'Słoneczko' stem content should not be higher than 34 % (Seidler-Łożykowska. & Kazmierczak 2001).

Tab. 1: Thyme herb yield [g/m^2], stem content [%], essential oil [%] and N-nitrate content [mg/kg d.m.]

locality	Dried herb yield	Stem content	Essential oil content	N-N0$_3$ content
Bolewice	155,2 ab	39 a	2,20 b	250,0
Cedry W.	120,1 ab	39 a	1,93 a	trace
Plewiska	293,9 b	38 a	2,35 b	trace
Słońsk	1150,0 c	49 b	2,18 b	118,5
Wiry	162,2 ab	34 a	2,37 b	trace
Cont. Plewiska	437,8 b	38 a	2,00 a	425,0
LSD $_{0,05}$	203,07	7,77	0,222	-

Essential oil content ranged from 1,93 (Cedry W.) to 2,37 % (Wiry) and was high in all the experiments; these results exceeded the one given by Dachler and Peltzman (1999) ranging between 0,5 and 1,5 %.

The content of N-nitrate in dried herb oscillated from traces (Cedry, Plewiska, Wiry) to 425,0 mg/kg d.m. (control) and varied according to its origin. Different results were obtained by, who analyzed nitrate content in medicinal plant raw materials of different origin. In her experiment the range of nitrate content oscillated from 207,9 (St John's wort herb) to 16 921,0 mg KNO_3/kg d.m. (nettle herb). Ours and the cited study of Leszczyńska (1999) showed that although spices are used in small amounts in daily diet, the nitrate content should be regarded while day allowance intake (ADI) is calculated. The mean content of nitrogen, phosphorus, potassium, magnesium and microelements (Fe, Mn, Cu, Zn) was higher in the organic thyme herb compared to conventional one, except the content of calcium (table 2).

Tab. 2: Macro- [%] and microelements [ppm] content in thyme herb

element	Organic cultivation		Conventional cultivation Plewiska
	range	mean	
N	1,89 - 2,70	2,28	2,12
P	0,22 - 0,40	0,30	0,35
K	2,07 – 2,50	2,35	2,07
Ca	1,09 – 1,89	1,42	1,54
Mg	0,31 – 0,51	0,39	0,27
Fe	251,2 - 725,2	552,0	404,10
Mn	25,9 – 334,5	146,6	54,90
Cu	12,3 – 18,2	15,2	8,10
Zn	56,9 – 116,8	87,3	65,10

In organic herb the content of Fe, Mn and Cu was higher, while in conventional herb Fe and Cu content was lower compared with the results obtained by Marsh et al. [9]. According to Kabata-Pendias and Pendias (1999) in Polish climatic conditions Cu content ranged from 5 – 20 mg kg^{-1} (Kabata-Pendias & Pendias 1999). The levels of Cu content in herbs obtained from both types of cultivation could be placed in the ranges set also by Suchorska-Orłowska et al. 2006. The results of microbiological analysis showed a great diversification of microbiological contamination of thyme herb depending on its origin (table 4). The most contaminated herb was from Słońsk and the lowest – from Bolewice. Though, all of the investigated herbs were below the level of standard contamination. Soil and organic fertilization are the main sources of microbiological contamination of raw material. After 12 months of storage the microbiological contamination of storage herb was diminished in the different rates. According to Kędzia (1999) there are two main reasons of this process: 1. bacteria have different susceptibility for dryness and 2. plant active substances (essential oil, anthocyanins and tannins) have strong effect on raw material microbes. Although *Escherichia coli* content was very low in all tested trials, the contamination of raw material organically produced should be controlled, following the fact that manure is a basic type of fertilization there.

Tab. 3: Microbiological purity of thyme after 6 and 12 months of storage

locality	Aerobic bacteria in 1g		Yeasts and moulds in 1g		*Enterobacteriaceae* in 1g		*Escherichia coli* in 1g	
	6 m	12 m	6 m	12m	6 m	12m	6 m	12m
Bolewice	41. 500	29.000	20	10	4.000	100	<10	<10
Cedry W.	430.000	32.000	420	10	41.000	100	<10	<10
Plewiska	485.000	34.000	125	40	4.000	850	<10	<10
Słońsk	780.000	32.500	7.400	140	91.500	500	<10	<10
Wiry	240.000	27.500	245	10	7.500	240	<10	<10
Control Plewiska	357.500	45.000	130	20	1.200	70	<10	<10
Standard	10.000.000		100.000		-		100	

Conclusions

Thyme herb yield only from Słońsk was higher compared with the yield from conventional cultivation. The quality of thyme herb from organic cultivation (essential oil, macro- and microelements content, microbiological purity) was high but not higher than the one from conventional cultivation. Thyme cultivar 'Słoneczko' is suitable for both organic and conventional cultivations.

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Amaranth farming: Rural sustainable livelihood of the future?

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Key words: Poverty, amaranth, sustainable livelihoods, value chain.

Abstract

Though amaranth has been studied intensively for its exceptional nutritional properties, little has been reported about its capacity for fighting poverty, securing food supplies, turning migrations, or its impact on the environment and the prospect for improvement of living conditions of those farmers cultivating amaranth. This paper addresses possibilities and limitations that Mexican small-scale farmers are facing to enhance sustainable livelihoods in the amaranth value chain. The study reveals that amaranth, as an alternative crop and livelihood, is perhaps one of the most complete endogenous natural resources that small-scale farmers have to combat the above-mentioned problems. The study identified several local and regional barriers for increasing the level of farming, production, processing and consumption. A striking and paradoxical limitation is the monopolization practices developed by some of the associations in relation to knowledge and technology transfer, seeds distribution and contact to potential national and foreign buyers.

Introduction

The rural areas of Mexico are hosting 60.7% of the country's extreme poor. Currently 25% of the Mexican population is undernourished, most of them are children from 0-5 years old (CONAPO 2006). The rural poor live mainly in the central and southern regions of Mexico, which have witnessed massive migration, economic instability, environment degradation and paradoxically, most of the small-scale organic farmers are currently located here, and that includes *the farming of amaranth too*. So why, when amaranth has been suggested as an alternative crop by The Food and Agriculture Organization of the UN to combat poverty and undernourishment 30 years ago, do the farmers still suffer from these problems? Our study (Bjarklev 2007) discusses the following question: What are the possibilities and limitations that small-scale farmers in Mexico are facing to enhance sustainable livelihoods in the amaranth value chain? We defined sustainable livelihoods as "the capabilities, assets (*capitals*) and activities for means of living. A livelihood is sustainable, when it can recover from stress and shocks and can maintain and enhance its capabilities and assets both now and in the future, while not undermining the natural resource base" (Carney 1998).

Materials and methods

The study was based on the Sustainable Livelihoods approach (Dalal-Clyton 2003), Value Chain and Clusters theories (Porter 2000). On that basis we constructed the analytical model shown in Figure 1. We analysed the context of each of the links of the amaranth value chain. These are supported by five types of *capitals*: human, financial, economic, natural and social, that either limit or enhance the capacity for development of each link of the value chain. The dimensions of sustainability are

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given by the enhancement or reduction of the capitals possessed by the actors. We conducted 25 in-depth individual interviews with actors involved in the Mexican amaranth value chain, 17 of which were tape recorded. We selected two cases in Central region of Mexico that traditionally cultivate amaranth: Sociedad Mexicana de Amaranto (conventional farming) and Quali (organic farming), both promoting the cultivation of amaranth as an alternative crop and livelihood for small-scale farmers. Our focus in this paper will be on Quali. Quali is an umbrella cooperative formed by non-farmer members from an NGO called Alternativas, but includes persons with specific knowledge about amaranth seeds and growing cuttings, processing and sale of amaranth.

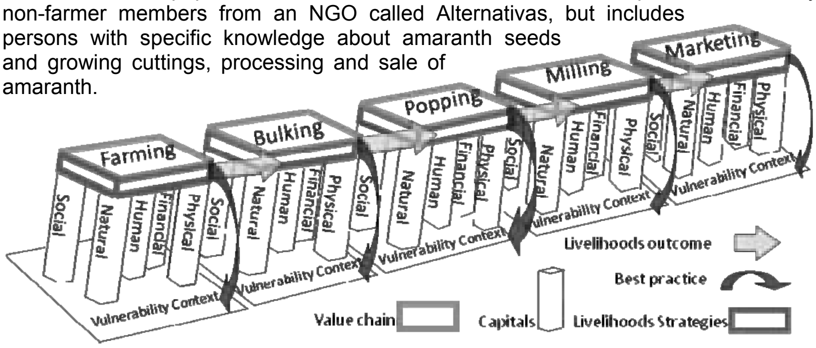

Figure 1: Schematic links in a value chain based on sustainability dimensions.

Though the intention was to get in direct contact with the small-scale farmers associated to this cooperatives, and although the cooperatives had agreed to that beforehand, the representative of both associations deliberately did all to avoid direct contact with the farmers associated. Due to the rejection of establishing contact with the associated small-scale farmers, interviews were conducted with 6 small-scale amaranth farmers that did not belong to these cooperatives in Puebla, Tlaxcala and Mexico City. In the Mexican value chain we also talked to small-scale manufacturers and small-scale sellers, representatives and researchers from Mexican State institutions, as the latter have regular contact with the mentioned cooperatives. In Europe we interviewed whole dealers, Kaffeklubben (a Danish fair trade consumer association) and CARITAS Denmark. Derived from the analytical model, we structured the project in five main sections as follows:

<u>What it is the amaranth farmer's current contextual situation</u>? The small-scale farmers conserve a huge diversity of amaranth varieties and, therefore, one of their main resources is the biodiversity. They also conserve traditional indigenous knowledge about farming the land and it opens possibilities for an easy adoption of *organic farming* principles and thereby possibilities for export to the EU market. However, the lack of infrastructure to capture rainwater and information on when and how to optimally irrigate amaranth is limiting its cultivation and not least prospects for increased yield. Quali representatives expressed that the organization has an extensive experience on these issues; however, the results are not published. The small-scale farmers' main complaint in the region, where Quali operates, was the lack of water for irrigation. Amaranth tolerates droughts, saline soils, and half of the water required to produce maize and wheat. This makes amaranth perhaps one the most

valuable natural capitals for small-scale farmers in the central and southern region of Mexico, but the monopolization of knowledge by the cooperative limits its use.

What are small-scale farmers' main strengths and limitations? Though the representative of the cooperatives claimed to possess considerable knowledge about certification, technology, processing, marketing, and export, this knowledge is centralized and distributed unevenly. Sociedad Mexicana del Amaranto has made efforts to communicate its results, but mainly through the Internet reaching only the already well-established farmers. Quali *does not publish* its results and according to government institutions even its associated members (the small-scale farmers) have difficulty accessing knowledge and information about amaranth farming. Quali does not allow its associated small-scale farmers to self commercialise amaranth products (not even locally) and the organic certification does not follow the farmer, if he/she decides to be independent of Quali. According to the interviews with Quali's representative, the economic benefits derived from the sale of amaranth are not allocated directly to the associated farmers neither are they involved in taking decisions on the processing and trading links. The explanation was that associated farmers *are not part of the cooperative as owners or co-owners*. As a paradox, the results of this investigation indicate that farmers that are organized in producer cooperatives but independent of the mentioned associations *seem to* have better and direct access to *physical* and *financial* capitals. The interview with the Agricultural Secretariat in Mexico revealed that small-scale farmers access to *financial capital* is very limited, as the government programmes are directed to the agro-industry, because the literacy level, the lack of access to the Internet, and the variety of languages spoken by small-scale farmers, and not least because credits are directed mainly to the processing and trade link but not to the farming level. As such the government programmes work in favour of the cooperatives to become the channel for small-scale farmers to potentially capture part of the subsidies allocated for amaranth.

What strategies where adopted and how where they implemented? The support from the Mexican Government to research centres or universities is very restricted - therefore the potential for transfer of knowledge to the small-scale farmers is limited. The main actors involved in the amaranth value chain in Mexico have been cooperatives or similar organizations focusing on the bulking of amaranth seeds, the processing and marketing of amaranth. The field study revealed that the cooperatives monopolize the knowledge about appropriate farming techniques (labelled the technological package by one of the cooperatives), certification and financial funding of projects related to marketing amaranth. The interviews with Mexican research institutes and government agencies indicated that Quali does not even distribute or share knowledge and experience among their own associated members, not to mention other cooperatives or local or regional research institutes. Similarly, the international cooperation is monopolized by a few organizations.

What are the main limitations and possibilities in the amaranth chain? The study revealed that the Mexican amaranth production is characterized by being controlled by national cooperatives. Lately, international companies have begun to penetrate the national amaranth value chain by establishing contact with Mexican small-scale farmers to set up a global amaranth value chain. One of these initiatives has been curbed by the dominant cooperative Quali who controls most of the national amaranth chain. Quali has made it impossible for external actors to get in contact with the small-scale amaranth farmers. According to the European dealers, the fact that the contact needs to be done through these cooperatives is linked to the fact that there is not a register elsewhere to find the small-scale organic amaranth farmers. Mexican small-scale farmers that have tried to expand the Mexican amaranth chain have experienced difficulty in accessing the European markets due to the high standards on labelling, product information and quality control. There are many potential branches in which the amaranth production can be diversified (e.g., oil or milk). The diversification and the conservation of the already existing ones *depend on a sure and sufficient supply of seeds*. In this relation, the small-scale farmers confront a series of limitations such as: low yields due to limited research and information about crop varieties and techniques, and an ineffective distribution of already improved varieties due to monopolized practices of the mentioned cooperatives. These practices undermine the small scale farmers' social capital. The interviewees voiced that they felt betrayed by the cooperatives and had difficulty in trusting any such organization.

Where can changes be made and what can be done to enhance small-scale farmers capitals in the amaranth value chain? The amaranth production chain may today be characterized as producer-driven, since there is little consumer knowledge about amaranth. Besides there are no amaranth consumer associations in the national market – or in the EU market. The existence of such associations could secure the amaranth small-scale farmers more influence in the value chain. Taking into account cluster theories, revealed that the Mexican government is currently focusing on the processing phase. However, targeting the *farming phase* and in particular the small-scale farmers should be given priority in order to support the whole farmers' influence on the amaranth value chain.

Conclusions

Initiatives that support the small-scale farmers active participation in the cooperatives are vital for ensuring the fair distribution of knowledge and ensuring consumers more information about amaranth and small-scale amaranth farmer's welfare. The monopolistic practices favoured by the cooperatives in the amaranth value chain are actually setting the strongest barrier for expanding the amaranth production and for furthering a sustainable livelihood for small-scale amaranth farmers. Consumers' associations both at the national and even more important in the European markets could reverse this pattern if they demand a more active and tangible participation of the small-scale farmers associated to cooperatives controlling the national amaranth value chain. The Mexican government could play a more active role supporting small-scale livelihoods by setting higher demands to cooperatives in order to include effectively small-scale farmers as real partners or co-owners. Considering the whole value chain: from *farming* to the final consumers, and not only the manufacturing process, is vital for furthering sustainable livelihood in amaranth.

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Organic vegetable production

Mineralization of lupine seed meal and seedlings used as N fertilizer in organic vegetable production

Katroschan, K.[1] & Stützel, H.[1]

Key words: C:N, lupine seedlings, lupine seed meal, N mineralization, organic fertilizer

Abstract

Seeds of grain legumes are currently discussed as N fertilizer in organic vegetable production. They can be produced by the farmers themselves and applied in well controlled amounts flexibly in time and space. Most research investigating the N mineralization of grain legume seeds was carried out using coarsely milled seeds. We hypothesized that seed germination alters the chemical composition leading to a higher N release compared to seed meal. In a pot experiment the C:N ratio of lupine seeds was shown to decrease noticeably within the first two weeks after sowing. After an incubation period of 1300°Cd net N mineralization was significantly higher for the lupine seedlings compared to the seed meal and close relationships between N mineralization and C:N ratio were found. In field experiments with white cabbage, carried out in 2005 and 2006, similar relationships were found but sowing followed by an early incorporation of seedlings after 12 and 13 days showed an N supply similar to the seed meal treatment only. Strong priming effects, mainly caused by the lupine seed meal, are discussed to be a possible reason. Late incorporation after 42 and 37 days resulted in significantly lower N supply and cabbage yield.

Introduction

Since organic vegetable production systems mainly lack livestock, manure is not available as N source. Legumes as N fixing crops have the potential to contribute significant amounts of N to the following vegetable crop and hence play a major role in organic vegetable crop rotations. Unfortunately, all traditional legume systems have in common that neither the amount of N fixed nor the time course of mineralization can be influenced satisfactorily, making it hard to fit the N demand of the following vegetable crop. The use of grain legume seeds as N fertilizer, which can be produced by the farmers themselves and which can be applied in well controlled amounts flexibly in time and space, can overcome this problem. However, reviewing comparative studies on animal- and plant-derived N fertilizers, Laber (2003) summarized that grain legume seeds generally showed lower N mineralization rates than animal products or pomace derived from castor beans. Differences between the N mineralization of faba bean, lupine and pea seed meals were shown to depend on their total N content or C:N ratio (Stadler et al. 2006).

As an alternative to the seed application as coarse meal, sowings with a correspondingly high plant density can be established and incorporated after a short period. During seed germination, energy is mobilized from reserves by respiration processes, resulting in the release of considerable amounts of CO_2 and consequently in a lowered C:N ratio. This would suggest a higher N mineralization of young

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seedlings compared to milled seeds. Hence, pot and field experiments had been carried out to investigate whether the N utilization of grain legume seeds used for fertilization can be significantly increased by sowing compared to the application as coarse seed meal.

Materials and methods

Lupine seeds were sown in pots at densities of 2440 seeds m^{-2} corresponding to 173 kg N ha^{-1}. After 8, 13, 18, 22 and 27 days seedlings were cut and mixed with the respective soils they developed in before. The obtained growth stages ranged from the cotyledon stage (8 days) to the six-leaf stage (27 days). A coarse seed meal treatment (CM) and an unamended control were established as references. The soils were adjacently incubated at 10 and 20°C and kept at a water holding capacity of 70% gravimetrically. Soil mineral N content was determined 0, 15, 38 and 65 days after incorporation.

Field experiments were carried out in 2005 and 2006 using white cabbage as test crop. They were located on organically managed fields at the Research Station in Ruthe, situated 15 km south of Hannover, Germany (52°14' N, 9°48' E) on a loess loam soil. Lupine seeds were applied in amounts of 3.8 t ha^{-1} corresponding to 180 kg N ha^{-1} as a dense sowing with either a short or long developmental period until incorporation or as seed meal. The dense sowing treatment with a short developmental time (DS-S) was given 13 and 12 days to germinate and grow, whereas the long time dense sowing treatment (DS-L) was incorporated 42 and 37 after sowing in 2005 and 2006, respectively.

Net N mineralization was calculated as difference between the amounts of N mineralized from amended and unamended control soils. A single first-order kinetics model was fitted to the data to quantify maximum net N mineralization. The C:N ratio of the seedling biomass was adjusted by taking non-recovered amounts of seed coat C and N into account. Since seed germination was partly low in the field, an additional adjustment, assuming C and N contents of lupine seed meal for the fraction of non-germinated seeds, was carried out. Statistical significance between treatments was assessed by analysis of variance followed by Tukey's HSD-test at $p \leq 0.05$.

Results and Discussion

In the pot experiment the C:N ratio was shown to decrease during germination within the first two weeks after sowing. With expansion of the first leaf pair and the corresponding increase in photosynthetic activity, the C:N ratio began to raise but stayed below the initial seed C:N ratio of 8.8 until the end of the experiment. Soil mineral N uptake by the seedlings started 10 days after sowing and caused negative values for net N mineralization at incorporation date (Figure). However, after an incubation period of 1300°Cd net N mineralization of seed meal was significantly lower compared to the lupine seedlings. Within the seedling stages N mineralization was found to be in the inverse order of seedling growing time, being highest for the youngest lupine plants incorporated already after 8 days. Maximum net N mineralization was strongly correlated with the adjusted C:N ratio of lupine seedlings and seed meal.

Under field conditions net N mineralization rates higher than 100% were recorded 39 and 33 days after incorporation in 2005 and 2006, respectively, indicating a strong interaction between the decomposing lupine biomass and soil organic matter.

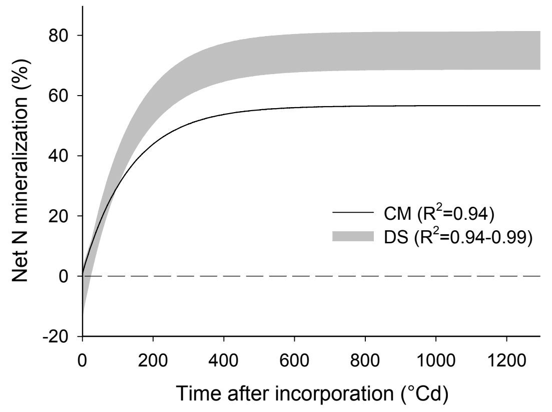

Figure 1: Time course of net N mineralization of lupine seed meal (CM) and seedlings (DS) in the pot experiment as derived from the single first-order kinetics model.

The grey area covers the range of mineralization time courses of the five DS-treatments.

According to Kuzyakov et al. (2000), this interaction is denoted as "positive real priming effect". Since mineralization rates were found to be within the expected range at following sampling dates, it was hypothesized that this short-term effect was not influencing medium-term net N mineralization. Thus, first sampling dates of both years were excluded, when fitting the first-order kinetics model to the field experimental data.

Despite the occurrence of strong priming effects in the field shortly after incorporation, the relationships between the maximum net N mineralization and C:N ratio of pot and field experiment were noticeably alike. Consequently, the DS-S treatment was expected to show a higher total N supply than CM. However, this was not the case. In both years there were no significant differences in total N supply between DS-S and CM and consequently not in cabbage yield (Tab.). This was partly caused by a low germination rate of lupine seeds, particularly in 2005. Furthermore, a positive influence of the priming effect, which was strongest for the CM treatment in both years, on total N supply could not be ruled out completely and might explain the tendency of an even higher N supply of the CM treatment in 2005. This finding is underlined by results from Müller and von Fragstein und Niemsdorff (2006a,b), who

Tab. 1: C:N ratio of incorporated lupine seed meal (CM), short time (DS-S) and long time lupine sowings (DS-L), resulting total N supply and cabbage yield

Year		CM	DS-S	DS-L
2005	C:N	8.6	8.1[1]	9.5[1]
	Total N supply[2] (kg ha^{-1})	308 a	267 b	257 b
	Yield (t ha^{-1})	56.1 a	54.2 a	47.2 b
2006	C:N	8.6	7.0[1]	10.9[1]
	Total N supply[2] (kg ha^{-1})	395 a	404 a	343 b
	Yield (t ha^{-1})	68.4 a	69.2 a	61.5 b

Significant differences between treatments are denoted by different letters (HSD, $p \leq 0.05$).

[1] Adjusted for non-recovered seed coat biomass and non-germinated seeds
[2] Sum of total amount of N in cabbage plants and residual soil mineral N (0-120 cm) at harvest

calculated N recovery percentages greater than 100% of mineralizing lupine seed meal when considering soil mineral N, microbial N and K_2SO_4-extractable organic N both under controlled and field conditions. However, an extension of lupine seedling growing time to 42 and 37 days (DS-L) resulted in significantly lowered cabbage yield (Tab.). This is in accordance with the results of the pot experiment in which net N mineralization was found to be in the inverse order of seedling growing time.

Conclusions

From the results can be concluded that lupine seedlings with even a more favourable chemical composition for decomposition do not necessarily show a higher net N mineralization than coarse seed meal. Priming effects can be expected to play a considerable role in lupine seed meal and seedling decomposition. Nevertheless, from the farmers' point of view, sowing can be an attractive alternative to seed meal application, since the milling procedure can be skipped and the N utilization of both systems had been shown to be similar, as far as lupine seedlings are incorporated in an early stage.

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Use of biodegradable mulching in vegetable production

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Keywords: soil mulching, thermoplastic starch, implementation, BIOMASS project.

Abstract

Trials were carried out in Liguria during three years (2004-2006) to evaluate the use of innovative starch based bioplastics for soil mulching. All trials carried out in open field as well as in greenhouse on different vegetable crops demonstrated the effectiveness of biodegradable films in controlling weeds and in increasing yield. The use of biodegradable mulching films found application in integrated production regulations set up by the regional authority and it is potentially adoptable in an organic farming context.

Introduction

Biodegradable mulching films represent a good alternative to herbicides or other chemicals for soil disinfestation, particularly when used just for weed control, being especially useful in organic farming (Minuto *et al*., 2002). Mater-Bi materials, produced by the Italian company Novamont Spa, have been introduced for several applications due to their different available processing systems, mechanical and physical properties and permeability to water. Mater-Bi materials are biodegradable, according to the European standards (Bastioli, 1997, 1998) and they can be industrially processed and produced by means of traditional film blowing and casting equipment (Thunwall *et al*., 2007). They have been adopted in the framework of demonstrative activities promoted by the European project LIFE04 ENV/IT/463 "BIOMASS" focused on the promotion of the substitution of existing non-biodegradable polymers with new biodegradable starched based plastics.

Materials and methods

Trials were carried out both in greenhouse and in open field in Liguria (La Spezia and Albenga locations); trial locations in La Spezia are certified for organic production. The behaviour of Mater-Bi films (NF 803/P - 12, 15 and 18 µm thickness) were compared to non biodegradable black polyethylene film (PE) (40 µm thickness). All films were laid both manually and mechanically and tested at least three times on different crops. The crops were managed following the cultural techniques commonly adopted by growers. Water was distributed through drip irrigation system. A complete randomised block design with 3 or 4 replicates of 25 m^2 to 300 m^2 each was applied. Data regarding behaviour of films during the crop cycle, mulching effect, crop yield, degree of degradation in the soil and climate condition were collected. In all demonstrative and experimental plots the effects of mulching films were evaluated counting the

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number of weeds/m^2 and, in some cases, the fresh weight (g/m^2) of aerial parts. The quantity (g/m^2) of biodegradable film on the surface of the soil and in the soil was evaluated 14 days after rototilling. All data were statistically analysed using Duncan's multiple range test (P=0.05). A comparison between costs of PE and biodegradable films was also calculated.

Results

Main results about trials carried out on tomato, lettuce, zucchini and Brussels sprouts are presented. Good results in terms of weed control and % of soil covered were obtained with 12 and 15 μm thick films designed for short crop cycles (from 3 to 5 months) (Table 1 and 2).

Tab. 1: Percentage of mulched soil, degradation of mulching film and effect on weeds of biodegradable and PE films on tomato^ crop grown under plastic tunnel [Sarzana (SP), March – September 2006].

Mulching film – thickness (μm)	% of mulched soil at						Degradation index of film at the end of the crop				Weeds at the end of the crop			
	25/04		02/07		12/09		film upon the soil °		buried film °°		number/m^2		Kg/m^2	
NF 803/P – 12	100	a*	90	a	85	a	7.3	b	3.6	c	3.0	a	0.4	a
NF 803/P – 15	100	a	90	a	85	a	8.4	a	6.6	b	0.9	a	0.2	a
PE black – 50	100	a	100	a	100	a	9.0	a	9.0	a	0.0	a	0.0	a
Bare soil	-		-		-		-		-		39.0	b	5.4	b

^Randomized blocks with 3 replications; Cultivar of tomato: "Pera d'Abruzzo"; density of cultivation: 6 plants/m^2; mulched surface/plot: 300 m^2; water supply: drip irrigation; film drawing up: mechanized; soil texture: silt (>90%); soil pH: 7.0. * Values followed by the same letter do not significantly differ according to Duncan's multiple range test (P=0.05). ° Degradation index of the film upon the soil (1=0% of mulched soil till 9=100% of mulched soil) and of the buried film (°°).

Tab. 2: Efficacy of different mulching films on tomato, zucchini and lettuce^ yield at the end of growing cycle [Sarzana (SP), March – November 2006].

Mulching film – thickness (□m)	Tomato °				Zucchini °°		Lettuce °°	
	Kg/plant		N° fruits/ plant		Kg/plant		Kg/m^2	
NF 803/P – 12	4.2	a*	13.3	a	4.5	a	278.0	a
NF 803/P – 15	4.8	a	14.2	a	4.6	a	296.6	a
PE black – 50	4.7	a	13.7	a	4.3	a	310.0	a
Bare soil	2.9	b	12.7	b	2.1	b	78.0	b

^Randomized blocks with 3 replications; mulched surface/plot: 300 m^2; water supply: drip irrigation; film drawing up: mechanized; soil structure: silt (>90%); soil pH: 7.0. *See table 1. ° Plastic tunnel, Cultivar "Pera d'Abruzzo", 6 plants/m^2 (march-september, 2006); °° Open field, Cultivar "Ibis", 2 plants/m^2 (may-august, 2006); °°° Plastic tunnel, Cultivar "Lollo verde", 20 plants/m^2 (September-november, 2006).

During the growing cycle only a limited degradation was observed, with tears and visible degradation particularly located in the buried parts. The residues of biodegradable film observed on the soil surface (g/m^2) immediately before rototilling, compared with the weight of new films, indicated that the degradation process of the material was already started. The same evaluation carried out 14 days after rototilling sieving the soil up to 20 cm depth confirmed the almost complete degradation of the film (Table 3).

Tab. 3: Film residues at the end of crop cycle of some vegetable crops (open field, winter-spring, Albenga 2005).

Mulching film –	New film	Tomato				Brussels sprouts				Lettuce			
thickness (□m)	(g/m²)	residues of film at the end of the crop cycle (g/m²)											
		upon soil°		in the soil^		upon soil°		in the soil^		upon soil°		in the soil^	
NF803 – 18	25.0	8.3	b*	0.6	b	4.0	b	2.2	b	7.8	a	0.9	b
NF803 – 15	22.9	7.4	a	0.4	a	2.2	a	1.2	b	7.0	a	0.7	b
NF803 – 12	15.3	7.2	a	0.2	a	1.3	a	0.1	a	7.0	a	0.2	a
PE black – 50	n.a.**	n.a.	-	n.a.	-	n.a.	-	n.a.	-	n.a.	-	n.a.	-
Bare soil		-	-	-	-	-	-	-	-	-	-	-	-

° g/m² of film residues upon soil before rototilling; ^ g/m² of film residues in the soil (evaluated sieving the soil up to 20 cm depth) 14 days after rototilling; * see table 1; ** because of technical and environmental reasons PE was not incorporated in the soil.

Tab. 4: Comparison between the costs of biodegradable films and conventional PE (being equal the application costs).

Characteristic of the film	PE	Mater-Bi films	
Thickness (µm)	45	15	12
average weight (Kg/ha)	450	180	140
Cost of the product (€/ha)	639	900	700
Cost difference (€/ha) (base: PE)	-	261	61
Cost difference (%) (base: PE)	-	40,85	9,55
Average removal cost (€/ha)	120	0	0
Average disposal cost (€/ha)	50	0	0
Overall cost of the product (€/ha)	809	900	700
Overall cost difference (%) (base: PE)	-	11,25	-12,11

Crop yield was not influenced by the different thickness of the mulching films and significantly differed from the yield obtained on bare soil due to high weed competition (Table 2). No differences in terms of film behaviour were observed between manually or mechanically laid films. Costs of biodegradable films (12 and 15 µm thick) including product, removal and disposal costs, proved to be comparable with the ones of conventional PE (Table 4).

Discussion

The results obtained testing different formulations of biodegradable films were generally encouraging and similar to those achieved by normal black PE. The same film behaviour was observed even on other crops which were grown during trials such as artichoke, garlic, onion, sweet pepper, water melon, eggplant and strawberry (data not shown). Thanks to their characteristics biodegradable films could mulch almost completely the soil during the crop cycle as well as standard PE assuring a constant control towards weeds and maintaining an accurate level of moisture in the soil. During application, mechanically laid films must be let free to rotate without any brakes in order to avoid stretching and consequent film thinning. No particular concerns are related to manual application. Biodegradable films proved also to be able to increase crop yield and quality and they are worth being used at the same extent of traditional films in consideration of the fact that even their cost is comparable when costs related to plants, removal and disposal of traditional films are taken in consideration. The evaluation of the percentage of mulched soil at the end of the crop along with crop yield suggests that an efficient weed control can be achieved as long as the film totally covers the soil during the major part of the crop cycle.

Conclusions

The major concern on biodegradable films in agriculture is primarily due to the effects of ageing and degradation during the growing cycle for long lasting applications, when premature breakings of the films can limit their applications. At this regards other researches demonstrated that well produced biodegradable films perform in a way comparable to the corresponding PE films (Briassoulis, 2007). Results demonstrated the effectiveness of biodegradable films manufactured using Mater-Bi films against weeds. Tested films appeared to be easily adapted during different seasons, in open field and under greenhouse conditions, being able to substitute conventional PE films for short crop duration. The revision of integrated production protocols and a further implementations of regulations at a regional level is expected to enhance a wider adoption of biodegradable films for the control of weeds without resorting chemical inputs, so stressing their capability to be used even for organic production.

Acknowledgments

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Japanese organic tomato intercropped with living turfgrass mulch

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Key words: blight, IMP, intercropping, living mulch, organic, VAM, tomato, turfgrass

Abstract

Stripe cultivation of crops with turfgrass as living mulch has been adopted in orchard systems and proved effective in disease control and fruit quality improvement. However, no research has tried turfgrass as living mulch for field vegetable crops. In the present study, field tomato was stripe-cultivated with Kentucky blue grass and showed high resistance against leaf blights resulting in improved fruit yield and quality. Lower nitrate concentration in tomato leaves stripe-cultivated with turfgrass might be one of the reasons for decreased risk of fungal infection. Turfgrass is alive with high activity throughout the year and the root is colonized and mutually benefiting from each other with mycorrhizae. The mycorrhizal colonization was high in turfgrass root, and also much higher in roots of tomato plants with turfgrass as living mulch than in the tomato plants without turfgrass. This might be another reason for decreased infection risk of fungi. In conclusion, as a living mulch, an annually ever living turfgrass root system with mycorrhizae colonized, making a living soil and improving soil conditions, avoided the infection by soil-borne pathogens in tomato plants that are stripe-cultivated with turfgrass.

Introduction

Organic agriculture seeks to use nature as the model for system design. Nature consistently integrates the plants and animals into a diverse landscape. However, monoculture in conventional agriculture has greatly reduced biodiversity by a limited selection of crop plants and animals. Therefore, a major tenet of organic agriculture is to create and maintain biodiversity since beneficial relationships exist between species within a community. Intercropping, mix-cropping or stripe cultivation among different crops or between crops and grasses or green manure plants is one of the efforts made on the restoration of the natural biodiversity. In addition to a healthy crop from the beneficial relations among species, another reason to grow two or more crops together is the improvement in productivity per unit of land. Recently, another kind of stripe cultivation, the main crop into a living mulch crop such as forage grasses, has been adopted in both IPM and organic systems. Succeeded cases include the cereal crops or vegetables (Frank, 2004) into clovers and other grasses to control pests. For a long time, living mulch or so-called sod culture has been adopted to orchard systems and proved effective in disease control and fruit quality improvement (Vossen and Ingals, 2007). The living grass mulch under the fruit trees is relatively permanent and it is also called permanent sod floor. In contrast, the living mulch adopted to crop systems is not permanent and in many cases it is an annual or perennial grown just for one year. Although legumes such as clovers have been tried in research, few cases have used the relatively permanent turfgrass as living mulch for field vegetable crops. Therefore, in the present study, field tomato was intercropped with Kentucky

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blue grass and the tomato leaf blight infection and also the root mycorhhizal colonization were examined.

Materials and methods

Seeds of Kentucky blue grass (*Poa pratensis* L.) were sown in October and mowed next spring into a normal turf. A band 30 cm wide was ploughed with the green aboveground part of the turfgrass upside down into the soil. The turf green band left was 90 cm wide and enough for the mower to pass through. In the control, the whole plot was ploughed clearly. In both grass and control plots, a biofertilizer with N-P-K concentrations of 58-30-20 mg kg^{-1} was applied at the rate of 200 g m^{-2} on the total land basis. The biofertilizer was fermented using oil mill sludge, rice bran and fish meal mixed with EM, a microbial inoculant, as the starter (Xu, 2006). Seedlings of tomato (*Lypercosicon esculentum* L. cv. Momotaro & cv. Chika) were transplanted into the cleared band on May 20 with an interval of 60 cm between plants (Fig. 1). The grass residuals mowed off from the turf were used for mulch on the soil surface in the cleared band.

The net photosynthetic rate (P_N) in the upper 5th leaf was measured at different photosynthetic photon flux (i) with the light response curve modelled by $P_N = P_C\ (1\text{-}e^{-Ki}) - R_D$, where P_C was the photosynthetic capacity; R_D dark respiration; K time constant; and Y_Q the maximum quantum yield shown as $Y_Q = KP_C$. Disease index for leaf blight was estimated as Index = ∑(Number of infected leaves to a certain degree × Degree constant)×100/(total leaf number × highest degree constant). The degree was scored from 0 (no symptom) through 1 (12.5% of the leaf area was infected), 2 (25%), 3 (50%) and 4 (75%) to 5 (completely infected). Roots of turfgrass and tomato were sampled and examined under microscope for the presence of mycorrhizae (AM) after cleaned with 2.5% of KOH, acidified in 1% of HCl and stained in 0.05% of aniline blue in lactoglycerol (Koske and Gemma, 1989). AM colonization was estimated in three scales: Poor —only mycelia present; Moderate —mycelia and vesicles present; and Abundant —mycelia, vesicles and arbuscules present. Root segments (n=80) were collected from the root system of a sample plant. The soils samples were collected from the upper 20 cm soil layer, air dried and ground to pass through a 2-mm sieve. Measurements were conducted for EC (1:5 H_2O, EC Meter, CM-30G, TOA), pH (1:2.5 H_2O, pH Meter F-21, HORIBA), extractable ions such as Ca, K, Mg and Na (Atomic Spectrophotometer, SHIMADZU, U-2000, HITACHI), the total C and total N (CN CORDER, MT-700, YANACO, Japan) and inorganic nitrogen and phosphorus (colorimetric method).

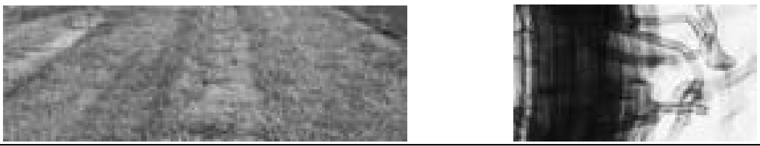

Figure 1: Tomatoes in turfgrass (Left) and mycorrhizae colonized in turfgrass root (Right)

Results

Both varieties of the field tomato intercropped into turf Kentucky blue grass showed high resistance to phytophthora and other leaf blights and improvements in leaf fruit yield and quality (Table 1) and photosynthetic activities at the later growth stages (Table 2). The nitrate concentration was lower in both the soil and leaves of tomato plants intercropped with grass (Table 3) and consequently decreased the risk of fungal infection (Table 1). Turfgrass is alive throughout the year and the root is colonized and mutually benefiting with mycorrhizae and other rhizosphere microorganisms. As shown in Table 3, the mycorrhizal colonization was high in turfgrass roots, and also much higher in roots of tomato plants intercropped with turfgrass than in the tomato plants without turfgrass intercropping. Although soil nutrient conditions were also improved, the disease avoidance was the critical factor for the high fruit yield of tomatoes in the turfgrass plots. The infection by leaf blight (*Alternaria solani* and *Fusarium oxysporum f.sp. licopersici* race 2) was much less severe in tomato plants intercropped with turfgrass than plants in control plot. In conclusion, as living mulch, the annually-ever living turfgrass root system with mycorrhizae colonized, making a living soil and improving soil conditions, avoided the leaf infection by soil-borne pathogens in tomato plants that were intercropped with turfgrass.

Tab. 1: Fruit yield and leaf blight infection of tomato plants with turfgrass as living mulch in comparison with tomato plants in control. (n=30)

	cv. Momotaro						cv. Chika					
Plot	Yield (g/pl)	Numb (fr/pl)	Size (g/fr)	Mark. (%)	Disease (%) Early	Disease (%) Late	Yield (g/pl)	Numb (fr/pl)	Size (g/fr)	Mark. (%)	Disease (%) Early	Disease (%) Late
Turf	4853**	32.5 **	149*	95**	6 **	16**	3759**	289**	13^{ns}	98^{ns}	2**	15**
CK	2429	18.9	128	46	44	81	1586	131	12	95	34	75

* significant for P<0.05; ** significant for P<0.01

Tab. 2: Photosynthetic activities of tomato plants with turfgrass as living mulch in comparison with tomato plants in control. (n=9)

	cv. Momotaro						cv. Chika					
Plot	P_C (μmol m^{-2} s^{-1})		R_D (μmol m^{-2} s^{-1})		Y_Q (mol mol^{-1})		P_C (μmol m^{-2} s^{-1})		R_D (μmol m^{-2} s^{-1})		Y_Q (mol mol^{-1})	
	Early	Later	Early	Later	Early	Later	Early	Later	Early	Later	Early	Later
Turf	30.4^{ns}	25.7**	4.1^{ns}	3.3^{ns}	0.0721*	0.0758**	32.7^{ns}	29.6**	4.7^{ns}	3.2*	0.0895^{ns}	0.0817**
CK	31.9	16.1	4.3	3.6	0.0784	0.0475	33.2	15.7	5.0	2.7	0.0889	0.0578

Tab. 3: Soil nutrition and mycorrhizal colonization in the plot of tomato in turf living mulch in comparison with tomato plants in control. (n=15)

Variable	Tomato in Control	Tomato in turfgrass	Turfgrass
pH	6.22±0.15	6.40±0.20	6.79±0.08
EC (dS m^{-1})	0.15±0.04	0.06±0.01	0.05±0.02
Na (mg kg^{-1})	54.6±14.8	32.0±15.1	34.9±17.5
K (mg kg^{-1})	874.9±57.2	601.8±30.4	541.6±99.9
Ca (mg kg^{-1})	2927.7±91.4	3181.7±84.1	3361.8±8.1
Mg (mg kg^{-1})	695.2±81.9	574.9±46.5	507.0±38.1
CEC (cmol kg^{-1})	22.16±0.65	21.65±0.55	24.18±0.73
P_2O_5 (mg kg^{-1})	226.8±33.0	171.6±2.05	128.9±36.9
NH_4-N (mg kg^{-1})	6.4±4.0	1.9±0.1	12.9±5.4
NO_3-N (mg kg^{-1})	40.7±20.8	14.0±2.3	17.0±10.1
Total N (%)	5.29±0.16	5.21±0.32	-
Total C (%)	0.44±0.02	0.43±0.04	-
C-N ratio	0.08±0.00	0.08±0.00	-
AM infected root (%)	9.33±4.33	18.33±5.33	32.67±2.67
Poor	3.33±2.33	6.33±2.33	12.67±1.33
Moderate	1.67±0.67	4.00±2.00	10.33±0.67
Abundant	4.33±1.67	8.00±2.00	9.67±1.67

Discussion

In Organic Agriculture, benefits of crop diversity are recognized, for example, planting mixtures or stripes of different crops in the field. In addition to a healthy crop from the beneficial relation among species, another reason to grow two or more crops together is the improvement in productivity per unit of land. However, the living mulch of turfgrass in this study differs from the common intercropping in three aspects: 1) the turfgrass is not the crop for harvest although it can be mowed and collected for forage; 2) the turfgrass is relatively permanent in comparison to annual crops; and 3) the microbial ecosystem in the rhizosphere is relatively stable because of the ever-alive root system. Instead of demand for productivity, the technique of living turf mulch is expected to avoid diseases, whereby a reasonable fruit yield is ensured in the organic field tomato production. The turfgrass absorbs the excessive N, if any, and excessive supply of N to tomato plants is avoided. This might be one reason for disease avoidance. Another reason for the disease avoidance is the microbial biodiversity in the rhizosphere that is maintained by the abundance of mycorrhizal colonization. Mycorrhizae colonize the turfgrass root with high density and the density is much higher than in roots of tomato plants without turf intercropping. Turfgrass adapts to hot and cold weathers and the roots are alive throughout the year, mutually benefiting from each other with mycorrhizae and other rhizosphere microbes. Moreover, the field biodiversity was also improved because turf grass grew between tomato plants and the naked soil was mulched with grass residuals. In the whole field no soil was naked and the tomato leaves never met the soil even after a heavy rain, whereby the plants were expected to be protected from being infected by the soil-born pathogens. There was no space and light competitive impact on tomato plants because the turf grass was mowed frequently and tomato plants were much taller than turfgrass. Turfgrass competed in nutrition, especially the N nutrition, with tomato plants. Therefore, enough nutrition from the organic fertilizer must be ensured. Usually, application of organic fertilizer is concentrated and localized near the tomato plants, although the rate is not really high on the total land basis. This high rate of localized fertilization will endanger the tomato seedlings to diseases that are usually caused by excessive N nutrition. If enough fertilization is not ensured, tomato plants may suffer malnutrition in the later growth periods. A proper fertilization rate and a sustainable organic fertilizer are necessary for the tomato plants intercropped into turfgrass. No any problem is induced from the water competition between turfgrass and tomato because the annual rainfall was around 2000 mm and only one or two times of sprinkle irrigation was needed. Turfgrass helps excessive water drain after heavy rains. More investment for the turf mower may be needed but the farmer can benefit from the harvested grass, which can be used as animal forage. In conclusion, using turfgrass as living mulch is a possible alternative way to avoid disease in organic field tomato production.

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Organic Methods for Control of Root Rot in Pea and Spinach in Northeastern U.S.

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Keywords: root rot, organic disease control

Abstract

The root rot disease complex is a limiting factor in organic production of cool season crops. This study aimed to increase seedling stands of peas and spinach by altering the seed environment such that the growing conditions of the seeds were favored over those of the pathogens. We compared treatments of raised (ridged) seed beds, dairy and vermicompost troughs, transplanting, and a biocontrol soil drench. Of the methods tested, transplanting provided the most reliable and best crop stands for both seasons (p=0.05) Since this method relies on the biological resistance the plants develop naturally with age, this method could prove applicable across many climates and other crops which are threatened by root rot.

Introduction

Root rot, seed rot, and damping off collectively represent a detrimental disease complex (hence referred to as root rot) which affects many vegetable crops. Root rot is marked by poor seedling emergence; infected seeds are soft, mushy and quickly deteriorate. In this study the pathogens identified were Pythium spp, Fusarium spp. and Rhizoctonia solani. The host crops in this study are spinach (Spinacia oleracea) and pea (Pisum sativum).

Conventional management of root rot relies on fungicidal seed treatments or, in severe infestations, methyl bromide fumigation. However, these treatments are not permitted in certified organic crops. Organic growers have few options for overcoming the detrimental effects of a root rot infestation. For many growers in the northeast U.S. obtaining a marketable crop of either peas or spinach can be nearly impossible due to the poor stands caused by root rot.

Peas and spinach share similar environmental growth conditions as root rot pathogens. Creating a seed bed which favors growth of the seed over that of the pathogen can be accomplished by exploiting the slight differences in the optimum growing conditions of the plants over that of the pathogens. Two important environmental factors which impact soil fungi are soil temperature and moisture, with the latter having greater potential influence on the severity of the disease. Kumar et al. (1999) have shown that the pathogens are more destructive at lower temperatures and higher moisture. Cultural management and techniques should therefore be geared towards creating higher temperatures and lower moisture environments than found in normal field conditions. Our objective was to compare ridge and furrow planting; compost amendments; a commercially available, certified organic soil

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drench; and transplanting as methods to establish these favorable environmental conditions, thus improving crop stands.

Ridge planting (Hodges, 2003) refers to planting seeds in a raised seedbed created during tillage. Another manipulation of the seed bed is to plant seeds in a furrow or trough of compost. By forming a physical barrier around the seed exudates, the compost environment may allow seedlings to develop beyond susceptibility of the pathogen (Mandelbaum Hadar, 1990). Additionally, the increase of antagonistic bacteria from the compost may suppress pathogen growth (Sullivan, 2004). It is well documented that mature composts contain a wealth of microbial populations (Boehm et al., 1993), although variation between types and batches of compost creates inconsistencies (Sullivan, 2004). We evaluated a locally-made dairy manure compost and commercially-produced vermicompost (from earthworm castings). The next treatment was the use of transplants. Seedlings are grown in flats of sterile media (usually 10-14 days, or until seedling shows 3-4 sets of true leaves) to mature beyond the most vulnerable stage of susceptibility to the seed rot pathogens. The seedlings are then transplanted into the field. We were able to compare the change in time and labour necessary for this by using records and data from a previous study (Childers, 2005). Finally, we evaluated a commercially available soil drench of Trichoderma harzianum as an antagonist to root rot pathogens. This product is registered for suppression of root rots in organic agriculture.

Materials and methods

All research was conducted at the West Virginia University Organic Research Farm located in Morgantown, WV, USA. The farm has been certified organic since 2003; all research complies with USDA organic standards. Spinach (Spinacia oleracea 'Whale F1') and garden pea (Pisum sativum 'Oregon Giant') seeds were used in all experiments. A 15.2-by- 7.6m plot, prone to root rot disease, was tilled and prepared for planting in fall 2006, spring 2007, and fall 2007. Eight treatments with three replicates each were established in a completely randomized design.

Treatments 1-4) Compost troughs (dairy manure compost and vermicompost, each at 2 rates): The planting rows were excavated of field soil and the trough was filled with either dairy manure compost (from WVU dairy research farms) or vermicompost (UNCO Industries, Racine, WI) at two rates: 1,967 cm3 compost m-1 or 3,387 cm3 m-1, referred to as Low and High respectively. The seeds were planted into the compost troughs such seeds were encased within the compost and had no contact with the field soil. 5-6) Ridge planting: In a prepared bed, the field soil was mounded to create a convex-shaped seed bed. Two different heights of the ridge bed (7.5 cm and 15 cm) were compared. 7) Transplanting: Seeds were sown in flats using organic growing media (made with WVU dairy compost, peat, and perlite) and allowed to develop for 10-14 days before being placed in the field (at the same time as seeds in the other treatments were sown). Both pea and spinach were transplanted as clumped groups containing 5-7 seedlings in each clump. 8) Control: Seeds were sown using traditional planting methods placing seeds directly into level rows.

Each treatment row (containing peas) was 1.2 m in length. Peas were planted 5 cm deep, 5 cm apart. Rows containing spinach were 60 cm long with seeds sown 3 mm deep, 5 cm apart. Seedling emergence/survival was recorded at 10, 15 and 21 days after planting. Soil moisture and temperature measurements were recorded continuously from the time of planting until the final field observation (21 days) with WatchDog data loggers (model 400, Spectrum Technology, East-Plainfield, IL). In fall

2007 we compared a commercially available organic soil drench, Root Guardian Biofungicide (Trichoderma harzianum, Gardens Alive, Lawrenceburg, IN), transplanting, and a control for their effect on seed emergence. Seeds were sown into the field and Root Guardian was applied as a soil drench at the recommended rate of 12 ml/L immediately after planting. The transplanting and control treatments were as described above.

Tab. 1: Mean emergence (%) of spinach and peas after 21 days in fall 2006 and spring 2007

	Fall-Spinach	Spring-Spinach	Fall-Peas	Spring-Peas
Transplant	95 a	90 a	99.1 a	93 a
Control	0 c	4.3 b	11.4 d	10.3 bc
Vermicompost-High	43.3 b	2.6 b	27.7 bc	8.6 c
Ridge-15cm	2.5 c	6 b	15.9 cd	16.6 bc
Dairy-High	3.3 c	1.6 b	19.6 bcd	31.3 b
Vermicompost-Low	29.1	5.3 b	39.2 b	8 c
Ridge-7.5cm	1.6 c	7.6 b	16.4 bcd	20.3 bc
Dairy-Low	6.6 c	8.6 b	15.9 bcd	21 bc

* Means separated by Tukey-Kramers HSD. $P<0.05$

Results

Transplanting of both pea and spinach resulted in survival rates nearing 100% for both years (Fig.1-4). Spinach emergence was greater ($P = 0.05$) in plots with high vermicompost than controls in 2006, but not in 2007. None of the other treatments differed significantly from the control in either year (Fig. 1 and 2). Pea emergence in plots with the high dairy compost treatment was greater ($P = 0.05$) than in controls or the high ridge treatment in 2006, but these differences were not significant in 2007 (Fig. 3 and 4). Pea emergence in the low vermicompost treatment was greater ($P=0.05$) than in controls in 2006, but the high vermicompost treatment did not differ from controls in 2006, and both vermicompost treatments resulted in the lowest pea emergence in 2007. In the fall 2007 experiment with Root Guardian, the transplanting treatment resulted in the highest plant (pea and spinach) survival (data not shown). No significant differences were observed between the Root Guardian treatment and the control. Temperature and moisture sensors were placed in only one replicate of each treatment, so statistical comparisons are not possible (data not shown); however no consistent correlations occurred between treatments or seasons and stand emergence for either crop.

Conclusions

Despite anecdotal evidence suggesting that improving drainage by planting seeds on a ridge will help in controlling root rot, we concluded that the differences in soil moisture or temperature between ridge plantings and the control did not significantly impact crop stands in our silt loam soil. Interestingly, the volume of compost made no difference in the results associated with the treatments, which we think illustrates the tenacity of the pathogens to migrate considerable distances in the rhizosphere to reach sprouting seeds. The pathogen population may be too overwhelming for an effective antagonistic suppression to take place. The inconsistent results between the two seasons demonstrated that these methods are unpredictable in resulting in an improved seed stand. This may be due to a significant interaction between climate and treatment that needs to be explored in more detail. We found the soil drench, Root Guardian, to be an ineffective treatment, as it was not statistically different from the control. We recognize the possibility of a seasonal interaction, and thus we will repeat the experiment with Root Guardian in spring 2008.

Finally, due to the overwhelming success of the transplanting method, small scale growers whose fields show poor stands of peas and spinach due to root rot are recommended to follow this technique. Though this method increased our planting time/labor by 25% we felt that this could be reduced by the efficiency of a larger scale farm operation. Moreover the additional time and labor was justified by the insurance of not losing crops to root rot. The minimal cost inputs created by the flats and media could be distributed over many seasons.

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Effects of shading on root and shoot development of melon (*Cucubrita pepo)* transplants in conventional and organic float system nurseries

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Key words: organic float system, conventional float system, shade, melon transplants.

Abstract

Float system is a common technique of tobacco and vegetables transplant production. We evaluated the shade effect on the roots and shoots development for two float systems surgeries (CV:conventional and ORG:organic) on melon transplants. The shade had differently influenced the development of the roots and shoots of the two float systems surgeries. Roots fresh weight and surface was significant higher under shade for organic transplants and significant lower under shade for conventional transplants. Hence, shoots fresh weight and surface was significant higher under shade for organic as well as conventional transplants. Because of the described differences in roots development, the transplants which were produced in the organic float system nursery had better quality under shade in contrast to those produced in conventional float system nursery which had better quality under light. The quality of transplants is related to their behaviour during the transplanting process, their resistance to the transplanting stress and their survival in the field.

Introduction

Conventional melon seedling production can be labour intensive. The float system may be a less labour-intensive alternative. Float system technology is used widely to produce tobacco transplants in greenhouse, but it is scarcely used for horticulture crops. Potential advantages may include lower production costs, more efficient use of water and nutrients, reduced foliar and root disease levels and elimination of nutrient leaching to groundwater below the greenhouse. However, if nutrient levels are not carefully managed, seedling can grow in very little time, resulting to tall, leggy and low quality transplants (Leal, 2001; Rideout and Overstreet, 2003).

Materials and methods

The experiments were conducted at the greenhouse of a Tobacco Research Station in West Greece, (Lat: 38°36´, Long: 21°21´, alt: 24m). Each experiment was set up according to a split-plot design, and two basins (dimension 110x90 cm and capacity 200 lt) at each one of the three replications were used.

Four polystyrene float trays consisted of 198 cells each (17 cm^3 volume cell) were placed inside each basin. Each cell was filled with substrate mixture (peat: perlite, 1:1) and sown with melon seed, *Cucubrita pepo* vs *galia F1*. In order to create shade,

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special curtain used, which allowed only 30% of light to get through. This curtain covered two of the four trays.

The first basin was managed by means of the conventional (common) technique (CV); with water-soluble fertilization, 150 g of Fytosrpint (19-19-19) by Fytothepriki Co. and two fungicides, 10 ml Previcur (i.e. propamocarb) by Bayer Crop Science and 10 gr Derosal (i.e. carbedazim) by Syngenta.

The second basin (ORG), followed the EU organic guidelines; with organic water-soluble fertilizer, 100 ml Fish–Fert (2-4-0.5, and other trace elements) by Humofert Co. and 10 ml by Trichomic (*Trichoderma sp.*) by Trichodex-Spain Co.

The estimation of LSD for means comparisons was accomplished by using the statistical program “SPSS”.

Results and Discussion

The Leaves Surface (L.S.) and Fresh Weight of Shoots (F.W.S.) had a different direction in the experiment. The shade influenced L.S. of organic and conventional transplants the same and they were significant higher than those in light. The same had been noticed in the values of F.W.S. (Table 1).

On the other hand the values of Fresh Weight Root (F.W.R) and Root Surface (R.S.) of the ORG were smaller where the shade was significantly higher than those in light. In the CT basins the values of R.S. was significant lower than those in light (Table 1).

Tab. 11: Effects of the shade in two float systems (CV and ORG) on plant parameters of melon. (LSD values ($p<0.05$) are also shown).

	R.S. ($mm^2.plant^{-1}$)			L.S. ($mm^2.plant^{-1}$)		
	CV	ORG	$LSD_{5\%}$	CV	ORG	$LSD_{5\%}$
shade	864.85	735.5	45.32	5298.85	1846.55	1232
light	1126.033	625.55	27.44	4964.2	1559.57	1651
$LSD_{5\%}$	211	159		231	227	
	F.W.R. ($g.plant^{-1}$)			F.W.S. ($g.plant^{-1}$)		
	CV	ORG	$LSD_{5\%}$	CV	ORG	$LSD_{5\%}$
shade	0.58	0.51	0.19	4.55	1.36	2.11
light	0.85	0.41	0.22	4.17	1.05	2.76
$LSD_{5\%}$	0.32	0.22		0.34	0.29	

Conclusions

In our experiments, there was a clear evidence of root colonization by AM fungi in the ORG float system. A combination of phosphorus (Mader, 2000) and Trichoderma organic form (type) as well as fungicide absence is responsible for the recorded root colonization.

The effect of the shade on transplants R.S. and F.W.S. was significant lower in CV float system nursery and higher in float system nursery. On the contrary, the effect of the shade on fresh weight and surface of transplants shoots was significant higher in both float systems. The roots behaviour, in the ORG float, under shade was due to the better management of N in the plant. The roots followed the development of the shoot in order to maintain plants' balance. This provided better behaviour of the transplants during transplanting process, as well as their resistance to the transplanting stress and their survival in the field. (Anthony S. D. and Douglass F.J. (2005))

On the other hand this balance did not appear at the CV float system nursery. The absence of light decreased the root development. Probably roots of conventional basins have no assistant factors to reduce shade effect like mycorrhiza or small N concentration in the water solution.

Our results shown, that ORG float system was responsible for a higher quality of the transplants under shade. In conclusion, a combination of higher root development and lower shoot elongation resulted in creating transplants of a higher quality, compared to that of the CV float system.

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Crop protection and soil fertility in organic okra cultivation in Mauritius

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Key words: *Abelmoschus esculentus, Allium cepa, Azadirachta indica*, pests, NPK, soil health, organic.

Abstract

Okra was grown in organic and conventional systems. The organic plots included an intercrop system, using onion in alternate rows. Well-decomposed manure was used as a soil amendment, and mulching was done with cane straw. A bird net prevented damage by birds to seeds. Neem extract was applied as and when needed based on economic threshold values of important pests. Parameters studied included plant height, leaf area index, soil pH, soil NPK, and yield and quality of harvested okra fruits. Okra was grown in the conventional plots in a monocrop system, fertilised with synthetic NPK fertilisers, and sprayed with synthetic pesticides. Comparison of soil, plant and yield parameters showed that leaf area index, plant height (from week 10) and fruit yield and quality were higher in the organic system compared to the conventional system, while pest damage was equal in the two systems. Soil pH and phosphorus levels were lower in the organic plots, while available nitrogen and potassium were higher in the organic plots.

Introduction

Organic production has been identified as a high value-added activity for niche markets by the Government of Mauritius in its Non-Sugar Sector Strategy Plan (2003-2007) and its Strategic Options in Crop Diversification and Livestock Sector Plan (2007-2015). Although Mauritius has a number of attributes that makes it a good candidate for developing organic production (Facknath and Lalljee, 2001), organic agriculture has not really taken off in the country. Research on organic farming so far has been restricted to investigating methods for pest control and soil fertility management.

The long crop cycle of okra (6 months) has been used as a reason for the unsuitability of this crop in organic cultivation in Mauritius, mainly because of the higher risk of pests and diseases and difficulties of plant nutrition management. However, preliminary studies (Facknath, unpubl.) have shown that with the help of plant allelochemicals (either in the form of extracted plant sprays and/ or the plant grown as an intercrop) and appropriate soil amendments, okra can be grown organically.

Onion (*Allium cepa*) allelochemicals repel aphids (Elwell and Mass, 1995) and leafminers (Facknath, unpubl), while neem (*Azadirachta indica*) compounds have strong antifeedant, growth regulating, and pesticidal activity on a range of insects and mite pests (e.g. Isman, 2000). The weed control effect of mulching is well documented (e.g. Reijntjes et al., 1995). Composted manure can provide the necessary plant nutrients.

Materials and methods

Okra was grown in organic and conventional plots (all plots had been left fallow for 5 years prior to the experiment) in a completely randomised design with 8 replicates of 14.4 m^2 each, and a distance of 3 m between sub plots. Following a germination test, okra (cv. Piton) seeds were planted at the rate of 5 seeds per 20 x 20 x 15 cm hole. In the organic plot, onion was grown as an intercrop.

In the organic plot, well-decomposed manure was applied at planting, while in the conventional plot, the recommended rates of ammonium sulphate, simple superphosphate and potassium sulphate were applied. Irrigation in all plots was carried out using a drip system. Bird net placed over the plots until germination prevented damage by birds. Thinning to one plant per hole was done in all plots. Folimat was sprayed in the conventional plot to control insect pests, and top dressing with ammonium sulphate was carried out as recommended (Anon, 1994). In the organic plot, cane straw mulch was used to suppress weeds. Soil and plants from both organic and conventional plots were analysed for pH, leaf area index, and levels of NPK. Available nitrogen was determined by the Markham's Distillation method; available phosphorus was determined by the Modified Truog's method, and available potassium by flame photometry. Incidence of pests was recorded in all plots, as was yield of okra. Yield was measured in terms of quantity as well as quality of fruits harvested. Data was transformed and subjected to analysis of variance. Means were separated using LSD at 5% level of probability.

Results

Tab. 1: Mean (± se) leaf area index for organic and conventionally grown okra plants

Treatment	7 weeks	9 weeks	12 weeks
Organic	259.9 ± 24.3 a*	471.4 ± 32.8 a	687.1 ± 55.8 a
Conventional	135.3 ± 14.0 b	457. 9 ± 37.1 a	530.6 ± 39.5 b

* significant for P<0.05 within a column

Tab. 2: Mean (± se) height of organic and conventionally grown okra plants

Treatment	5 weeks	8 weeks	10 weeks	15 weeks
Organic	16.6 ± 0.9 a	30.2 ± 0.9 a	50.0 ± 3.8 a	76.8 ± 2.3 a
Conventional	13.3 ± 1.1 a	25.2 ± 1.2 a	38.8 ± 1.2 b	62.5 ± 4.5 b

* significant for P<0.05 within a column

Tab. 3: Mean (± se) number of aphids in organic and conventionally grown okra plants

Treatment	Before spraying	2 days after spraying
Organic	403.9 ± 22.2 a	2.0 ± 0.8 a
Conventional	597.8 ± 31.0 b	1.9 ± 0.5 a

* significant for P<0.05 within a column

Tab. 4: Mean (± se) pH of soil in organic and conventional okra plots

Treatment	Prior to planting	Middle of crop cycle	Post harvest
Organic	6.6 ± 0.09 a	5.7 ± 0.03 a	5.7 ± 0.03 a
Conventional	6.6 ± 0.09 a	6.0 ± 0.05 b	6.2 ± 0.08 b

* significant for P<0.05 within a column

Tab. 5: Mean (± se) level of nitrogen (%) in soil in organic and conventional okra plots

Treatment	Prior to planting	Middle of crop cycle	Post harvest
Organic	0.05 ± 0.0009 a	0.06 ± 0.0003 a	0.06 ± 0.0005 a
Conventional	0.05 ± 0.0009 a	0.04 ± 0.0003 b	0.05 ± 0.0008 b

* significant for P<0.05 within a column

Tab. 6: Mean (± se) level of phosphorus (ppm) in soil in organic and conventional okra plots

Treatment	Prior to planting	Middle of crop cycle	Post harvest
Organic	506 ± 1.14 a	600 ± 0.94 a	650 ± 1.25 a
Conventional	506 ± 1.14 a	820 ± 0.94 b	855 ± 0.47 b

* significant for P<0.05 within a column

Tab. 7: Mean (± se) level of potassium (ppm) in soil in organic and conventional okra plots

Treatment	Prior to planting	Middle of crop cycle	Post harvest
Organic	590 ± 1.41 a	650 ± 1.25 a	600 ± 1.25 a
Conventional	590 ± 1.41 a	585 ± 2.49 b	565 ± 0.94 b

* significant for P<0.05 within a column

Tab. 8: Quality of okra fruits from organic and conventionally-grown plants

Treatment	Grade A (kg)	Grade B (kg)	Grade C (kg)
Organic	11.01	5.39	3.20
Conventional	8.03	3.77	2.03

* significant for P<0.05 within a column

The following can be deduced from this experiment :

Leaf area index, plant height (from week 10), and fruit yield and quality were higher in the organic system compared to the conventional system.

Level of pest incidence was similar in the organic and conventional systems.

Soil pH and phosphorus levels were lower in the organic plots, while available nitrogen and potassium were higher in the organic plots.

Total yield of okra fruits, in terms of weight, was higher in the organic plots than in conventional ones ($F = 14.23$; df=1; $p < 0.01$).

Discussion

In the conventional plots, the presence of aphid and leafminer damage required the application of pesticides, while in the organic plots there were significantly fewer pests. The neem extract was as effective as the synthetic insecticide in controlling pest attack. Allelochemicals released by the onion intercrop in the organic plots may be the reason for fewer pests being observed in these plots. Furthermore, organic fertilisers build up resistance against pests in plants (van Emden, 1997; Stoll, 1988), and this could also explain the lower pest incidence. The higher levels of nitrogen in the soil could have contributed to the larger leaf area and greater plant height, which in turn would mean greater photosynthetic capacity and better growth of plants. Although earlier studies have shown that higher nitrogen content in soil can lead to higher incidence of leafminer damage (Facknath and Lalljee, 2005), this was not observed in the present study, perhaps due to the repellent property of onion allelochemicals.

Conclusions

Organic practices were found to be better than organic ones, in terms of both crop yield and soil health. With the well-known environmental and health benefits of organic agriculture, farmers in Mauritius should be encouraged to shift to organic systems of production.

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Research Needs in Organic Vegetable Production Systems in Tropical Countries With a Focus on Asia

Juroszek, P.[1] & Tsai, H.H.

Key words: soil fertility, crop nutrition, superior variety, pest control, natural resources

Abstract

Well-managed organic vegetable production systems (OVPS) can provide food security and healthy diets for humans, while being less harmful to the environment and more efficient in natural resource use. However, most OVPS research is carried out in developed countries, mainly under temperate or subtropical climatic conditions. Institutionalized research in organic farming in most tropical countries appears to be relatively new, and it is not a significant focus for the International Agricultural Research Centers. Tropical farmers in Asia producing vegetables organically, whether by design or default, must overcome significant challenges organic growers in temperate climates seldom face, including a lack of suitable varieties, heavy rainfall and the year-round presence of pests. According to our online literature survey, tomato is the vegetable most commonly researched in organic farming, followed by lettuce, carrot and cucumber; we found little research on crops important to tropical Asia, such as eggplant, chili pepper, different cucurbits such as gourds, and locally important indigenous vegetables. To improve and promote OVPS in tropical countries, institutional research is needed to identify and develop vegetable varieties, alternative crop protection and management methods better suited to the tropics.

Introduction

In tropical Asia, vegetables are an integral part of the diets of many people, providing the essential micronutrients vital to human health and development. While conventional vegetable production has generated income for Asia's many small-scale farmers, consumer concerns about synthetic pesticide residues have led to a greater demand for 'safer' organically produced vegetables (UN, 2003). Although there are constraints, the potential exists for smallholders to further increase their incomes by producing vegetables organically. For example, according to Pai (2006), there were 914 certified organic farms in Taiwan in 2006, covering an area of 1,442 hectares. The area of organic rice was largest with 746.4 hectares followed by organic vegetables with 372.7 hectares. However, in terms of production value, organic vegetables (NTD 249 million or USD7.55 million) were more important than organic rice (NTD158 million or USD4.78 million), or any other organically produced crop in Taiwan. This relationship is also true for other countries in the tropics/subtropics such as Thailand (Danuwat, 2007).

To participate in this expanding market, Asia's organic farmers – including traditional farmers who are "organic by default" because they cannot afford chemical inputs – need help to increase yields and improve the quality of their produce. Research should focus on the development of superior, disease-resistant vegetable varieties, safe botanical pesticides and crop management techniques specific to the tropics.

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Organic production constraints in tropical countries

According to an electronic survey by Stoll (2003) lowland vegetable production is the predominant form of organic vegetable cultivation in the tropics, followed by upland vegetable cultivation. Vegetable farmers in tropical and subtropical countries are confronted with a range of production constraints including climatic stress (heat, seasonal drought, heavy rainfall, floods, and tropical cyclones) and the year-round prevalence of insect pests and diseases (UN, 2003). Poor soil fertility, low-quality seed, and a lack of varieties adapted to these conditions further complicate organic vegetable production. Successful organic vegetable production requires a minimum level of key inputs, but in most tropical countries organic input markets are poorly developed. Weak linkages persist between vegetable producers and their input suppliers and produce markets. Traditional farmers considered to be 'organic by default' often lack basic agricultural equipment, have limited access to credit, must expend a significant amount of labor to satisfy their daily basic needs, and may not have access to education and information (Freyer, 2007).

Lack of research on tropical organic production

A simple literature search using internationally available databases shows that tomato is the most commonly researched vegetable in organic farming systems, followed by lettuce, carrot and cucumber (Table 1, column two).

Tab. 1: Number of records returned when entering keywords related to organic vegetable production

Key words entered	Records returned CAB-Abstracts + (AGRICOLA, AGRIS) 1)	Records returned CAB-Abstracts only 2) (without 'organic' in front, vegetable name only)
Organic tomato	27 + (9) = 36	32,536
Organic lettuce	16 + (3) = 19	7,255
Organic carrot	9 + (2) = 11	5,684
Organic cucumber	8 + (1) = 9	11,411
Organic onion	7 + (1) = 8	7,349
Organic pepper	5 + (0) = 5	9,026
Organic bean	5 + (0) = 5	25,192
Organic pea	5 + (0) = 5	16,740
Organic cabbage	5 + (0) = 5	9,374
Organic broccoli	4 + (1) = 5	2,847

(Databases AGRICOLA 1984 – September 2007, CAB-Abstracts 1989 – September 2007, AGRIS 1975 – June 2007, accessed 8 November 2007)

1) The same records already returned in CAB-Abstracts not included to avoid duplicate records

2) The database CAB-Abstracts was used only in order to avoid duplicate records

Note: if potato would have been considered to be a vegetable, tomato would be just the second most important vegetable crop in organic vegetable research.

Organic vegetable research is only a small subset of overall vegetable research – most of which has been done in developed countries under temperate and subtropical climatic conditions (Table 1, column three). Very few records related to organic vegetable production in tropical countries appeared in our search. For example, in the search for "organic tomato" production only four records were returned from tropical countries (three from Brazil and one from India). The FAO report 'Organic Agriculture and Food Security' states that there is almost no organic agricultural research taking place in most developing countries. Even in developed countries allocations to organic farming do not exceed one percent of total agricultural research budgets (Scialabba EL-Hage, 2007).

A focus for future research

To promote and improve organic farming in tropical Asia research efforts should focus on crops important to the region, including eggplant (brinjal), chili pepper, and different cucurbits such as gourds, etc. Some indigenous vegetables may be more suited to regional OVPS than introduced 'exotic' vegetables because of their adaptation to tropical environments, and often good tolerance of pests, diseases and low soil fertility.

Research into plant protection strategies based on a combination of preventive and direct methods will help organic vegetable producers to better manage their crops. Preventive methods such as crop rotation and maintaining soil fertility enhance the vigor and health of crop plants (UN, 2003). Soil-borne diseases and insect pests such as flea beetle (Phyllotreta spp.) are in general very difficult to manage. We found in tropical Taiwan that it is extremely difficult to control small sucking insect pests (often virus vectors) such as white flies (e.g. Bemisia tabaci), aphids (e.g. Myzus persicae) and melon fruit fly (Dacus cucurbitae) in the open field without nets. In contrast, larvae of several important Lepidoptera such as Spodoptera spp., Leucinodes orbonalis, Plutella xylostella, and Helicoverpa armigera can be controlled relatively easily with Bacillus thuringiensis (Bt) foliar applications, provided the larvae are small and remain exposed on leaves and stems. Fungal diseases are difficult to control in organic farming due to a lack of effective fungicides (Aini et al., 2005), particularly if copper and sulfur products are omitted or not available. Therefore, the most important research need in organic (and conventional) farming is to manage plant diseases through the development of disease-resistant or tolerant varieties (Aini et al., 2005).

Botanical pesticides offer a fertile area for research. More than 1,000 plants with potential applications in crop protection have yet to be investigated in detail (Prakash & Rao, 1997). Field experiments are needed to confirm the abilities of the most promising candidates observed in laboratory studies. The efficacy, human and environmental toxicity, and mode of action of most home-made botanical pesticides remain to be studied. Research should consider aspects influencing their efficacy, such as optimized extraction methods, use of natural additives such as alcohol, and target pests in relation to their vegetable host plants, as well as phytotoxicity and the effect on non-target beneficial organisms.

Research in soil fertility and plant nutrition management is needed to ensure the most effective use of limited resources such as phosphorus, and to provide the best management options for stressed soils affected by salinity, acidification, low organic matter content or nutrient depletion (eg. Grenz & Sauerborn, 2007). Being able to produce effectively under low fertility conditions may become more common (Juroszek et al., 2008) due to increasing land degradation and soil nutrient depletion as well as the expected depletion of sources of high-grade phosphate fertilizers this century (Runge-Metzger, 1995). Breeding of modern varieties is conducted mostly under high-input situations and has missed out on exploiting genetic differences expressed at low levels of inputs (Ceccarelli, 1996). Lammerts van Bueren (2002) pointed out that for very low yield-level environments, selection in ‘low-input’ systems is necessary. For instance Moura et al. (2001) found in a pot experiment a large variation in the phosphorus (P) efficiency of 10 tested sweet pepper lines, suggesting that genetic improvement programs aimed at increasing this characteristic in sweet pepper could be successful. In addition to breeding P-efficient vegetable varieties to cope with expanding low-fertility situations, other approaches such as the use of microbes for enhancing P-availability, improved technologies to use low-grade phosphate rocks, and extraction and recycling of ‘safe’ P from organic resources such as waste water and solid waste should be considered (Grenz & Sauerborn, 2007).

To conclude, more institutionalized research in organic agriculture and horticulture is needed to improve and promote organic farming systems in tropical countries.

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"Aurora Tropical": a model of Ecological Horticulture, Case studies of 11 Onion and Shallot cultivars

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Key words: semi-arid climate, tropic, alliums, vegetable, sustainable

Abstract

A proposal is presented for a model programme of ecological horticulture which could contribute to improved vegetable crop production and biodiversity in tropical agroecosystems. Each step of the model "Aurora Tropical" was successfully applied for producing pesticide-free onions and shallots in semiarid conditions of Venezuela and for comparing simultaneously growth and productivity of 11 cultivars. The model steps include a good knowledge of the vegetable crop, market, soil/substrate, irrigation water, climate, microclimate, companion crops and the current and indigenous horticultural technologies. Also, the proposal recognizes the distinction between agriculture and horticulture in tropical environments. Growth and yield results indicate that the onion cultivars Americana, Cimarron and H10020 were the top performers for leaf area, bulb diameter and yield. Furthermore, the red shallot 10026 showed the highest total soluble solids and dry matter content, and also a good relative yield. Shallots (from true seed) and other local and exotic vegetables have a great potential in tropical environments.

Introduction

In tropical areas, sun's rays striking the ground intense and continuously, means a faster and more diverse growing season year-round for plants, animals, microorganisms, and humans. These regions cover approximately 40 % of the world's land area and are home to a large proportion of the world's total population and to most of the world's poor, undernourished and deprived inhabitants (Lal, 2000).

The common features of farming communities in many tropical locations include infertile acid soils, low organic matter content, steep slopes, high risk of erosion, a warm, humid climate, economically-poor farm families, many minority ethnic groups, high population growth, and poor infrastructure (Craswell and Lefroy, 2001). Additionally, most assessments indicate that climate change will have negative effects on agriculture and forestry in the tropics (Zhao et al., 2005). Notwithstanding these constraints, some farmers all over the tropics find it is profitable to diversify from agricultural into mainly horticultural crops. In recent years, the supply of fruits and vegetables has increased continuously on a global scale; much of this growth has been concentrated in Latin America and China (Weinberger and Lumpkin, 2005). Unfortunately, vegetable production systems in the tropics and elsewhere are mostly intensive, and this approach has been identified as one of the largest contributors to the loss of biodiversity and natural resource degradation (Weinberger and Lumpkin, 2005). Thus, there is an urgent need for the development and implementation of

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ecological vegetable production systems to mitigate tropical degradation. In this context, the aim of this research is to propose an ecological model named “Aurora Tropical" for sustainable vegetable production in tropical areas and to apply and test it in the production of onions *(Allium cepa* L.) and shallot cultivars (*Allium cepa* L. *Aggregatum* Group) in the Quibor valley of Lara state, Venezuela.

Materials and methods

As a model of ecological horticulture, Aurora Tropical integrates current and indigenous knowledge from various agricultural systems including local, modern, integrated, organic agriculture and agroecology, permaculture and agroforestry, adapting all to the tropical regions. Table 1 shows the 6 steps followed by the model and their applications for producing onions and shallots in tropical conditions.

Results and Discussion

Table 2 shows the results of a trial comparing growth, yields and postharvest quality of 9 onion cultivars and 1 shallot cultivar. A second shallot cultivar (100026 Hazera Seeds, Israel), did not survive after transplanting. This cultivar may not have been appropriate for this region and/or transplanting season. The integrated model Aurora Tropical proved to be very effective, producing good quality, pesticide-free onions and shallots under tropical conditions. Each step had an interesting response. For example, companion cropping was a very useful technique, mainly intercropping with sunflowers. Results from Jones and Gillett (2005), indicate that sunflowers indeed attract and play host to numerous beneficial insects in a vegetable agroecosystem. This is a very important finding, as we know that almost all vegetable crop production in tropical countries follows the conventional system, whereby production activities are the largest users of plant protection products, since most of these crops are rather susceptible to pest and climatological hazards. As vegetables are often traded and consumed in fresh form, biological contamination, pesticide and heavy metal residues and waste products are also very serious issues (Weinberger and Lumpkin, 2005), especially in tropical conditions. Research done in Venezuela and Peru supports this concern (Pierre and Betancourt, 2007; Yucra et al., 2006).

As shown in Table 2, the onion cultivar Americana was the top performer for leaf area, bulb diameter and yield, followed by Cimarron and H10020. However, this cultivar showed a high thicknecking percentage (data not shown) which negatively affects keeping quality and market. The red shallot showed the highest total soluble solids and dry matter content, and gave a relatively high yield. Shallots are not a well known vegetable crop in Latin American countries. In fact, this is the first experiment with shallots in Venezuela. Nevertheless, in Asian and African countries, the shallot is an economically important crop and much more in demand than common onion, because of its pungent flavour, culinary value and high adaptability to tropical and subtropical conditions. For example, in Vietnam, shallots are sold in every market all over the country, as fresh green or dry bulbs. For dietary consumption, it is used as a vegetable, spice, pickle or as medicine to reduce fever and cure wounds (Phuong et al., 2006).

Tab. 1: Steps of the ecological model "Aurora Tropical" and its application for producing onions and shallots in semiarid tropical conditions of Venezuela

Step	Application
1. Crop, Market, Climate, soil/substrate and water: Historical and current analyses of these resources (quality and quantity) are compulsory	Onions and shallots for trading as fresh produce direct to the local market. Climate: first peak of the humid season (May to September), at the "Hacienda El Tunal" in Quibor valley, Lara state, Venezuela (lat. 9º 57´ N). Soil: Previous analyses see Ramirez, (2002). A clay loam soil with low organic matter and high phosphorus and potassium content was used. Water. The electric conductivity (EC) of the irrigation water was 0.7 dS m^{-1} and the pH 7.
2. Sowing/transplanting season and system: according to the vegetable crop, market, climate, soil/substrate and irrigation water.	Onion and shallot seeds were sown in plug flats of 288 cells (5 seeds per cell) on 20 April 2006. On 27 May, the seedlings were transplanted in six rows with 15 and 10 cm between rows and plants respectively on a raised, shaped, standard vegetable bed (1 m wide).
3. Vegetable cultivar: productive genetic material adapted to the local area, sowing season and tolerant to main local constraints is necessary.	Growth, development, yield, postharvest quality and adaptation (mainly to day length) of 11 hybrids (8 onions, 2 shallots) and 1 onion open pollinated (OP), were compared using a complete randomised block design with 5 replications (55 plots, each 6 m long). All cultivars were certified short-day materials.
4. Companion crops: mainly plants well known as hosts of beneficial insects. These crops are chosen in relation to the main vegetable crop, sowing season and main pests limiting the main crop.	On 27 May, crops of carrot, vegetable and herb mixture (parsley, coriander, beet, fennel, alfalfa, carrot, and basil), soy, and the outer crop of sunflower were directly sown on individual beds (1 m wide and 30 m long). These crops were completely surrounding the main crop (onions and shallots) as a core frame. Carrots were located just next to the main crop. According to Stoll (2000), mixed cropping of carrots and onions contributes to a reduction of the thrips populations (the main onion pest locally and worldwide).
5. Horticultural technologies: A key factor. It means picking and using the appropriate and adapted technologies (indigenous or modern), such as an integrated tillage, irrigation system, fertilization and pest management (IPM) among others. All technologies are used for "preventing" and not for curing.	Main and companion crops were drip irrigated and organically fertilized (10 ton ha^{-1} of "Tunal Compost" from a mix of cattle, chicken and pig manures). Moreover, main crops were mineral fertigated (only using 155 kg ha^{-1} of Nitrogen and 50 kg ha^{-1} of Potassium). Regarding IPM, roots of onion and shallot seedlings were soaked in a mixed solution of trichoderma and humus. This solution was also foliar applied. Diseases were managed with preventive foliar application of copper, sulphate, and organic pesticides. Meanwhile, insects were controlled by using natural repellent solutions (neem, basil, garlic, etc.). Also, insect pests on the coloured plastic traps (yellow, blue and white) and crops were monitored. Hand weeding was undertaken as needed.
6. Harvest, postharvest and complementary steps.	When most onion cultivars were harvested (112 days after transplanting), bulb yields and postharvest quality were recorded. After sorting by size and skin colour, the produce was sold at the local growers market, labelled as an ecological product. During the application of the model, there were guided visits, open field days, workshops, cookery demonstrations, etc., at the experimental plot.

Conclusions

Aurora Tropical could become a useful tool for producing sound vegetables in tropical regions which still rely on an agriculture-based economy and are classified as developing countries. It is crucial to point out the big distinction between horticulture and agriculture under tropical conditions. The selection of the precise vegetable cultivar for the current season, companion crops and other adapted horticultural technologies are very useful skills for breaking down the monoculture structure, promoting biodiversity, providing pest and weed control benefits, reducing erosion, and improving water infiltration, among others. Shallots and other adapted crops have a great potential for producing and developing new markets in tropical areas.

Tab. 2: Growth, yields and postharvest quality of 9 onions and 1 shallot short-day cultivars applying the ecological model Aurora Tropical

Cultivar	Origin	Skin colour	Leaf area* (cm^2 $plant^{-1}$)	Bulb diam.* (cm)	Yields* (kg ha^{-1})	TSS* (ºBrix)	Dry matter (%)*
H. Sequoia	Nunh. Chile	Yellow	100bc	4.7abc	22797bc	5.54de	4.0cd
H. 10020	Haz. S. Israel	Red	115b	5.1ab	28153b	7.02bc	4.6bc
H. Cimarron	Nunh. Chile	Yellow	117b	5.2ab	26368b	5.01de	3.6d
H. 10000	Haz. S. Israel	Yellow	63cde	4.1cde	12223cde	4.81de	3.5d
OP Reina438	Paim. S. Italy	Yellow	86bcde	4.7abc	17029bcde	4.88de	3.6d
H. 1478	Haz. S. Israel	Yellow	39e	3.5e	5768e	5.11de	3.4d
H. 1297	Haz. S. Israel	Yellow	48de	3.6de	7828e	4.35e	3.3d
H 10026, Sh.	Haz. S. Israel	Red	97bc	4.3bcde	18677c	10.83a	7.0a
H. Americana	Seminis USA	Yellow	164a	5.3a	35020a	7.34b	4.9b
H. 10021	Haz. S. Israel	Red	69cde	4.4bcd	14420cde	6.01cd	4.0cd

* Means followed by the same letter are not significantly different by Duncan test at the 0.05 level. H.: hybrid, OP: open pollinated, Sh.: Shallot, TSS: total soluble solids, Nunh: Nunhems, Haz: Hazera Seeds, Paim: Paimer seeds.

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Change in the weed seed bank during the first four years of a five-course crop rotation with organically grown vegetables

Sjursen, H.[1], Brandsæter, L.O.[1] & Seljåsen, R.[2]

Keywords: weed seed bank, red clover, yellow sweetclover , vegetables, crop rotation

Abstract

In a five-course rotation with organic vegetables (white cabbage, carrot and onion) the weed seed bank was reduced the year after two continuous years with red clover, mainly because of mowing and no soil cultivation the second year red clover. The year after the weedy yellow sweetclover the weed seed bank increased.

Introduction

The weed observations were an integrated part of the project 'Optimum crop rotation for secure organic vegetable production', started in 2002 at Bioforsk Arable Crops – Landvik, in the southern part of Norway. The project has focused on different N-sufficient crop rotation systems on a clay rich soil. Of five production years two have been used for green manure fertilisation with legumes. Our results have shown that the systems provide abundant levels of nitrogen for white cabbage, carrots and onions.

The soil seed bank is recognized as the primary source of annual weeds in arable land. The majority of seeds entering the seed bank come from annual weeds growing in the fields. The size of the seed bank reflects past and present field management (Cavers & Benoit, 1989). Albrect (2005) found that the number of weed seeds increased at sites with low crop cover and high density of weed plants at the soil surface. Winter cereals, sunflowers and lupins increased for example the weed seed bank by 30-40%. Grass-clover mixtures, however, reduced the seed bank by 39%. In an organic farmed six-course rotation investigation in Norway, the seed bank was reduced from a maxiumum of 17600 m^{-2} to a minimum of 7200 seeds m^{-2} after three years with perennial grass-clover ley (Sjursen, 2001).

The main objective of the present study was to evaluate the effect of two years with a N-fixing clover crop on the weed seed bank, either two continuous years with red clover or two alternating years with yellow sweetclover.

Materials and methods

The investigated area had four different fields with three replicates. Two of them had this rotation: Red clover, red clover, white cabbage, onion, followed by a last year with carrot. Two other fields had this rotation: yellow sweet clover (ribbed meliot), white cabbage, yellow sweet clover, onion and carrot. The plot size was 8 x 15 m. Soil samples down to 0.20 m for weed seed investigations were taken each year before

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the growing season started (around 25th of April). The seed number analysis were carried out by the seedling emergence method described by Sjursen (2001). Number of emerged weeds on the soil surface were counted in a frame 0,5 x 0,5 m (clover crops) or 0,1 x 1,0 m (vegetable crops) during the end of June – beginning of July. The fields were weed managed by common organic methods, like flaming before planting/sowing, inter-row hoing/ploughing, and manual weeding in vegetables, and two-three times mowing in clover leys.

Results

The weed seed bank in the whole investigated area increased the first three years by 11% from about 28000 to 31000 seeds m^{-2}, and was redused by 7% to 29000 seeds m^{-2} the fourth year. 23 weed species occurred in the seed bank. The most frequent species were *Spergula arvensis* L., *Filaginella uliginosum* (L.) Opiz., *Poa annua* L., *Capsella bursa-pastoris* (L.) *Medicus*, *Chamomilla suaveolens* (Pursch) Rydb. and *Stellaria media* (L.) Vill.

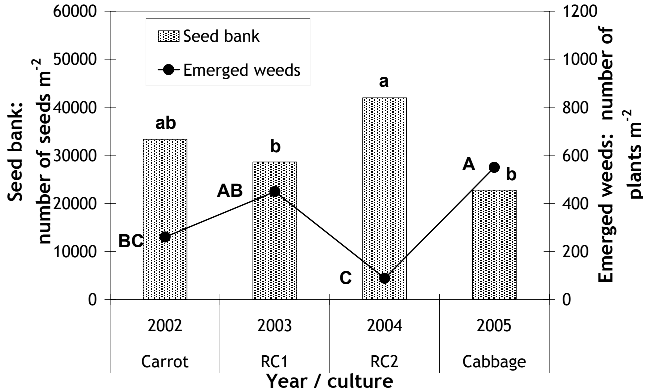

Figure 1: Weed seed bank in the soil (left hand y-axis) and emerged weeds (right hand y-axis) during two continuous years with red clover (RC1 and RC2) in rotation with carrot and white cabbage. Onion is the fifth year. Values with the same letter (lower case or upper case) are not significantly different at p 0.05 (n = 6).

The same species were most frequent among the emerged species. The seed bank increased after one year with red clover, but was reduced after the second year of clover (figure 1 and 2). The seed bank increased the year after yellow sweetclover (figure 3 and 4). The density of emerged weed plants was high in the first year with red clover (figure 1 and 2) and in yellow sweetclover (figure 3 and 4).

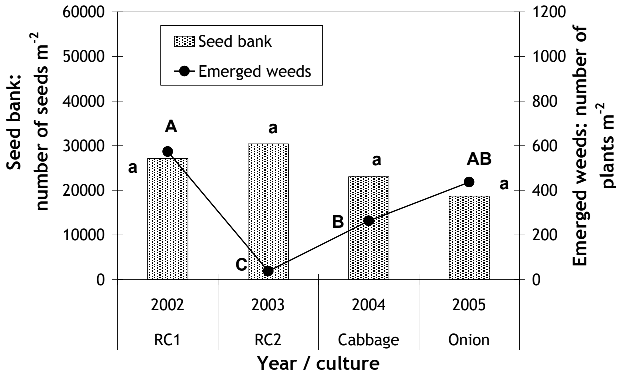

Figure 2: Weed seed bank in the soil (left hand y-axis) and emerged weeds (right hand y-axis) during two continuous years with red clover (RC1 and RC2) in rotation with carrot and onion. Carrot is the fifth year. See figure 1 for statistics.

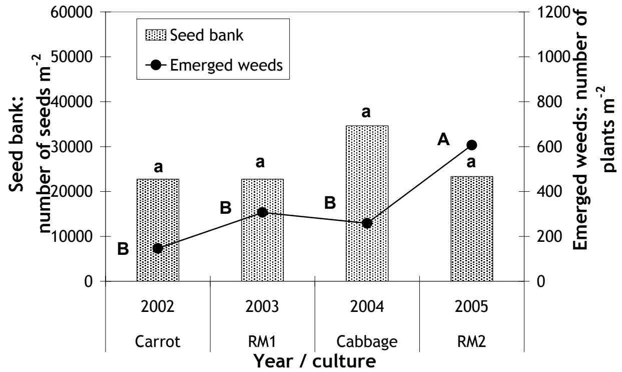

Figure 3: Weed seed bank in the soil (left hand y-axis) and emerged weeds (right hand y-axis) during two alternating years with yellow sweetclover (RM1 and RM2) in rotation with carrot and onion. Onion is the fifth year. See figure 1 for statistics.

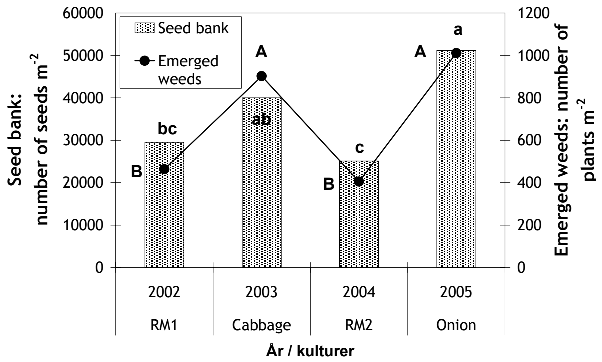

Figure 4: Weed seed bank in the soil (left hand y-axis) and emerged weeds (right hand y-axis) during two split-up years with ribbed meliot (RM1 and RM2) in rotation with white cabbage and onion. Carrot is the fifth year. See figure 1 for statistics.

Discussion and conclusions

The results show that there are a close relation between the emerged weed plants at the soil surface and the seed bank the following year. The red clover was mowed two-three times the second year. This resulted in low emergence of annual weeds, and reduced seed bank the following year (figure 1 and 2), in accordance with the investigations by Sjursen (2001) and Albrecht (2005). This effect was not seen in yellow sweetclover. There was a tendency of weed seed bank reduction the year after white cabbage, which can be explained by the strong competition by the fast-growing cabbage leaves and the manual weeding. This effect was not seen the year after carrot and onion, which is known as low-competitive crops. Teasdale et al. (2004) force the importance for organic farmers to minimize opportunities for rapid buildup of the seed bank.

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Changes in mineral content and CO_2 release from organic greenhouse soils incubated under two different temperatures and moisture conditions

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Key words: soil respiration; moisture content; biological activity; soil temperature

Abstract

In organic greenhouse vegetable productions, the turnover rate of organic amendments may be a limiting factor for optimal crop productivity and quality. Hence, we determined the mineralization potential of several organic greenhouse soils maintained at two temperatures (17, 23□C) and water potentials (–35, –250 mbars). Replicate cores of structurally intact soils were collected in plastic cylinders, saturated with water and adjusted to the appropriate matric potential. Additional soil samples were sieved, placed in glass jars and incubated under the same treatment conditions. Soil nutrients, gas concentration (O_2, CO_2, N_2O) and microbial activity (CO_2 release) were measured over a 25-week period during aerobic incubation. Large variations in nutrient and organic matter content were observed among intact soil samples. CO_2 efflux declined exponentially with time, decreases being most apparent in soils having high organic matter content. An increase in temperature lead to enhanced soil respiration rates, mainly during the first weeks of incubation. Overall, mineralization rates were only slightly affected by moisture level or temperature. Gas diffusion, and thus soil biological activity, may be momentarily hindered during frequent irrigations. Yet, our findings indicate that in general matric potentials of –35 and –250 mbars both result in similar mineralization rates in these soils.

Introduction

The foundation of organic farming is based on soil biological activity, which depends on soil properties (C/N, % organic matter, pH, O_2), cultural practices (fertilization, amendment, crop rotation, tillage, irrigation) and environmental factors such as temperature and soil moisture (Dorais, 2008). Although the growing conditions can easily be controlled in a greenhouse, the turnover of organic amendments for organically-grown vegetable crops may become a limiting factor for optimal crop productivity and product quality. Indeed, nutrient requirement of greenhouse tomato crops is higher than that of field tomato crops, with yield being up to 10 times greater in greenhouse crops than field crops (Heuvelink & Dorais, 2005). Soil texture and structure, as well as temperature and moisture may all affect the activity of soil microorganisms and hence, the mineralization rate of organic matter in the soil (Angers & Carter 1996; Schjønning *et al*. 1999; Thomsen *et al*. 1999). For instance, pore size distribution and total porosity both impact on soil organic C mineralization by

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influencing soil moisture availability for microbes (Yoo *et al*. 2006). Irrigation management is thus a key factor to optimize soil biological activity. A better understanding of mineralization processes under different greenhouse growing conditions is important for optimizing crop nutrient supply, while minimizing losses to the environment (i.e. to the groundwater). The objective of the present study was to determine the mineralization potential of several organic greenhouse soils maintained at two temperatures and two soil water potentials.

Materials and methods

An incubation experiment was conducted using two temperatures (17°C, 23°C), two soil matric potentials (–35 mbars, –250 mbars = field capacity) and five incubation periods (1, 4, 8, 16 and 24 weeks). Three replicate 196-cm^3 cores of structurally intact soil (0–10 cm depth; 5-cm diam. cylinders) per treatment and time period were collected from five organically managed greenhouse soils in 2006 (n=300; Table 1). Soil samples were first saturated with distilled water, then adjusted to matric potentials of –35 and –250 mbars using a tension-plate assembly and a pressure-plate apparatus. Based on soil water release characteristics, these two matric potentials resulted in a mean (±SD) water-filled pore space of 80% (±6%) and 68% (±5%), respectively. Additional samples (n=240) were collected, saturated and brought to the appropriate matric potential, then sieved through a 6-mm mesh and placed in sealed glass jars. Cylinders and glass jars were placed into two growth chambers under constant temperature in completely randomized blocks (n=3). Soil samples were weighed once a week and distilled water was added when necessary to compensate for water loss. Samples were rotated weekly both within and between chambers to minimize chamber effects. Microbial activity (CO_2 efflux) was measured in larger soil samples (~900 cm^3) at 4 to 8-week intervals using a portable gas exchange system (model LI-6400, Li-Cor) and a Soil CO_2 Flux Chamber. Three cylinders and glass jars from each soil and treatment were sampled at the end of each incubation period to determine water-extractable minerals (K, P, Mg, Ca, Na, etc.; readily available to plants) and KCl-extractable inorganic nitrogen (NO_3, NH_4). Soil organic matter content was determined using the Walkley-Black method (for mineral soil) or the loss by ignition method (for soil having >20% organic matter). Mean changes in nutrient content were analyzed using an ANOVA with soil type, temperature, matric potential and incubation period as fixed factor effects. All statistical analyses were computed using *SAS* v.8.2 (SAS Institute, Cary, NC) with a level of significance of $P < 0.05$.

Results and Discussion

From our glass jar trials, we observed a significant increase in nutrient contents of soil samples during the 24-week incubation period (Table 1) and a corresponding decrease in organic matter (data not shown), thus suggesting microbial activity. Similar trends were obtained with intact soil cores, but a greater variability was observed due soil heterogeneity within the greenhouse. Microbial activity was also inferred from soil respiration measurements. CO_2 release from incubated samples declined with time (Figure 1). As expected, CO_2 fluxes were greater at 23°C than at 17°C in all types of soil ($P<0.01$). However, soil matric potential had no significant effect on CO_2 efflux (data not shown). There were no statistical differences in nutrient and organic matter contents between the different types of containers, hence similar soil respiration rates were assumed.

There was a significant effect of incubation temperature on the mineralization of NO_3 in sandy loams (Figure 2; P<0.05), and a consistent trend of increasing nutrient content with temperature in most soils, except for NH_4 and K in OS~20, and P content in general. Matric potential (i.e. moisture) had no consistent effect on nutrient change over a 24-wk period (Figure 2). Further, we did not detect any significant effect of moisture and temperature on Mehlich-3 extractable micro- and macro-nutrients (data not shown). This was partly due to high soil greenhouse variability in nutrient content and thus, between intact soil cores.

Tab. 1: Changes in nutrient content of organically managed greenhouse soils after a 24-week incubation period.

Textural class	Cultivation time	Organic matter	Changes in nutrient content (mg kg^{-1} soil day^{-1})			
	(years)	(OM, %)	NO_3	NH_4	K	P
Sandy loam (SL)	1	4.9	0.77*	–0.09	0.08*	0.0035*
Sandy loam (SL)	2	6.3	3.38*	0.31*	0.13*	0.0068*
Loam (L)	4	8.5	4.82*	0.29	0.22*	0.0043*
Loam (L)	~15	11.3	1.77	<0.01	–0.01	0.0360*
Organic soil (OS)	~20	33.4	5.33*	0.44*	0.82	–0.1101*

NOTE: a soil is considered organic when the content of organic matter > 20%. Cultivation time refers to the number of consecutive years a crop was organically produced on the same soil. * indicates a significant ($P \leq 0.05$) change in nutrient content between week 1 and week 24.

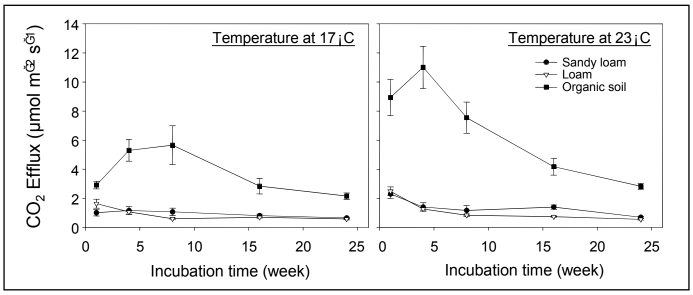

Figure 1: Relationship between incubation time and soil respiration for three types of organically cultivated soil (sandy loam 1-year, loam 15-years, and organic soil 20-years) exposed to two different soil temperatures

Conclusions

Based on our results and studied soils, we conclude that increasing greenhouse soil temperature from 17°C to 23°C would significantly enhance soil respiration rates, particularly during the first few months. However, mineralization rates in intact soil cores were only slightly increased by higher soil temperature or lower moisture content. Since gas diffusion and soil biological activity may be momentarily hindered during frequent irrigations (required by vegetable greenhouse crops), soil moisture conditions close to field capacity should improve the turnover of soil organic matter. Yet, similar changes in nutrient contents were observed in soil samples incubated during 24 weeks at matric potentials of –35 vs. –250 mbars. Enhanced turnover of organic amendments and release of plant available nutrients may be possible by further improving air-filled porosity (lower matric potential, i.e. drier soil) or by stimulating the activity of soil microflora and fauna.

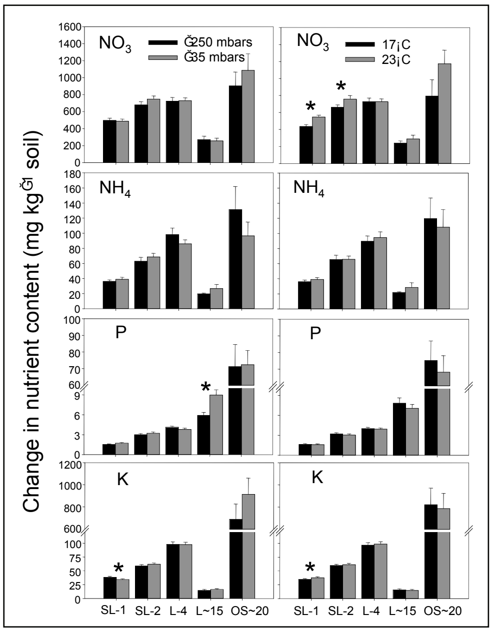

Figure 2: Mean changes (±SE) in nutrient contents of soil samples maintained at two temperature and matric potentials over a 24-wk incubation period

Acknowledgments

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Plant traits affecting thrips resistance in cabbage

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Keywords: *Brassica oleracea* var *capitata*; *Thrips tabaci*

Abstract

The development of thrips populations and thrips damage in 15 cabbage varieties was monitored in two years of field experiments in the Netherlands.. A number of morphological and physiological plant traits were also measured. The most important factors leading to a low level of thrips damage were late development of a compact head, a low Brix value and a high amount of leaf wax. Two open-pollinated cabbage varieties with low and high susceptibility to thrips damage were crossed in both reciprocal combinations. The resulting F1 populations were intermediate for susceptibility to thrips damage.

Introduction

Cabbage is one of the main field crops grown by organic farmers in the Netherlands. When cabbage is cultivated for storage, it is usually harvested around mid-October. This type of cabbage crop may be severely damaged by thrips (*Thrips tabaci*). Thrips damage can already appear in August, but the thrips population on the plants and the more severe symptoms develop mostly during September and October. Also during cold storage symptoms continue to develop. In conventional cultivation chemical treatments may be used to control thrips damage, but as the insects are protected within the developing head this is not always effective. In organic farming no effective natural crop protection is available.

The damage caused by thrips is due to the symptoms that develop after feeding, which are small callus-like growths (warts) that will turn brownish after some time. Although the presence of the insects themselves, and the direct yield loss due to feeding are not important, the induced symptoms necessitate the removal of the outer leaf layers before marketing. This increases labour costs and reduces marketable yield (North & Shelton, 1986; Fail & Penzes, 2004).

Among modern cabbage varieties, large differences are known to occur in the susceptibility to thrips damage (a.o. Shelton et al, 1983). It is not clear whether these differences are due to resistance (affecting the thrips population in the plant) or to tolerance (affecting the development of symptoms upon thrips feeding). Further, not much is known about plant traits affecting the resistance or tolerance to thrips. This research is aimed at elucidating these points.

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Materials and methods

Plant material and cultivation

In 2005, ten cabbage accessions with varying scores for thrips damage, wax layer, earliness of heading and of maturity were obtained from the Centre of Genetic Resources of the Netherlands (open-pollinated varieties) and from seed companies (F1 hybrids). Seedlings were transplanted to plugs at 2 weeks after sowing and planted in the field at 6 weeks.

In 2006, 13 accessions were grown, including 5 F1 varieties that had not been tested in 2005 and two reciprocal F1 combinations between two OP varieties with high and low susceptibility to thrips damage.

In both years, all accessions were planted end May. In 2005, four accessions were planted also mid-June. The experiments were replicated in two fields, one in Wageningen and one in Zwaagdijk. Both fields were laid out in three blocks, each with one plot per accession/plant date and 45 plants per plot. Cultivation was according to organic farming regulations.

Evaluation of traits, thrips population and damage

At four dates (early August, early and late September, and early or mid-October) three plants per plot were evaluated a.o. for head circumference, leaf thickness, developmental stage, head compactness and leaf wax (visual grading). Heads were halved longitudinally. One half was peeled, the total number of adult thrips were counted, and the thrips damage (affected leaf area and size of warts) graded visually; the three other halves from each plot were pooled and ground, and analyzed for Brix (Atago N-20 refractometer) as an indication of sugar content.

Statistical analysis

Data were transformed where necessary to obtain uniform residual variances. This involved logarithmic transformation of developmental stage and of thrips damage scores; for other traits no transformation was necessary. Next averages (of transformed values if necessary) were calculated per plot. All ANOVA analyses and correlations were based on plot means, and carried out in Genstat 8.

Results and Discussion

Development in time

At the first harvest date in both years, most plants had barely started to form a head. Only a few thrips were found in the entire experiment and no damage was observed. During the next three harvests all heads grew and matured. Differences in maturity and compactness were clearly evident at the earlier harvests but became less pronounced at the last harvests. For leaf thickness and Brix no clear trends were observed. Leaf wax was lower at the first harvest than at the next three harvests.

Effect of planting date

In 2005, four of the accessions were sown and planted at two dates. For developmental stage, size and compactness, large differences between the two planting dates were observed during the earlier harvests, which decreased towards the last harvest date. No clear effects on leaf wax or leaf thickness were observed, while the Brix values were slightly lower in heads from the late planting. The number of thrips was considerably smaller, and the damage slightly smaller in the late planting, with exception of the highly resistant cultivar Galaxy F1 which showed no consistent differences between the planting dates.

<u>Location effects</u>

In each year separately we observed significant differences between the two locations for many of the measured traits, and within the same year these differences were more or less consistent between harvests. For example, in 2005 the cabbages grew and matured faster and became larger at Wageningen than at Zwaagdijk, leaves were thicker and had more wax at Zwaagdijk and thrips damage was generally higher in Wageningen. However, these location differences were not consistent between the two years, indicating that transient effects such as weather and nutrition were more important than the locations themselves.

<u>Genotypic effects</u>

The varieties showed a large variation for all traits studied, as was expected from the selection criteria. Based on earlier observations and information from breeders and growers, the F1-hybrid varieties Slawdena and Bartolo were selected as highly susceptible standards and Galaxy as a resistant standard. These varieties performed as expected, while the other test material showed a full range of responses, at some harvests even extending beyond the susceptible and/or resistant varieties (*e.g.* Figure 1) Thrips population and damage were highly correlated, especially at the two late harvest dates of both years (R ranging from 0.86 to 0.91), in line with the observations of Stoner & Shelton (1986). There were no varieties with a remarkably low damage in relation to the number of thrips, as would be expected if low thrips damage were caused by small plant responses to feeding rather than by reduced thrips population development. This indicates that among the tested accessions, resistance rather than tolerance is the cause of the observed differences in thrips damage.

<u>Correlations between plant traits and thrips damage</u>

Thrips damage and thrips numbers in the last two harvests were positively correlated. Both were also positively correlated with Brix, and with compactness and developmental stage in the first two harvests. This indicates that a cabbage head with tightly packed leaves early in the season leads to higher thrips populations; presumably because the insects are sheltered against predators. These results are at variance with those of Shelton et al (1983) who could not attribute varietal differences in thrips damage to dry-matter quality or to date of maturity. This may be due to the different sets of varieties tested, or to differences in climate or thrips populations between the test locations.

Further, a large amount of leaf surface wax was shown to be negatively correlated with thrips damage and thrips population size, indicating that wax gives some protection against thrips. No relation was found with head size. Contrary to earlier indications from growers, we also found no clear relation between leaf thickness and thrips population or damage.

<u>Inheritance of resistance to thrips damage</u>

Open-pollinated varieties Langendijker Bewaar (resistant) and Bewama (susceptible) were crossed reciprocally, and the two reciprocal F1's were tested together with the parental varieties and st,andards in the 2006 experiments. At the later two harvests, when the thrips damage was well established, and at both locations the two reciprocal

F1's showed thrips damage intermediate between that of the parental varieties (Figure 1). This is in contrast to the results of Stoner et al (1986) who observed dominance for susceptibility. The discrepancy may be due to the different cross combinations and/or to the observation scale. The inheritance will be studied further in an F2 / F3-line population derived from our crosses.

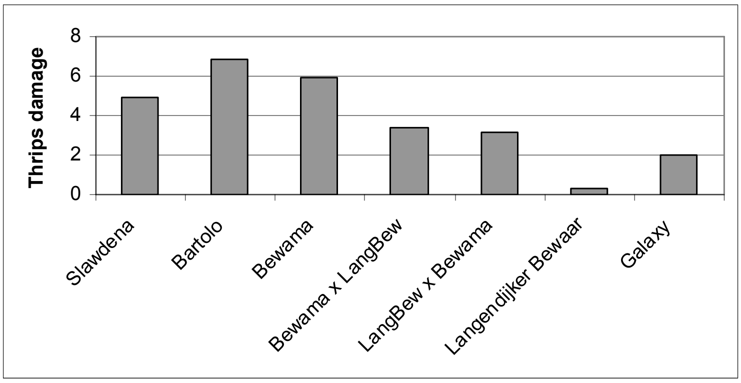

Figure 1. Thrips damage means for two reciprocal F1's between varieties Bewama (susceptible) and Langendijker Bewaar (resistant) in comparison with the parents and standard varieties Slawdena and Bartolo (susceptible) and Galaxy (resistant)

Conclusions

Thrips damage and thrips population size were found to be highly correlated, and no varieties were found with high thrips numbers but low damage. This indicates that resistance rather than tolerance is the dominating factor affecting thrips damage.

Important plant traits that limit thrips damage are the late formation of a compact head, a low dry matter content and a high amount of leaf surface wax.

Highly resistant and susceptible OP varieties were identified. F1's of crosses made between those varieties showed an intermediate level of resistance.

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Increasing Cultivar Diversity of Processing Tomato under Large Scale Organic Production in California

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Key words: cultivar mixtures, plasticity, interaction, cover crop

Abstract

At an organic farm in California, higher plant diversity was hypothesized to enhance ecosystem functions and services. Plant diversity was manipulated temporally and spatially: mustard cover crop vs. no cover crop (fallow) in winter, and mixtures with one (farmer's best choice), three, or five processing tomato cultivars in summer. Soil N, soil microbial biomass, crop nutrient uptake, canopy light interception, disease, GHG emissions and biomass were measured. Results show that the mustard cover crop reduced soil nitrate (NO_3^-) in winter and also during the tomato crop, which was associated with decreased growth and canopy development. All cultivar mixtures had fairly similar yield and shoot biomass. The 'choice cultivar' (i.e. farmer's best choice) showed plasticity depending on the mixture, tending to have higher biomass production in mixtures. This study shows the complexity of cultivar-mixture interactions. To achieve the greatest benefit for ecosystem functions in organic farming, mixtures require greater understanding of cultivar plasticity and phenological and physiological trait diversity.

Introduction

Cultivar mixtures have been studied primarily for increasing yields (Burton et al., 1992) and disease control (Mundt, 2002), but other ecological processes have not been adequately evaluated. Cultivar mixtures may potentially provide a strong benefit for ecosystem functions in organic systems because of their limited management options and dependence on on-farm resources. Interaction among cultivars, and the effects of surrounding environment, may stimulate genotypic responses that could maximize the potential performance of a cultivar.

Mixtures are increasingly important in the framework of sustainable agriculture. Examples include rice in China (Meung et al., 2003), winter wheat in USA (Gallandt et al., 2001), and barley in the German Democratic Republic (Finckh et al., 2000). Even so, difficulties in managing cultivar mixtures can often be overestimated. Cultivar selection for mixtures depends on characteristics such agronomic compatibility, genotypic diversity (Mundt, 2002), high yields, and marketability. The number of genotypes in a cultivar mixture tends to be three (Mundt, 2002).

The central question of this study was: Why choose a cultivar mixture instead of a monoculture in an organic agroecosystem? It was hypothesized that increasing plant diversity may increase ecosystem functioning. A diverse tomato community may better use available nutrients, water and light resources. Some mixtures may perform similarly in different environments (yield stability). Cultivar differences in allocation and

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growth, including plasticity responses in different mixtures, may help to increase resource use and yield stability, and decrease N loss due to complementarities in root system development, depths, and N needs.

The main objectives of this study were: to measure the effects on phenotypic, nutrient uptake, and yield response of a 'choice cultivar' (i.e. farmer's best choice) when interacting in three different tomato communities, and thus on yield stability; to assess the effects of tomato community composition on resource utilization and its response to the surrounding environment, i.e., disease pressure and abiotic stress, using indicator variables; and to examine, at the ecosystem level, the effects of soil N availability on tomato communities.

Materials and methods

Our study involved participatory research with a 14-year organic processing tomato grower at a 44 ha organic certified farm in Yolo County, California (California Certified Organic Farmers http://www.ccof.org/). His main commodities were processing tomatoes and oats as hay, as well as a fall/winter cover crop. Processing tomatoes were grown every other year on alternating fields using conventional tillage, and were furrow irrigated during the processing tomato crop, i.e., spring and summer season.

Two different sets of environmental conditions were established prior to tomato planting: winter fallow and mustard cover crop, i.e., main plot treatments of 16x9 m, each with 6 beds. Three cultivar mixtures as subplot treatments of 5x9 m with 6 beds utilized processing tomato cultivars that had the following characteristics: high yielding and currently marketable, grown commercially with similar amounts and timing of inputs, mid-maturity varieties, i.e., ~125 days from planting to harvest, and fruit quality that met industry standards. Subplot treatments consisted of the 'choice cultivar' grown by the farmer in the entire field (1 cv); a mixture of the 'choice cultivar' plus two more cultivars used by the same farmer on other of his fields (3 cv); and these three cultivars plus two more that were currently used by other organic growers in California for a total of 5 cultivars (5 cv). A completely randomized block design with a split-plot treatment structure was used. A total of eight blocks were established.

Soil sampling and measurements were as follows. Nitrate (NO_3^-) and ammonium (NH_4^+) by KCl extractions of field moist soil at three depths (0-15, 15-30 and 30-60 cm). Microbial biomass carbon (MBC) was analyzed for the 0-15 and 15-30 cm depths using the fumigation extraction method (Vance et al., 1987). Carbon dioxide (CO_2) and nitrous oxide (N_2O) gas emissions were sampled on the bed shoulder after irrigation events using closed, capped chambers for 30 min (Rolston, 1986). Biomass samplings for shoots and fruits of individual plants for the 'choice cultivar' and for the cultivar mixtures were done throughout the season. These samples were analyzed for N content by C/N combustion. Measurements of canopy light interception using a portable tube solarimeter with sensors for photosynthetically active radiation (PAR) and disease evaluation for *Sclerotium rolfsii* (Southern blight) were also performed intermittently.

Results

Yields were similar for all tomato cultivar treatments within each of the two winter treatments, with and without a cover crop. The vegetative growth of all cultivar mixtures performed better in winter fallow plots, e.g., canopy light interception and aboveground biomass were higher. Total N uptake (g N m^{-2}) tended to be lower in the winter mustard plots, and did not differ between cultivar mixtures and the 'choice cultivar' (Table 1). Plants lost to disease tended to be higher in winter mustard plots.

The ‘choice cultivar' (farmer’s best choice) had higher biomass productivity when in mixtures of 3 or 5 cultivars, at mid-season and in the N-limited winter mustard plots, e.g., its shoot and fruit biomass was highest in the 3 cv mixture at 75 DAP in the winter mustard plots. By the end of the season, however, similar yields for harvestable tomatoes were found in the 'choice cultivar' in the three tomato mixtures.

Inorganic N was more available in winter fallow plots. The winter mustard cover crop decreased N availability from prior to cover crop incorporation through tomato harvest, and it generally increased soil microbial biomass (significant only at 7 days after planting (DAP), suggesting higher microbial activity. CO_2 and N_2O emissions were generally similar in the tomato cultivar treatments, but CO_2 emissions were initially higher in the winter mustard plots. CO_2 emissions in the fallow plot were higher for the monoculture in the last two spot samplings, and N_2O emissions were variable with a tendency of the 5 cv mixture to be higher in winter fallow plots.

Tab. 1. Light interception, aboveground biomass, harvest index and N uptake at early and mid crop season and harvest time for processing tomato mixtures in California. Data shown for cover crop mainplots and cultivar mixtures (cv).

DAP^	Variables	Cover crop treatment		Winter fallow plots			Winter mustard plots		
		Fallow *	Mustard	1cv	3cv	5cv	1cv	3cv	5cv
35 DAP	PAR** intercepted (%)	19.54 ± 1.05 a	15.27 ± 0.94 b	21.56 ± 1.20	18.51 ± 1.85	18.55 ± 2.25	15.47 ± 1.89	14.88 ± 1.50	15.47 ± 1.68
69 DAP	PAR intercepted (%)	45.64 ± 1.04 a	38.52 ± 1.34 b	46.07 ± 1.43	45.63 ± 2.18	45.20 ± 1.96	38.75 ± 1.54	39.86 ± 2.65	36.93 ± 2.76
95 DAP	PAR intercepted (%)	46.83 ± 1.18 a	42.57 ± 1.26 b	48.05 ± 2.61	46.38 ± 1.61	46.07 ± 2.00	45.05 ± 1.88 x	39.99 ± 2.23 y	42.67 ± 2.29 xy
39 DAP	Shoot biomass (g m $^{-2}$)	70.43 ± 6.82	53.83 ± 4.71	71.61 ± 9.80	73.98 ± 11.60	65.69 ± 16.41	68.12 ± 3.76 x	48.97 ± 8.49 xy	44.39 ± 7.21 y
75 DAP	Shoot biomass (g m $^{-2}$)	245.68 ± 17.42	275.38 ± 19.74	251.00 ± 21.15	249.80 ± 42.01	236.30 ± 32.86	222.11 ± 35.10 x	323.86 ± 27.00 y	280.17 ± 24.28 xy
111 DAP	Shoot biomass (g m $^{-2}$)	293.62 ± 9.25	273.75 ± 13.16	274.04 ± 17.37	292.02 ± 15.04	310.55 ± 14.33	302.44 ± 29.23	262.06 ± 21.95	256.77 ± 13.88
75 DAP	Fruit biomass (g m $^{-2}$)	122.20 ± 12.55	126.31 ± 13.78	135.57 ± 22.62	123.43 ± 16.15	107.59 ± 28.77	99.96 ± 23.15 x	163.04 ± 28.14 y	115.93 ± 6.60 xy
111 DAP	Total fruit (g m $^{-2}$)	351.86 ± 15.36 a	251.94 ± 15.12 b	365.84 ± 29.75	351.84 ± 23.77	337.89 ± 28.65	269.49 ± 35.61	233.99 ± 18.64	252.33 ± 23.40
111 DAP	Harvestable fruit (g m $^{-2}$)	234.45 ± 14.75 a	161.98 ± 15.56 b	240.75 ± 26.06	232.80 ± 26.90	229.81 ± 27.06	185.68 ± 38.69	146.77 ± 20.08	153.49 ± 19.03
111 DAP	Harvest index	0.36 ± 0.02 a	0.30 ± 0.01 b	0.37 ± 0.03	0.37 ± 0.02	0.35 ± 0.03	0.31 ± 0.04	0.29 ± 0.02	0.30 ± 0.02
111 DAP	Aboveground N (g N m $^{-2}$)	11.53 ± 0.38	9.57 ± 0.38	11.56 ± 0.71	11.86 ± 0.61	11.19 ± 0.81	9.83 ± 0.70	9.06 ± 0.83	9.82 ± 0.52

^ Days after transplanting; ** PAR, photosynthetically active radiation; * Different letters indicate statistical differences using the Tukey test.

Discussion

Cultivar mixtures showed little difference compared to the 'choice cultivar' alone, in terms of any of the variables that were measured: yield, vegetative biomass, canopy light interception, and disease. These results imply that the cultivars are fairly similar in terms of response to abiotic and biotic environmental conditions. In fact, the breeding lines for processing tomatoes in California are from the same genetic stocks, and have specific genes that adapt them to the machine harvest of processing tomatoes, e.g., similarly early flowering times, determinate growth, and compact canopies (Jones et al., 2007). Breeding programs in California have developed cultivars that are high performers as monocultures, and thus have selected the highest yielding cultivar rather than the best cultivar mixture. Results suggest potential benefits if mixtures are formed with cultivars that complement and maximize their performance when interacting with each other, e.g., the grower’s ‘choice cultivar' showed early benefits in vegetative growth in mixtures. Overall mixture productivity might increase if environmental stress had been greater.

The winter mustard cover crop did not benefit tomato production and decreased N availability, probably because of the high microbial activity that immobilized N early in the tomato growing season. While N leaching potential was reduced, this came at the cost of lowered productivity. Also the late, rainy spring forced the grower to delay the incorporation of the winter mustard crop, and the maturity of the plants may have been a factor in increasing N immobilization potential.

Conclusions

Cultivar interactions, their complementarity or competitiveness in a mixture, may potentially provide benefits for ecosystem functions on organic farms. Cultivars of such a mixture would likely perform better in a mixture than in monoculture. In such a situation, cultivars would be expected to have greater trait variation than is presently found in mainstream California processing tomatoes. In addition, phenological and physiological trait diversity of a cultivar mixture must be incorporated into management practices, e.g., nutrient management, irrigation, and harvest time. This study shows the difficulty of grouping together a set of cultivars that as a mixture can enhance ecosystem functions and benefit organic systems. Improving mixtures for multifunctional benefits will require better understanding of functional traits (Balvanera et al., 2006), and testing many combinations of diverse assemblages, so that the highest yielding mixture can be selected in comparison to the highest yielding monoculture (Cardinale et al., 2006).

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Plant breeding

Possibilities for breeding to improve responsiveness to arbuscular mycorrhizal fungi in onion

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Key words: Onion, *Allium cepa* L., arbuscular mycorrhizal fungi, low input farming, *Allium fistulosum, Allium roylei*

Abstract

Arbuscular mycorrhizal fungi (AMF) play an important role in the uptake of nutrients and water from soil. However, some crops, for example onion, Allium cepa L., have a poorly developed root system. As a result, onion plants need a lot of fertiliser for growth, and they are sensitive to drought. The aim of this project is to study the beneficial effects of mycorrhizal fungi on the growth and development of Allium species and to determine whether it is possible to improve onions for mycorrhizal responsiveness by breeding. Variation among Allium species indicated that selection and thus breeding for high responsiveness to AMF is possible. Two years of experiments with genotypes of a population segregating for mycorrhiza responsiveness indicated that increase in dry matter may be a more reliable trait than responsiveness.

Introduction

Arbuscular mycorrhizal fungi (AMF) are fungi that occur naturally in soil. They play an important role in plant growth since they contribute to the uptake of nutrients and water from soils (Ryan and Graham, 2002). Onion (*Allium cepa* L.) is an important vegetable crop worldwide, but one of the major challenges in onion cultivation is to provide the plants with sufficient nutrients (Brewster, 1994). Large amounts of fertiliser are needed, but, because of the poorly developed root system (Portas, 1973), much of the applied nutrient is not used. For low-input systems, plants have to be good nutrient scavengers. Therefore, productivity and stability of onion production in such systems can be particularly problematic (Greenwood et al, 1982).

Two ways were studied to improve the uptake of water and nutrients in onions. The first was to improve the root system. A wild relative of onion, *Allium fistulosum* L., is known for its extensive root system. Genes from *A. fistulosum* can be introgressed into onion germplasm via a bridge cross with *Allium roylei* (Khrustaleva & Kik 2000). De Melo (2003) used this population to study the genetic basis of the root system of *A. fistulosum* and concluded that it should be relatively easy to improve the root system of onion through breeding. A second and complementary approach is the use of arbuscular mycorrhizal fungi (AMF). From earlier studies, it is known that onion plants can associate with AMF (Stribley, 1990; Charron et al., 2001). For example, the application of AMF in greenhouse experiments using organically managed soils

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resulted in yield increases of *Allium fistulosum* between 50 and 60% and a comparable increase in number of stem born roots (De Melo, 2003).

The aim of the present research was to study the beneficial effects of arbuscular mycorrhizal fungi on the growth and development of *Allium* species, and to determine whether it is possible to improve onions for mycorrhizal responsiveness by means of breeding.

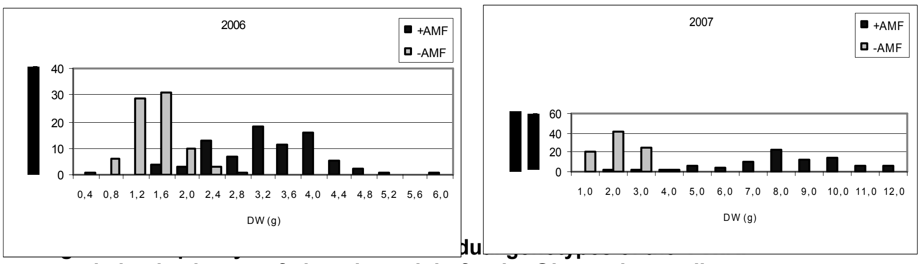
Materials and methods

A tri-hybrid population was developed as described by Khrustaleva and Kik (1998). First, *Allium roylei* (RR) was crossed to *A. fistulosum* (FF). A specific RF genotype was chosen as pollen donor in a cross with onion (CC). Subsequently, a population of *A. cepa x (A. roylei x A. fistulosum)* was built (referred to as CCxRF), each genotype carrying a set of *A. cepa* chromosomes and a set of an *A. roylei - A. fistulosum* combination. AMF species *Glomus intraradices,* was kindly provided by Dr. Y. Kapulnik, Volcani Centre Israel.

Experiments were carried out in 2006 and 2007 in a climate-controlled greenhouse (day/night 22/17 °C), using the population, the parental species and the RF-hybrid. Each genotype was multiplied vegetatively, and transferred to individual pots containing a mixture of sterilized clay soil, sand and perlite (6:1:1, v/v/v). AMF was added to the plant hole just before transplanting. Per genotype, six replications were used with AMF (treated plants) and six with sterilized AMF (control plants, NM). After five weeks, AMF-colonization was quantified using the grid method (Brundrett *et al.* 1996). Colonization ranged from 30-40% in the AMF treatment, and no mycorrhiza was observed in roots of control plants. Plants were harvested thirteen weeks after transplantation. During their growth, and also at harvest, several characteristics of the plants were measured, including total fresh and dry weight, and their partitioning into leaves, bulb or stem, and roots. The number of leaves, stems, and roots was also recorded, as well as plant height. AMF responsiveness was calculated as the increase in plant height or weight compared to the non-mycorrhiza treatment: $(W_{AMF} - W_{NM})/W_{NM} * 100$. Responsiveness was considered significant when the AMF and control treatment were statistically different ($p<0.05$). In this paper only results for plant dry weight are considered.

Results and Discussion

AMF had a significant effect on plant dry weight of the tri-hybrid population (Figure 1). In 2006, the dry weight of the non-mycorrhizal control varied between 0.4 and 2.8 g per plant, whereas plants with mycorrhiza had weights up to 6 g. In 2007, weights were higher. Control plants had weights up to 5 g, whereas the mycorrhiza-inoculated plants weighted up to 12 g. The frequency distribution of individual genotypes of the tri-hybrid population for their responsiveness to AMF with respect to dry weight, demonstrated variation, from plants that had no or little response to AMF, to plants that responded to 400 % in 2006 and even >1000% in 2007 (Figure 2).



population in classes of plant dry weight for the *Glomus intraradices* treatment (AMF) and the control.

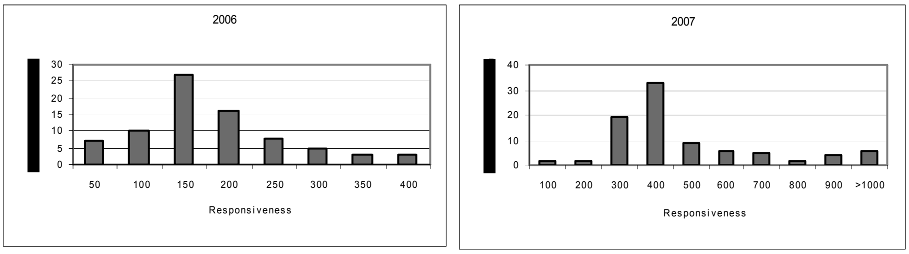


Figure 2: Frequency distribution of responsiveness of individual genotypes of the CCxRF population in plant dry weight to *Glomus intraradices* (see text for calculation).

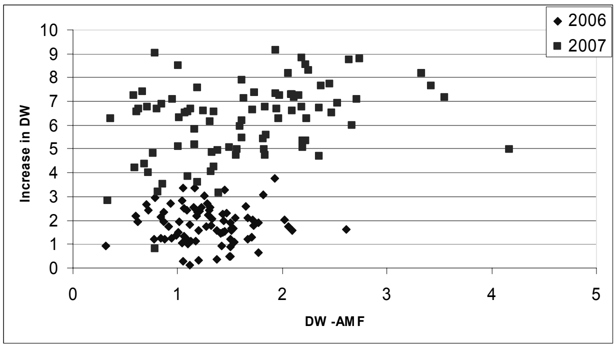


Figure 3: Absolute increase in dry weight in genotypes of a population when grown under AMF compared to the non-mycorrhizal control (DW –AMF).

Examining plant sizes however, it was obvious that responsiveness was influenced largely by the size of the non-inoculated control plants. Variation in soil type and amount of nutrients available will influence the growth of the non-inoculated control plants. We started to question ourselves whether or not selection for high responsiveness (as it is defined now) will result in a situation that is truly ideal for organic farmers: or that a better approach would be first to select plants that perform relatively well under poor conditions and then select plants that profit more from colonisation by AMF than other plants. For that reason, the absolute increase in dry weight of the genotypes was analysed. Results show that there is variation in dry weight among plants grown under mycorrhizal conditions as well as variation in absolute increase in dry weight (Figure 3). This is an indication that not all genotypes respond similarly to the presence of mycorrhizal fungi indicating that selection for absolute response should be possible.

Based on these results, the next step will be the analysis of the genetic basis of reaction to the presence of mycorrhizal fungi in the CCxRF population by QTL mapping. Clarification of the genetic basis may help in identifying onion cultivars more suited for low input farming. In addition, plants will be transplanted into organic fields and grown under high and low input conditions to study both the rooting system and their growth in the field. The reason for this is that we expect to find not only traits to improve the rooting system but also to improve the mycorrhizal responsiveness from the crosses between *A. fistulosum* and onion.

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Response of old, new and organically bred winter wheat cultivars in different farming systems: concept and experimental layout in the DOK field trial

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Key words: Organic farming, organic breeding, winter wheat cultivars, arbuscular mycorrhizal fungi, nutrient acquisition potential

Abstract

Organic farmers often use winter wheat (Triticum aestivum L.) cultivars that have been bred under conventional high-input conditions. We test the hypothesis, whether old and organically bred cultivars are better adapted to low-input conditions through a better functioning of the symbiosis with arbuscular mycorrhizal fungi (AMF). Our aim is to assess the nutrient acquisition potential of old, new and organically bred winter wheat cultivars and to identify the role of AMF for nutrient uptake and growth. In October 2006, an experiment with 10 wheat cultivars was superimposed to all four field replicates of the DOK long-term experiment, comprising four different treatments with increasing nutrient input: unfertilized, biodynamic low and moderate intensity and conventional mineral system. Growth and harvest parameters such as plant density and length, growth habit, plant health, yield and grain quality will be assessed. Shoot and root samples were taken at tillering and flowering to analyse nitrogen and phosphorus content and AMF root colonization. In this paper, the current state of literature findings in the field of organic breeding is summarized and the experimental setup for variety testing in an existing long-term trial is outlined.

Introduction

Organic farmers often use the same wheat cultivars as conventional farmers. Most of these cultivars have been bred under and for high input conditions. In organic farming systems these cultivars cannot perform to the full extent of their high genetic potential because organic soils frequently do not deliver enough nutrients and fertilizers are limited. Better nutrient uptake efficiency would be of great value for organic farms and conventional farms producing under low-input conditions.

Nitrogen (N) and phosphorus (P) are usually the most limiting macro-elements in organic farming. A large part of P in soils is secluded in minerals and organic compounds, or heavily absorbed, and the supply of soil-N by mineralization is limited. The AMF symbiosis can positively influence plant growth and health. AMF are known to be strongly affected by the concentrations of soluble nutrients, specifically P, and plant genotype. This suggests a suppression of the AMF symbiosis with wheat cultivars obtained in selection programmes under high-input conditions. In addition,

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physiology and rooting of such cultivars may be adapted to high soil nutrient content. New cultivars may have a negative influence on AMF root-colonisation due to resistance introduced against fungal root pathogens.

In the current project we will test, whether old and organically bred wheat cultivars are better adapted to low-input conditions than conventionally bred cultivars through a better functioning of the AMF symbiosis. The aim is to assess nutrient acquisition potential and to identify the role of AMF on nutrient uptake and growth.

Review of the Science

Symbiotic relationships of wheat and AMF can play an important role for growth and productivity. There is clear evidence, that AMF colonization is affected by nutrient supply and AMF infection potential of the soil, as it has been shown in pot trials for P (Zhu et al., 2001). Highest values for shoot and root weights of wheat were measured for inoculated treatments in a pot trial with a soil low in P (Rubio et al., 2003). AMF symbiosis can lead to an increased uptake of P by plants. AMF hyphae could contribute up to 50-80% of total plant P-uptake in pot trials with wheat (Li et al., 2006).

AMF occurrence and diversity shows a strong dependence on the land use management. AMF root colonization in the DOK-trial decreased with increasing farming intensity. Colonization was highest in the unfertilized control and 30-60% higher in the organic than in the conventional farming systems. Similar results were found in additional pot experiments with field soils from the DOK-trial (Mäder et al., 2000). The results agree with Covacevich et al. (2007), where AMF colonization was highest in plants receiving no annual P supply compared to plants grown at elevated nutrient levels. Native AMF could contribute considerably to the P-uptake of field grown wheat, even at typical soil fertility levels (Schweiger et al., 1999). Oehl et al. (2003) compared the influence of low-, moderate- and high-input conditions on AMF occurrence and diversity. Numbers of spores were highest under low- and moderate conditions. A shift in the AMF diversity could be shown with highest species numbers in the organic field, which was part of the DOK-trial. Results from the DOK-trial also showed that older wheat varieties might have a higher capacity to take up P: Grains of an old wheat variety had a distinctly higher P-content than grains of two recently released varieties, suggesting wheat x variety x AMF interactions (Mäder et al. 2007).

Wheat yield worldwide increased rapidly, especially during the second half of the last century due to an increased use of chemical fertilizers, and pesticides (Ceccarelli, 1996) and the introduction of semi-dwarf cultivars (Manske et al., 2002). Wheat breeding was targeting the improvement of nutrient use efficiency; especially of N and P. Little is known about the influence of the nutrient level during breeding on the performance of cultivars under low- and high-input conditions. Brancourt-Hulmel et al. (2005) assessed the efficiency of low- *vs.* high-input selection environments to improve wheat for low-input conditions. They concluded, that breeding programmes targeting low-input environments should include low-input selection environments to maximise selection gains. Results in barley could show a genotype x environment interaction. High-yielding lines selected in high-yielding environments showed lower yields on farmers' fields (Ceccarelli et al., 1996). Wheat cultivars differ in their ability to form AMF symbiosis (Hetrick et al., 1995). There is evidence that wheat cultivars bred before 1900 and the beginning of the intensive chemical fertilization were more responsive to AMF than modern cultivars (Hetrick et al., 1992). Hetrick et al. (1996) found a relationship between AMF root colonization and biomass only in responsive wheat cultivars. Average yield of wheat during 21 years was only 20 % lower in the organic systems of the DOK-trial depending on the variety (Mäder et al., 2007). This supports the hypothesis of a cultivar x AMF symbiosis x farming system interaction.

Materials and methods

A field trial experiment with 10 wheat cultivars was performed in the DOK-trial with organic and conventional land use management (Mäder et al., 2002). Two organic systems (BIODYN 1 and 2), a conventional system (CONMIN) and an unfertilized control plot (NOFERT) were included, differing mainly with respect to fertilization strategy and the concept of plant protection management. The organic systems stand for mixed farms with arable land and livestock, CONMIN for a stockless conventional system. Level of fertilization increased gradually from NOFERT to BIODYN 1, BIODYN 2 and CONMIN. This concept may show a correlation between AMF symbiosis and the level of fertilization. The field experiment is designed as a randomized block with four replicates. Wheat cultivars were sown in October 2006.

Winter wheat cultivar experiment in the DOK trial and selected varieties

Ten subplots with winter wheat cultivars were sown in each DOK-plot (5 m x 20 m) in the described four treatments and in all four replicates, resulting in 160 subplots (3 m x 1 m). Plots of BIODYN 1 were adjacent to BIODYN 2, plots of NOFERT adjacent to CONMIN. Cultivars were sown marginal in each plot, with five subplots at the inner and the outer side, with a border of 0.50 m between two cultivars. Sowing density was 420 seeds m^{-2} according to the usual local level. Cultivars with different breeding history were chosen for the field trial:

- Old cultivars: Rouge de Bordeaux (France, 1840), Mont Calme 245 (Switzerland, 1926), Probus (Switzerland, 1948)
- Conventionally bred cultivars: Titlis (Switzerland, 1996), Antonius (Austria, 2003), Caphorn, (France, 2001), DI 9714 (France, not registered)
- Organically bred cultivars: Scaro (Switzerland, 2006), Sandomir (Germany, not registered, Composite Cross Population (Great Britain, not registered)

Except for the composite cross population (CCP), they had to be of bread wheat quality and suitable for the growing conditions in Therwil (Basel, Switzerland). By including four Swiss cultivars (one in each breeding group) it will be possible to trace the development of cultivars with a similar genetic background, adapted to the local conditions in Switzerland during the last century. The field experiment aims to observe different agronomic growth and harvest parameters, nutrient uptake and the occurrence of AMF symbiosis during the growing season. At the beginning of the experiment, soil parameters were analysed and the number of AMF spores were counted. Samples of roots (soil core Ø 4 cm, 20 cm deep) and shoots were taken at tillering and flowering to measure nutrient uptake and for AMF assessments. During the growing season plant density was counted, plant length measured, plant growth stages, pests and diseases were recorded. Harvest took place at the end of July. We are now working on the analysis of the harvest samples: Yield of grain and straw, thousand seed weight and hectolitre weight will be measured. Additional following quality parameters of the grain will be measured: falling number, quantity and quality of protein (Zeleny). Furthermore we will analyse macro-and micro-nutrients in shoots, grain and straw to trace the relocation of nutrients. Analysis of harvest parameters showed the same ranking of yields for all varieties and treatments, whereby conventionally bred varieties had the highest yields. No statistical interaction between varieties x treatments was found (2-way ANOVA). On the meeting we will present agronomic performance of the varieties and selected quality parameters.

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Does regional organic screening and breeding make sense? Experimental evidence from organic outdoor tomato breeding

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Key words: Organic breeding, tomato, *Phytophthora infestans*

Abstract

Does regional organic screening and breeding make sense? To answer this question we looked for experimental evidence in an organic outdoor tomato project. Potentially suitable varieties were collected, genotype x environment interactions were investigated and selection was carried out within three crosses at three farms in Central and Northern Germany. The resulting selections were compared at all farms. Screening within organic horticulture was the most important means of finding suitable varieties. After three years of evaluation, 71% of the 18 most successful varieties came from colleagues within organic horticulture. The analysis of the regional evaluation did not reveal strong interactions of varieties and locations. The rate of Phytophthora *(late blight) fruit infections significantly depended on the year, thus stressing the need for long-term evaluation. Site specific adaptation was partially observed for late blight infections and for yield. The main advantage of multilocational selection, however, was to make use of the selection potential at each farm. At Rhauderfehn, the farm with the highest level of* Phytophthora *infections, selection led to reduced fruit infection and extended harvest period. Selection at Ellingerode resulted in the highest yield. We recommend multilocational breeding approaches with frequent exchange of breeding material and data.*

Introduction

Within the organic agriculture movement, we are facing both chance and challenge to develop breeding approaches that are particularly suited for organic systems. Breeding for adaptation to site specific conditions on-farm or in-garden is the most discussed issue. It does present an alternative to breeding for general adaptation in breeding stations. Integrated in an organic outdoor tomato breeding project, we have chosen three approaches to answer the initial question. 1) We collected and evaluated potentially suitable varieties. 2) Genotype x environment interactions were investigated in the regional evaluation. 3) Selection was carried out within three crosses at three farms, and the resulting selections were compared.

On a global scale, tomato (*Lycopersicon esculentum* Mill.) is the most important vegetable (FAO 2007). In many areas production is limited by late blight (*Phytophthora infestans*) infections, particularly so in organic outdoor cropping.

Materials and methods

Regional evaluation was based on 3500 accessions. In close contact with genebanks, NGOs, seed trade and private seed savers, 92 varieties were selected for comparative trials at three organic farms in central and northwestern Germany. The number of va-

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rieties was reduced during 2003 to 2006. Some additional varieties with superior performance in a screening at one farm were included. Two replications with two plants (2006: 3x2) were grown per location. Layout and maintenance of the plots favoured *Phytophthora*-infections.

At the same farms selection for yield and *Phytophthora* field resistance was carried out within three crosses. In 2004 20 F5-progenies Celsior x Matina with 2x2 plants, 9 F3-progenies Golden Currant x Matina with 5 plants and 30 F2-plants Rote Murmel x Campari F1 were grown at each location. 3 to 11 individual plants per cross were selected. For the latter two crosses, selection was repeated in 2005. The comparison of all selections was carried out at each farm in three replications with two plants. Analysis of variance was calculated with PLABSTAT Version 2n (Utz 1997).

Results

In 2005, after two years of evaluation, 88% of the remaining 33 varieties had been provided by non-commercial sources, i.e. genebanks, NGOs and private seed savers. 71% of the most successful 18 varieties in the final year 2006 were originally maintained and recommended by seed savers and NGOs within organic horticulture.

In the regional evaluation, the varieties were the most important variance component for all traits (Table 1). Site specific adaptation, i.e. variety x location interaction, was of minor importance or absent. For fruit infection variety x year interactions were larger than variety x location interactions. Generally threefold interactions were high. The high heritability of *Phytophthora*-infections on leaves and fruits, and for yield confirmed the suitability of the experimental design.

Tab. 1: Variance components for late blight infections and yield

Years	Number of varieties	Variance components: Varieties	Varieties x Locations	Varieties x Years	Varieties x Locations x Years	Heritability
Leaf infection [1]						
2003-2004	44	1051**	0	266.8**	1053**	86.61
2003-2005	22	1588**	57.02	224.6**	605.0**	94.31
2003-2006	10	1772**	146.8*	76.85	629.5 [2]	96.11
2005-2006	17	1993**	206.3*	49.32	373.8 [2]	95.82
Fruit infection [1]						
2003-2004	44	969.8**	0	354.9**	1291**	81.74
2003-2005	22	1512**	74.31	653.9**	708.5**	85.86
2003-2006	10	784.7**	84.41+	429.4**	481.1 [2]	84.18
2005-2006	17	1284**	77.12	734.1**	483.4 [2]	74.15
Yield per plant in g						
2005-2006	17	73574**	0	0	186407 [2]	79.04

0 indicates negative estimates
[1] Area under disease progressive curve
[2] The estimate includes a part of the error and was not tested for significance
+, *, ** significant at the 0.10, 0.05, 0.01 probability level

Tab. 2: Influence of the selection site on the performance of three crosses at three farms

Test site	Selection site Schönhagen	Ellingerode	Rhauderfehn	Mean
Late blight leaf infection [1)]				
Schönhagen	151.0	146.9	147.8	148.6
Ellingerode	151.1	143.4	163.2	152.6
Rhauderfehn	224.4	203.4	200.3	209.4
Mean	175.5	164.6	170.4	
Late blight fruit infection [1)]				
Schönhagen	69.7	61.9	60.6	64.1
Ellingerode	74.5	71.3	72.3	72.7
Rhauderfehn	234.8	220.8	216.4	224.0
Mean	126.3	118.0	116.4	
Yield per plant until 15.10. in g				
Schönhagen	1227	1316	962	1168
Ellingerode	1718	2115	1491	1775
Rhauderfehn	560	648	574	594
Mean	1168	1360	1009	
Harvest period in days				
Schönhagen	71.6	73.7	75.1	73.5
Ellingerode	67.7	68.3	69.6	68.5
Rhauderfehn	46.7	47.6	52.6	49.0
Mean	62.0	63.2	65.8	

[1)] Area under disease progressive curve

The selection Schönhagen suffered the heaviest infections with late blight (Table 2). Selection at Rhauderfehn led to the lowest level of fruit infections. Concerning both leaf and fruit infections the selections Ellingerode and Rhauderfehn revealed the best performance at their site of selection. Mean yield results were best for the selection Ellingerode. Selection at Rhauderfehn resulted in an extended harvest period. Site specific adaptation for yield was observed for one of the crosses (Table 3). The selections Schönhagen and Ellingerode of Golden Currant x Matina yielded best at their site of selection. Relative performance of the selection Rhauderfehn was improved at Rhauderfehn, but was outyielded by the selection Ellingerode. The test sites were characterized by a different yield level and different yield dynamics. Due to heavier infections with late blight, yield was reduced at Rhauderfehn and yield after 15.9. was very low.

Discussion and Conclusions

Screening within organic horticulture was the most important means to find suitable varieties. Observations in practical organic crop husbandry can be of major significance in the selection of genotypes for an organic breeding program.

The analysis of the regional evaluation did not reveal strong interactions of varieties and locations compared to genetic variance. We have to bear in mind, that the variation between the varieties included in the experiment was high. The data indicated that the ranking of varieties according to yield and late blight field resistance was basically the same at all locations. *Phytophthora* fruit infections depended significantly on the year, thus stressing the need for long-term evaluation.

Tab. 3: Influence of the selection site on the yield of Golden Currant x Matina at three farms

	Selection site			
Test site	Schönhagen	Ellingerode	Rhauderfehn	Mean
Yield per plant until 15.9. in g				
Schönhagen	677	576	393	549
Ellingerode	1024	1164	729	972
Rhauderfehn	848	1004	853	902
Mean	849	915	658	
Yield per plant until 15.10. in g				
Schönhagen	1697	1571	1225	1498
Ellingerode	2475	2920	1884	2426
Rhauderfehn	1019	1095	1037	1050
Mean	1730	1862	1382	

Divergent evolution of populations at different selection sites is a known phenomenon (Goldringer et al. 1998). We know that selection on farm can lead to site specific adaptation (Horneburg and Becker 2008), but experimental evidence is scarce. In the experiment presented here, specific adaptation was partially observed for late blight infections and for yield. The main advantage of multilocational selection, however, was the use of the selection potential at each farm. At Rhauder-fehn selection led to reduced fruit infection and extended harvest period, while selection at Ellingerode resulted in the highest yield. As a conclusion, we recommend multilocational breeding approaches with frequent exchange of breeding material and data.

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Organic wheat breeding

Wheat populations: population performance and stability in organic and non-organic environments

Wolfe, M., Boyd, H.E., Clarke, S., Haigh, Z.E.L. & Jones, H.[1]

Key words: winter wheat, organic, non-organic, mixtures, yield stability, populations

Abstract

Twenty winter wheat varieties were used as parents in a half diallel crossing programme for the production of wheat populations and physical mixtures that were then grown in field trials at two non-organic and two organic sites over three years in England. Yields of the populations and mixtures were compared with those of the relevant varieties grown as pure stands. In general, there was an improvement in yielding ability in the populations which was achieved while maintaining a high level of stability across environments. Potential improvements through selection or introduction of broader based populations are discussed.

Introduction

Rapidly increasing global climate change will amplify variability in crop performance unpredictably in all types of farming. Options for dealing with such changes will be limited by the increasing costs of oil-based inputs, both fuel and chemicals. For these reasons, we started a programme of population breeding in wheat based on Suneson's (1956) 'evolutionary breeding' in barley (Phillips & Wolfe, 2005; see also Goldringer *et al.,* 2006). The principle is to inter-cross in all combinations a number of varieties with different useful characteristics to generate a complex segregating population. This is then exposed to natural selection at field sites to allow adaptation. The objective is to generate a reservoir of genetic variation that can buffer the population against a wide range of environmental variation, more than would be possible in pedigree line varieties, or physical mixtures based on single genotypes.

The programme is based on twenty parent varieties that have expressed high yield and/or quality potential over many years and large areas, or that have contributed significantly to the pedigrees of such varieties. Field trials from 2004 to 2007 generated data on the performance of the varieties, their mixtures and their populations. Here, we summarise some key points concerning the performance of the populations and mixtures; the performance of the parents is considered in a second paper (Jones *et al.,* this Conference).

Materials and methods

The F2 progeny from the original crosses were divided into three groups, Yield (Y), Quality (Q) and Yield/Quality (YQ), with a further set that included hybrids with four naturally-occurring male sterile genotypes. The Yield populations were based on the nine varieties, Bezostaya, Buchan, Claire, Deben, HTL (High Tiller Line), Norman, Option, Tanker and Wembley. The Quality populations were based on the twelve varieties, Bezostaya, Cadenza, Hereward, Maris Widgeon, Mercia, Monopol, Pastiche,

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Renan, Renesansa, Soissons, Spark and Thatcher. The Yield/Quality populations contained the progeny from all crosses. Controls were provided by the parent varieties and by physical mixtures of the relevant parents. The variety Norman was excluded from the data because of seed stock problems. The populations, mixtures and parents were planted in randomised block field trials in the autumn of 2004, 2005 and 2006 at four sites in England. The sites comprised two organic (Sheepdrove, Berkshire and Wakelyns, Suffolk) and two non-organic (Metfield, Suffolk and Morley, Norfolk) sites. Each subsequent season, seed was harvested from the populations and mixtures and re-sown. In addition, population samples were switched between sites each year to increase the selection on them.

Assessments were made on a range of characters. Here, we report only on yield behaviour. Initial data analysis used univariate statistical methods to observe some of the patterns. Later analysis made use of the AMMI approach (Additive Main effects and Multiplicative Interactions; Ebdon and Gauch, 2002) with biplots.

Results

Performances of the populations, without or with male sterility, and the mixtures were compared with the relevant parent varieties both for yield and yield stability (Table 1).

Tab. 1: Yields of the Y, Q and YQ populations, without or with male sterility, and the mixtures, relative to the appropriate parent means. Values of less than 3% above or below 100 are unlikely to be significant.

	Non-Organic			Organic		
	Y	Q	YQ	Y	Q	YQ
Population	103	103	101	102	103	109
Population with male sterility	101	99	100	107	105	104
Mixture	105	104	103	100	105	105

Although the yield gains from the populations and mixtures are relatively modest for the three years, they are consistent, with the larger gains tending to occur under organic conditions, as expected. A further trend, which requires confirmation, is that under non-organic conditions, the mixtures tended to perform slightly better than the populations. This was reversed under organic conditions, with useful gains more evident from the populations. We assume that this difference under organic conditions was due to the greater genetic diversity in the populations compared with the mixtures. Under non-organic conditions, it may be that the amount of genetic variation in the populations is excessive in the sense that many genotypes fail to make a positive contribution in the controlled and more limited non-organic environment. From the initial AMMI (Additive Main effects and Multiplicative Interactions) analyses of the yield data, it was also encouraging to find from the IPCA-1 scores, that the populations and mixtures tended to show values close to zero, indicating that the recorded yield values were stable relative to the pure line varieties. One exception was the Q set under organic conditions, in which the populations and mixture had closely similar but relatively high scores. In 5 out of 6 comparisons, the populations showed greater stability than the mixtures, as expected, with the populations without male sterility having the most consistently low scores.

Tab. 2: IPCA-1 scores of the Y, Q and YQ populations, without or with male sterility, and the physical mixtures, relative to the appropriate parent means. The closer the score is to 0.0, the more stable the performance.

	Non-organic			Organic		
	Y	Q	YQ	Y	Q	YQ
Population	0.39	0.09	0.02	-0.07	0.47	0.04
Population with male sterility	0.21	0.21	-0.03	-0.23	0.4	-0.08
Mixture	0.16	-0.15	-0.05	0.45	0.49	0.5

Under non-organic conditions, the yields of the YQ populations and mixture were intermediate between those of the Y group (highest) and the Q group (lowest), as expected. Interestingly, under organic conditions, the yields of the YQ populations and mixture were equal to those of the Y group, which may have been due to greater buffering capacity in the YQ material. This was also reflected in a general tendency for the YQ group to be more stable than both the Y and Q groups.

It had been expected that over the three years of trials (F4 - F6) there would have been a trend in population performance either in terms of yield or yield stability. From the data analysed so far, however, there is no such evidence: population advantage in yield and stability appears to be similar in each year. Some time-related trend was expected also for the mixtures since the seed for each year came from the mixture harvested at the end of the previous season, but, again, there was no obvious effect.

One important trend arose from population samples of YQ which were exchanged between sites at the end of each year. Populations were either exchanged between sites within a farming system (organic or non-organic), or between farming systems. Where the exchange involved different farming systems, there was no change in yield in either direction. However, when populations were exchanged within a system there was a trend towards increasing yield in all cases. Within non-organic systems the yield increased either from 92% to 103% of the parent mean after three years or from 100% to 107%. Within organic systems, the yield increased either from 96% to 107% of the control or from 99% to 129%.

Discussion

In broad terms, the trials confirmed the hypothesis that composite cross populations of a range of wheat varieties, together with mixtures of the same varieties, should perform at least as well if not better than the means of the varieties involved, grown as pure stands. In practice there was a consistent improvement in yield, particularly for populations that were exposed to more than one site within a farming system. Furthermore, the mixtures and particularly the populations were stable in performance, tracking the yields of the relevant parent means. In other words, for the risk averse farmer (and particularly the organic farmer), the use of these populations and mixtures presents a more practical and safe strategy than growing the whole range of parent varieties. Furthermore, such a strategy would be as good as growing pure stands of a more limited range of the parent varieties chosen for their higher average, but often less stable, yields.

However, this raises several questions. First, what happens if the future includes greater environmental variation? In our view, the populations would still provide the best strategy for risk avoidance, based on their inherent genetic variation and their observed performance when grown at different sites. This is confirmed from the observation that a sample of the YQ population grown in Hungary produced a low yield in that first year because the severe winter conditions killed a considerable number of plants. However, the survivors were planted again in Hungary in the following autumn and yielded significantly more than local control varieties.

A second question relates to the detailed management of the populations. So far, they have not been subjected to any form of human selection. This will change from 2008 with a comparison of the effects of no direct selection versus hand selection against 'poor' genotypes versus mass selection against excessive height and small grains. Whether or not such 'interference' proves disadvantageous will probably depend on the severity of the applied selection rather than the particular form of selection.

A third question relates to the range of characteristics currently available in the populations. The parents used represent a wide range of successful genotypes from the Atlantic coast region of Europe. However, these genotypes gained their success over what will soon be recognised as a narrow range of environments as climate change develops. For the long term, we believe it is necessary to develop populations based on much wider genetic variation. In this context Kovacs (pers. comm.) suggests developing new lines of the parents and relatives of bread wheat which could then be inter-crossed to produce 'new' species and lines to form novel composite crosses. In our view, this approach merits serious consideration.

Conclusions

Field trials over three years under non-organic and organic farming systems enabled comparisons to be made of the performance of composite cross populations based on inter-crosses of high yield or high quality parents, or on all parents, against the appropriate mixtures and the parents grown as pure stands. The results so far indicate a satisfactory performance of the populations in terms of both yield and yield stability. The material should now be subjected both to directed selection and to a wider range of test environments to verify their potential ability to buffer the wheat crop against large variations in the growing environment.

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Wheat populations: parental performance and stability in organic and non-organic environments

Jones, H[1], Boyd, H.E.[1], Clarke, S.[1], Haigh, Z.E.L.[1] & Wolfe, M.[1]

Key words: winter wheat, organic, non-organic, yield stability, populations

Abstract

Twenty winter wheat varieties used as parents in a half diallel crossing programme for the production of wheat populations were grown in field trials at two organic and two non-organic sites over three years in England. Yields of the varieties between the two non-organic sites were highly correlated, but less so between the two organic sites and between the non-organic and organic sites. At the non-organic sites, most of the variation in yield (60%) was due to varietal differences, whereas, at the organic sites, it was due largely to the effects of environment (79%), and genotypic variation only accounted for 9%. More detailed analysis, using AMMI (Additive Main effects and Multiplicative Interaction), allowed stricter comparisons among individual varieties. With the exception of the variety Deben, different varieties performed well in terms of yield and stability in the two systems. In particular, Tanker performed well in the non-organic trials, but was below average under organic conditions, whereas Renan gave the reverse response. The results indicate the importance of specific trials for non-organic and organic variety performance evaluation.

Introduction

The rapidly increasing impact of global climate change will amplify variability in crop performance unpredictably in all types of farming. Options for dealing with such changes will be limited by the increasing costs of oil-based inputs; both fuel and chemicals.

For these reasons, we started a programme of population breeding in wheat based on Suneson's (1956) 'evolutionary breeding' in barley (Phillips & Wolfe, 2005). The principle is to inter-cross, in all combinations, a number of varieties with different useful characteristics so as to generate a complex segregating population. The population is then exposed to natural selection at field sites to allow adaptation. The objective is to generate a reservoir of genetic variation that can buffer the population against a wide range of environmental variation, more than would be possible in pedigree line varieties, or, indeed, physical mixtures based on single genotypes.

The programme is based on twenty parent varieties that have expressed high yield and/or quality potential over many years and large areas, or that have contributed significantly to the pedigrees of such varieties. Field trials from 2004 to 2007 generated data on the performance of the varieties, their mixtures and their populations. Here, we summarise some key points concerning the performance of the parents; this will be considered in relation to the mixtures and populations in a second paper (Wolfe et al., this conference).

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Materials and methods

The twenty winter wheat varieties were considered in three groups, Yield, Quality and Yield/Quality, corresponding to the three populations, Y, Q and YQ. The Yield group comprised nine varieties, Bezostaya, Buchan, Claire, Deben, HTL (High Tiller Line), Norman, Option, Tanker and Wembley. Unfortunately, Norman had to be eliminated from the field trials because of poor seed stocks. The Quality group comprised twelve varieties, Bezostaya, Cadenza, Hereward, Maris Widgeon, Mercia, Monopol, Pastiche, Renan, Renesansa, Soissons, Spark and Thatcher. The Yield/Quality group comprised all twenty varieties with the exception, again, of Norman. The nineteen winter wheat varieties were planted in randomised block field trials in the autumn of 2004, 2005 and 2006, together with the populations and mixtures, at four sites in England. The sites comprised two organic (Sheepdrove Organic Farm, Berkshire and Wakelyns Agroforestry, Suffolk) and two non-organic (Metfield Hall, close to Wakelyns Agroforestry, and Morley Agricultural Research Station, Norfolk) sites, both using high levels of synthetic inputs. Assessments were made on a range of characters from crop emergence through to yield and characteristics of harvested grain. Here, we report only on yield behaviour. Initial data analysis used univariate statistics to observe some of the patterns. Later analysis made use of the AMMI approach (Ebdon and Gauch, 2002) with biplots.

Results

In all trials, all varieties had higher grain yields under non-organic (9.41 t/ha) than organic conditions (5.31 t/ha, $P < 0.001$). However, a major difference between these overall values lay in the distribution of the sums of squares in ANOVA among genotype (G), environment (E: years and locations within farming systems) and G x E interaction (Table 1).

Tab. 1: Distribution of ANOVA sums of squares (percentage) among items G, E and G x E for the same 20 winter wheat varieties in organic and non-organic field trials.

System	G	E	G x E
Non-organic	60.4	26.2	13.4
Organic	9.4	79.3	11.3

This means that the non-organic approach of using synthetic materials to control the environment was relatively successful so that much of the variation observed was due to differences among the varieties, with relatively little due to environment or the interaction G x E. Conversely, under organic conditions, a large proportion of the variation observed was due to the impact of the environment with relatively little due to differences among varieties. Further, the G x E interaction, though small in absolute terms, was large relative to the G term, much more so than under non-organic conditions. These differences were responsible for the contrast in correlations among varieties in yield (or yield rank) at the two non-organic sites ($r = 0.94$) compared with the two organic sites ($r = 0.61$). Correlations values between non-organic and organic sites were highly variable ranging from $r = 0.36$ (significantly different at $P<0.05$) to $r = 0.75$.

AMMI allowed further exploration of these interactions in terms of relative values and stability of yield for individual varieties. In summary, the analyses showed that the same five varieties were consistently high yielding in all non-organic environments (Table 2), although the higher IPCA-1 scores for Option, Tanker and Claire, i.e. larger departures from the mean of 0.0, indicates less stability for these varieties than for Deben and Mercia. Under organic conditions, there was much greater variation in variety ranking across environments, with a different range of highest yielding varieties. Furthermore, the highest yielding varieties, Deben, Claire and Soissons, were less stable than Wembley and Renan.

Tab. 2: Mean yields (t/ha @ 15 % moisture content) and IPCA-1 score for the highest yielding of 20 varieties under non-organic and organic conditions.

Non-Organic			Organic		
Variety	**Mean yield**	**IPCA-1 score**	**Variety**	**Mean yield**	**IPCA-1 score**
Deben	11.25	0.0937	Deben	6.41	0.823
Mercia	11.18	-0.115	Claire	5.95	0.5067
Option	10.87	0.2119	Soissons	5.86	-0.4552
Tanker	10.78	0.3142	Wembley	5.78	-0.0232
Claire	10.42	-0.2832	Renan	5.72	-0.0951

The most extreme differentiation in performance between non-organic and organic conditions was expressed by the two varieties, Renan and Tanker (Table 3).

Tab. 3: Reversed performance of Renan and Tanker under Non-organic and Organic conditions.

	Non-Organic			Organic		
Variety	**Mean yield**	**IPCA-1**	**Average yield rank**	**Mean yield**	**IPCA-1**	**Average yield rank**
Renan	8.92	-0.2159	11	5.72	-0.0951	5
Tanker	10.78	0.3142	3	5.09	0.2215	16

Discussion

The objective of the reported trials was to provide a control background for the development of populations and physical mixtures derived from the variety set. However, the data generated provided a useful, comprehensive example of the performance of a disparate range of winter wheat varieties under non-organic and organic conditions. There were positive correlations between the performances of wheat varieties in both systems, but there were also important differences. The variation in performance is likely to predominantly be management system, but the environment, including soil conditions may also be contributing factors. The group of higher yielding varieties showed little overlap between systems although Deben was the highest across all environments. Even this exceptional variety was less stable under organic than non-organic conditions. Interestingly, the second best variety under non-organic conditions was an older variety, Mercia, which combines high yield with high quality (it declined in popularity during the mid-1990s and breeders rights were removed in 2002). A number of the varieties that gave stable yields under both farming systems were also low yielding. Several varieties showed some change of ranking in comparisons between different non-organic and organic trials. However, the most extreme and consistent was between Tanker, which performed well under non-organic but not under organic conditions, and Renan, which gave the opposite response. Further analysis of the data in terms of the measured growth characteristics may help to indicate the nature of these reversals. DNA marker analyses will also help to determine whether these varieties contribute differentially to the populations that include them as parents. Simple correlations of varietal performance across environments are clearly inadequate; analyses are needed that recognise stability and performance of the individuals involved. Using the AMMI analysis, the next stage will be to use the data collected on other aspects of variety performance. There are clear differences among varieties and systems in, for example, plant height and ground cover as well as in quality characteristics. Integrating these with the yield data will help to determine a more comprehensive view of how different varieties respond to different environments, and how these characteristics may contribute to the mixtures and populations based upon them. It should also be possible to analyse the impact of some features of the environment such as rainfall, temperature and sunshine hours. We expect to find that there are many different gene complexes and interactions involved and that single genes rarely have an identifiable, large and stable effect.

Conclusions

Positive correlations for yield performance between varieties grown under organic and non-organic conditions are often used to suggest that non-organic trials can indicate performance under organic conditions, eliminating the need for specialised trials. Such positive correlations were evident in the trials described above, but more detailed analysis at the level of the individual variety indicates that there may be numerous differences among varieties exposed to the two types of farming system, as well as the effect of the soil type and climate, in terms of both absolute yield and the ability to achieve that yield (stability). For this reason, we recommend separate trials for non-organic and organic production. However, we also recognise that generalisation can be dangerous in the sense that the observations summarised above were the result of the interaction of a particular set of winter wheat varieties grown in a particular set of circumstances, which is not repeatable. Indeed, it is also important to recognise that, with rising oil prices and increasing environmental variation, growing circumstances are likely to change rapidly, increasing the need to monitor performance of relevant germplasm in a changing world.

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Breeding for nitrogen use efficiency in organic wheat systems

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Key words: nitrogen use efficiency, plant breeding, winter wheat, dryland systems

Abstract

Improving crop nitrogen use efficiency (NUE) is important to reducing the environmental impacts of agriculture, for both perennial and annual crops. This study tested winter wheat breeding lines developed in organic and conventional systems, historic wheat varieties and perennial wheat under organic management. There were significant differences among selection categories and among genotypes. However, standard methods of measuring NUE may not be appropriate when the breeding objectives are to reduce N use. Alternative methods of evaluating breeding materials, including regression analysis of grain protein deviation (GPD) and principal component analysis (PCA) were explored. GPD was not found to discriminate well between genotypes in this study, but PCA showed promise in examining the relationship among measured variables and among genotypes.

Introduction

Because organic and conventional systems differ significantly in terms of soil N cycling, traits needed for high NUE may also differ significantly. To improve NUE in organic systems, breeders must determine whether there is genetic variation for traits related to NUE and identify genotypes with traits that contribute to NUE. The goals of this study were to understand variation in N use among historic varieties, conventionally and organically bred annual wheat genotypes (conventional and organic lines, respectively, hereafter) and perennial wheat in an organic system. Conducting this study in an organic system provided information about genetic differences that can be used in to select for high NUE under conditions of relatively low available N. Breeding wheat with superior performance in organic systems will help wheat farmers transition to more sustainable fertility management.

Historic varieties were developed before synthetic N sources were available, so these varieties may be important sources of adaptive traits for organic N cycling. In perennial wheatgrass, natural selection has been acting on species in competitive prairie ecosystems where N is limited. Deep root systems and longer photosynthetic duration may indicate that perennials are more efficient at capturing and using N. It is also possible that modern varieties have important traits for N-uptake because increasing the harvest index (HI) requires plants to assimilate more N for and equivalent biomass as grain has higher protein concentration than straw. Breeders may have indirectly and inadvertently selected for improved N uptake along with HI (Sinclair, 1998).

Materials and methods

The study ran from 2005-2007 on transitional organic ground at Spillman Agronomy Farm in Pullman, WA (Spillman) and at Sara and Joe DeLong's certified organic farm

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in St. John, WA (the DeLong's). Wheat genotypes (selection categories) included six F5 lines each from our organic and conventional breeding programs, six historic varieties and a genetically diverse bulk population of perennial wheat. Organic lines were selected under USDA certified organic management practices. Conventional lines were selected under standard management, including seed treatments, synthetic fertilizers and herbicides, but no pesticides or growth regulators. Historic varieties were released before 1955, when the use of synthetic fertilizers became common in breeding programs and on farms. Check plots included the popular soft white winter wheat Madsen (Allan et al., 1989), and J99C0009, a Madsen derivative with foot rot resistance. Madsen is a parent of the organic lines and J99C0009 is a parent of the conventional lines. Foot rot was not evident in the experiment during either season.

At Spillman, the soil type is Palouse silt loam and at the DeLong's, the plots were on a Snow silt loam in 2005-2006 and on a Mondovi silt loam in 2006-2007. Annual average precipitation is 540 mm at Spillman, and 428 mm at the DeLong's. Most precipitation occurs during the fall and winter months, and summers are generally hot and dry. The experiment followed spring peas plowed under as a green manure each year at Spillman and at the DeLong's it followed fallow with hog manure in 2005-2006 and dry peas in 2006-2007. A 3.5 m^2 plot of each annual genotype and the perennial bulk was planted in a randomized complete block design (RCBD) with four replicates at each location. Spillman was fertilized with Perfect Blend 4-4-4 enhanced organic fertilizer (granulated poultry manure) each spring at a rate of 42 kg N ha^{-1}. No additional fertilizer was applied at the DeLong's due to higher soil N. The breeding program does not control diseases or insect pests to select resistant genotypes. Hand weeding was used to reduce and equalize weed pressure across blocks.

Soil samples were taken twice each year before planting and in the spring. Eight cores 2 m deep were taken in each field. Cores were divided into 6 segments to determine inorganic N and soil moisture. The gravimetric method was used for soil moisture content, and nitrate (NO_3^-) and ammonium (NH_4^+) were extracted using KCL (Keeney and Nelson, 1982) and analyzed with a flow injection analyzer (FIA, Lachat Instruments, Loveland, CO). Leaf chlorophyll content was measured using a chlorophyll meter (SPAD 502, Minolta Co, Japan). Readings were taken three times during the growing season. Five plants were chosen at random in each plot and four readings were taken along the youngest fully expanded leaf and averaged. Readings corresponded to plant growth stages of 8-9 leaves (SPAD1), pre-anthesis/anthesis (SPAD2), and post-anthesis (SPAD3). At maturity plants from a 0.6 m long segment of a row within each plot were cut at ground level. Total weight and grain weight of these samples were measured and HI was calculated as grain weight/total weight. Plots were harvested with a Wintersteiger plot combine, and grain was weighed for plot yield, then analyzed for protein content on a 12% moisture basis by near infrared (NIR) spectroscopy (Tecator Infratec 1226 Grain Analyzer, Foss, Eden Prairie, MN).

Analysis of covariance (ANCOVA) in SAS (SAS Institute, Cary, NC) was used to asses variation among and within selection categories for grain yield, grain %N, total grain N and total biomass. SPAD meter readings were used as quantitative covariates to test for significant correlations between SPAD readings and the dependent variables. The SPAD covariate was retained in the final model if significant. Regression and PCA analysis in SAS were used to determine the relationship between grain N components and other measured variables.

Results

It is apparent that there is significant genetic variation for traits related to N use in organic systems in this sample of genotypes. The check genotypes Madsen and J99C0009 had the best performance in terms of yield, biomass production and total grain N. The conventional lines were not significantly different from the checks. Comparisons among categories showed that the selection categories were all significantly different from each other in terms of yield, grain %N, total grain N and biomass production with the following exceptions. Organic was not significantly different from perennial for biomass production, and historic was not significantly different from perennial for total grain N or grain yield. Ranking the categories showed a definite pattern, with conventional being higher for grain yield, total grain N and biomass followed by organic, perennial and historic genotypes. For grain % N, the ranking was almost exactly reversed, with perennial followed by historic, organic, conventional and control genotypes. Regression analysis showed a negative relationship between grain %N and grain yield, but no genotypes were identified with significant GPD (large standardized residuals from this regression), possibly because most genotypes were soft white wheat and the number of locations and years in this study was limited.

In the PCA, the first three components explained over 60% of the variation in the data. Genotypes with high scores for PC1 are likely to have high yield, total grain N, straw yield and total biomass. Grain yield and grain %N were not strongly correlated to HI. In conventional systems, HI is often positively correlated with yield but in this case, good vegetative growth may increase weed competitiveness and may serve as an N source for developing grain when soil N supplies are exhausted.

Tab. 1: Ranking of selection categories for agronomic traits related to NUE

Grain yield	control = conventional > organic > perennial = historic
Grain %N	perennial > historic > organic > conventional > control
Total grain N	control = conventional > organic > perennial = historic
Biomass	control = conventional > organic = perennial > historic

> or < comparisons significant for $P<0.05$

Discussion

While historic varieties have desirable traits, as a group they had the lowest yield, total grain N and biomass production. Organically bred lines were lower yielding than the conventionally bred lines, but significantly better than the historic varieties. Because the organic lines were derived from crosses between Madsen and a historic variety, the fact that several were not significantly different than conventionally bred elite lines is encouraging, and further gains are expected from selection. Conventionally bred modern lines generally had the highest yields and total grain N, showing that it is useful to include these lines in breeding for organic systems, to take advantage of gains from selection over the past 50 years while incorporating traits from historic varieties that are important to organic systems. The comparisons that were not significantly different are also of interest. The perennial bulk population had the same total grain N as the historic lines and the same biomass as the organic. Although perennial wheat currently has lower yield, total grain N and biomass, it has a very short breeding history. With continued selection for yield, it is possible that perennial wheat will show progress similar to that observed in annual wheat, where modern varieties now exceed their historic counterparts. As high grain %N is not required in soft white wheat, lines able to yield well at lower grain %N may be advantageous in organic systems. If end-use and mineral nutritional quality do not suffer, using negative GPD as a selection criteria as well as yield under low N conditions could reduce grain N requirements. Interestingly, quality checks used by Oury et al. (2007) had negative GPD, so it appears that high protein with respect to yield is not necessarily an indicator of end-use quality. PCA was useful to visualize important sources of variation in the data and to discriminate among genotypes. Factor loadings and correlations among measured variables can asses redundancy in the data and measurements which are highly correlated to other variables or not well correlated to traits of interest may be eliminated. This method could be very useful to breeding programs when deciding which variables are of most importance in certain environments for breeding goals.

Conclusions

Standard methods of calculating NUE are predominantly based on grain yield. This may not be appropriate when other factors, such as crop environmental impact, are also considered. While grain yield is important, other traits contribute to NUE, and these traits may be more useful when attempting to increase NUE from an environmental as well as an economic perspective. Alternative methods of analysis, such as GPD or PCA, may be useful in analysing these other traits. While PCA cannot replace careful observation and selection, it may be a useful tool in identifying trends or genotypes that merit more detailed analysis and observation.

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Contribution to organic breeding programmes of wheat variety testing in organic farming in France

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Key words: variety, winter bread wheat, breeding, screening, organic farming.

Abstract

Bread winter wheat is one of the most important cash crops for French organic farmers. Nevertheless, most of varieties available on the market were bred for conventional farming systems (with high inputs of mineral fertilizers and chemicals for crop defense). In order to obtain correct levels of yield and quality, it is important i) to screen current varieties to find the best suited for organic conditions, and ii) to rapidly obtain suitable varieties that are specifically bred for organic farming conditions. Bread wheat variety trials under organic conditions have been coordinated since the year 2001, to centralize and evaluate results at national level. The ringtest not only aims to compare varieties, but also to support organic breeding, as it provides an opportunity to evaluate the ability of advanced lines bred for organic farming to meet the needs of farmers and millers for agronomic and quality traits. Trials are also used to study specific traits required for organic farming (such as weed competitiveness), so that they can become selection criteria in specific breeding programmes. In addition, protocols and results obtained in variety trials in organic farming give information to discuss about possibility of low input VCU testing (Value for Cultivation or Use).

Introduction

The acreage of bread wheat is considerable in French organic agriculture (about 30 000 ha in 2006). As bread wheat is the most important cash crop, the type of varieties organic farmers should be using is very important. That is why it is essential to assess wheat varieties in terms of their productivity and quality, and to assess stability across years and sites under French organic conditions. Varieties that are compared encompass modern varieties that are available on the seed market, but also new cultivars that are supposed to be more suitable for organic production, including lines from organic breeding. The coordination of wheat variety testing at national level has two main objectives: i) To determine relative performance of cereal varieties grown under organic conditions. This should improve productivity and quality of organic cereal production by identifying cultivars that are best suited to organic farming systems. ii) To provide information for organic breeding programmes in order to support them, as these trials give opportunity to evaluate the relative performance of advanced lines bred for organic farming, and to study specific traits (such as weed competitiveness) usually not used as selection criteria.

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Materials and methods

Considering that numerous wheat variety trials were conducted independently with no connection and only local evaluation of results, Technical Institute for Organic Farming (ITAB) proposed in 2001 to centralise results and evaluate them at national level, in order to coordinate methods and reduce costs. The first step was to apply the same protocol and to have common varieties in each trial. Furthermore, as very few baking tests were locally processed because of cost, they have been centralized and taken in charge by ITAB for the last three years. All trials, run on organic farms, use a randomised block design with either 3 or 4 replicates. Where possible, organically certified seed is used, otherwise conventionally produced untreated seed is used. The basic principle is to have diverse environmental conditions that reflect reality (farmers standard practises are generally applied[1]), in order to assess the ability of varieties to adapt to different constraints. Varieties assessed in the ringtest are conventional varieties with traits that are supposed to best fit organic constraints (i.e. a good response to low level of nutrients, a good competitive ability against weeds), foreign varieties (with priority to those specifically bred for organic agriculture), and advanced lines from French breeding programmes specifically for organic agriculture. Agronomic and quality parameters that are currently centralized at are: yield (t/ha) and proteins content (% -NIR method-) for all trials, and if available: specific weight (kg/hl), height (cm), ground cover, diseases notations, quality/bread-making data. As a result, for the last 5 years data of 20 to 30 wheat variety trials per year have been combined for yield and proteins content. As a large range of soil types and climatic conditions are concerned; these results are processed by large geographical areas (roughly: north, south, centre and west). Since last year, results on important traits such as height, diseases, test weight, and baking quality have also begun to be combined and evaluated at national level.

Results

Figure 1 gives an example of annual results for the Southern area: yield versus protein content. Besides, stability across sites is observed. The variety Saturnus, which has clearly higher protein content, has low and very variable yields across sites, whereas the variety Orpic, in the average for both yield and protein, appears to be very stable across all five sites.

In addition, there is an analysis of stability of results across years for both yield and protein content: for the 2 or 3 last years for most varieties, for the last 5 years for three of them. Results are similarly analyzed for the five main areas of France. Complemented by baking quality results (example in figure 3), these analyses are the base used to elaborate list of recommendations to organic farmers: the results are published each year, including long-term results over the years.

Within the ringtest, we include advanced lines bred for organic farming (cultivars from Lemaire-Deffontaines and INRA), in order to assess in different organic conditions their performances and compare them to current varieties. Two lines bred by INRA appear to be promising: both have yields among the more productive (see figure 2, lines are underlined), while their response to baking test is good (figure 3) and a nutrient analysis indicates good level of magnesium.

[1] For fertilisation: N provided through crop rotation or manure, 30 to 60 kg/ha if direct fertilisers.

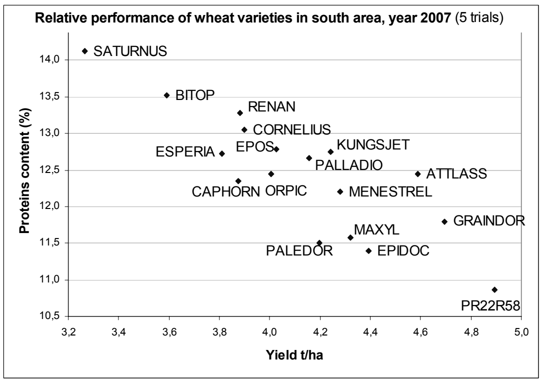

Figure 1: Relative performance of winter wheat varieties in south area, year 2007

In addition, measures of height and ground cover show good weed competitiveness. For this criteria, it is interesting to add that the network of organic wheat variety trials is used to study how to improve measurement of weed competitiveness, as it offers a large range of weed species found under different conditions of climate and soil.

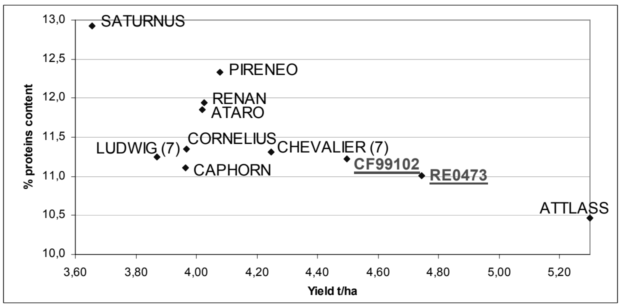

Figure 2: Relative performance (yield and proteins content) of 2 winter wheat lines bred for organic farming (results of 8 trials across France, year 2007).

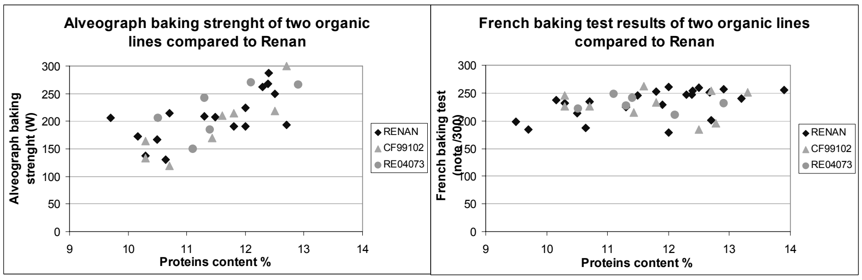

Figure 3: Baking quality results of 2 winter wheat lines bred for organic farming (samples from year 2004 to 2007).

Discussion

Currently, referent varieties such as Renan (a compromise between yield and proteins, with good baking quality), Attlass (for yield) or Saturnus (for proteins) perform relatively well from North to South. The results demonstrate that advanced lines bred for organic farming CF99102 and RE04073 perform well compared to current varieties with good levels of yield and ground cover; baking quality data are good up till now, but have yet to be completed for RE04073. According to those results, a proposition for official registration may be done next year.

In addition, it is important to underline that network gives large information to discuss about the possibility of low input VCU testing. As official VCU in France is conducted under conventional conditions, the network of variety trials in organic farming provides knowledge on i) reference varieties cultivated in organic farming and ii) assessment of weed competitiveness and specific baking quality required for organic bread making.

Conclusions

Organic farmers need bread wheat varieties suitable for both organic conditions (agronomic traits) and organic market demand (quality traits). Already in France some initiatives exist to set up specific organic breeding programs to meet the requirements for adapted genotypes. Besides screening of conventional varieties, a national network of variety trials in organic farming complements those breeding programs, as the network provides data on the performance of advanced lines and help to improve selection criteria. A problematic issue which needs more attention is the registration system, not being adapted to lines for very low input and organic conditions. Therefore another value of the national network could be to transform some of the trials into official VCU trials, or to be recognized as post-registration system for organic agriculture if VCU trials are eliminated. This still has to be discussed.

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Wheat trials networks for determining characters for organic breeding

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Key words: plant breeding, organic farming, low inputs, pure lines, winter bread wheat

Abstract

The objectives of the French national institute of agronomy (INRA) cereals programme are to evaluate genetic material from breeding programmes for low input systems (high disease and lodging resistance, low seeding rate, good response to low level of nutrients, standard quality) including organic conditions.

The aim of the study is to define important agronomic characteristics of cultivar adapted to organic farming. Despite some relation with agronomical performances in low input system, weeds competitiveness, productivity and baking quality are specific in organic farming. Productivity and baking quality are linked to nutrient acquisition ability: nitrogen uptake and nitrogen-use-efficiency. The selection of new lines based on weed competition and N efficiency is necessary. Thus, we define an index selection method.

Introduction

To develop sustainable agriculture, INRA conducts projects in close relationship with organic and low-input systems enhancing exchanges between research on integrated (i.e. low inputs) and organic farming systems. We intend to follow a global approach, which combines interdisciplinarity research (agronomy, genetics, technology, etc).

In France winter bread wheat is one of the most important cash crops in organic farming (more than 30 000 ha in 2007). Hardy bread wheat cultivars, originating from public and private breeding programmes combine, as never before, resistance to diseases with satisfactory yield potential in integrated farming (Loyce and al. 2007). The objective is, first, to evaluate genetic material originating from breeding programmes for low input systems (high disease and lodging resistance, N standard quality) under organic farming conditions and, then, to define important agronomic characteristics of cultivar types adapted to organic farming in collaboration with technical institute on organic farming (ITAB) (Rolland et al 2002). Thus, we suggest an index selection method for the selection of new lines.

Materials and methods

From 2004 to 2007, INRA conducted a multidisciplinary study in a multi-site experiment in four organic certified farms and INRA experimental stations close to

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organic farms: Rennes (Bretagne), Le Moulon (Ile de France), Toulouse (Midi toulousain) and Lusignan (Poitou). From 25 to 30 bread wheat pure lines were compared annually. Experiments were designed in randomised complete block with four replicates per environment in organic and two replications in low inputs (low sowing density, N-60 kg, only one herbicide). Plots were assessed for weeds, diseases, nitrogen nutrition, lodging, yield and grain quality traits (protein content, zeleny, alveograph, French bread-making test). The aim was to test varieties in various conditions to screen its ability to adapt to different agronomical and edaphic constraints. Varieties assessed were selected from (1) conventional French breeding programme with traits that are supposed to best answer organic demand, (2) varieties from Austria, Germany and Switzerland (with priority to those specifically bred for organic agriculture), and (3) advanced lines from INRA breeding programmes.

Results

Crop Yield : According to locations, crop yield varies from 6.9 t.ha^{-1} when soil fertility and climatic conditions were favourable for high crop yield in organic conditions (2004 in Rennes) to 2.7 t.ha^{-1} in non optimal conditions with poor soil and-or brown rust and weeds (Lusignan 2007). From Koreli to CF99102 genotypes, including mixture (association), good yields are registered in organic conditions (Figure 1).

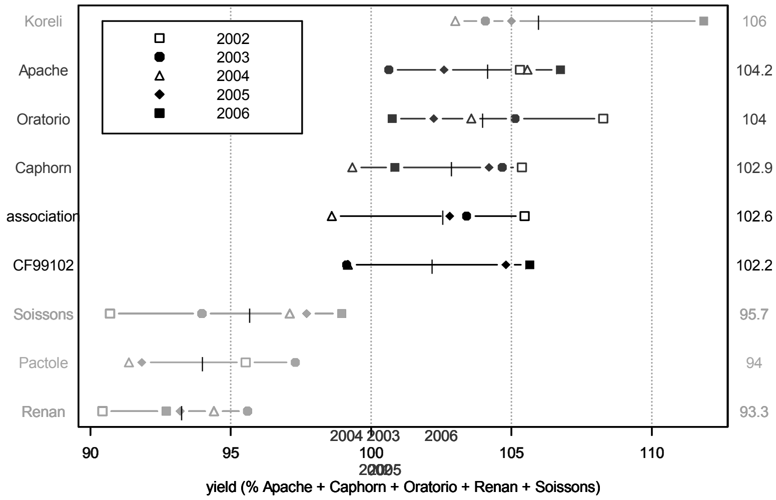

Figure 1: Yield for lines tested for more than three years in organic trials

Weed competitiveness: Important wheat traits influencing shading ability and thus weed growth are plant height and ground cover. Goyer (2004) proposed a method simplified from Hansen (2000) to approach weed competitiveness with two parameters (using standardized variables): crop canopy height and wheat ground cover at GS34. Pegassos is the cultivar with one of the best morphologies, due to a planophile leaf inclination and high plants (Drews, 2002). We also measured the genotype competitiveness for weeds suppression. Two controls were used, with and whitout weeds (manual weeds control) on two cultivar references: Caphorn (low competitiveness) and Renan (high competitiveness).

Quality for bread-making: French bread-baking, protein content, zeleny and alveograph baking strength (W), are relatively closely connected (Figure 2). A quality index taking into account protein content and W seemed relevant.

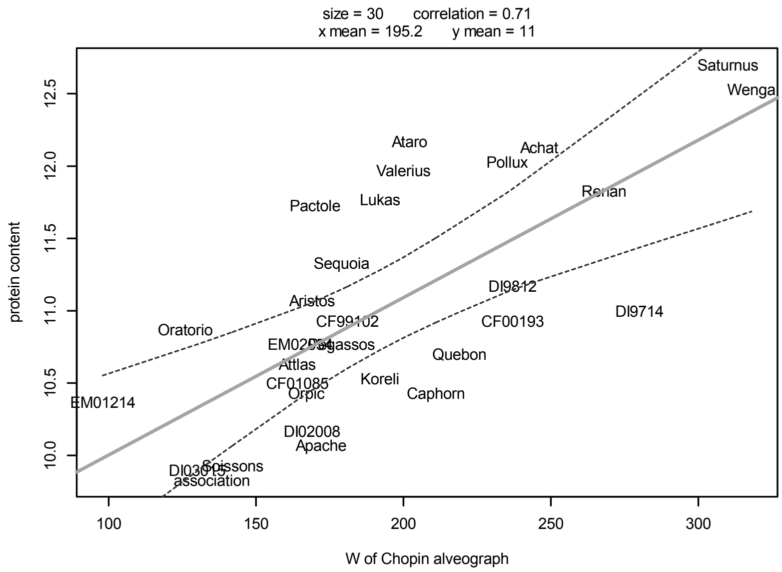

Figure 2: Correlation between W of alveograph and proteins content, year 2005

Discussion

INRA bread wheat ring test aims also at comparing the performance of a particular set of varieties over contrasting environments with an emphasis on low-input and organic conditions. Genotype and environment interaction, stability of yield (figure 3) and quality as well as research for particularly useful germplasm, traits and ideotypes for low-input and organic farming – for both direct use and breeding – are the main interest. The low inputs trial results are always higher than organic. According to occurrence of relevant limiting factors in each pedoclimatic situation (N, weeds, brown rust, etc), variety yield from fourteen low inputs trials are more or less correlated with results from organic trials ($0.256<r^2<0.967$). 2004 and 2005 are quite different years but low inputs are useful for low-input and also organic selection. Different degrees of yield stability and protein yield stability were found.

To improve selection criteria to select cultivars best adapted to organic farming (good response to low level of nutrients, good competitive ability against weeds, etc), we proposed a global selection index (IGS) which takes into account yield (Y), quality (W of alveograph and protein content (P)) and weed competition (crop canopy height (H) and wheat ground cover (WGC)) to optimise results. The higher weighting given to the quality data compared with the data for weed competition is due to commercial value.

$$IGS = Y + 2\times(W + P) + (H + WGC)$$

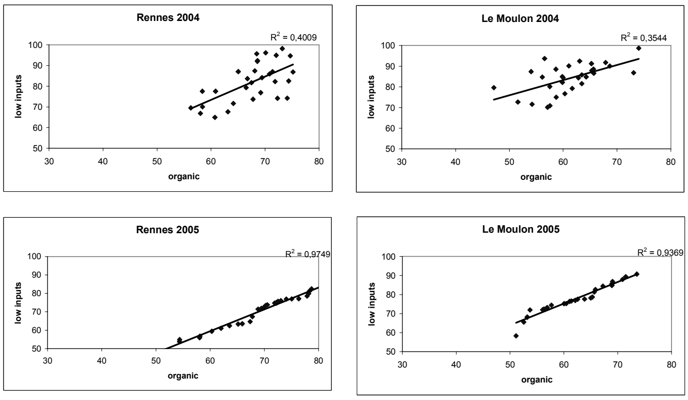

Figure 3: Correlation between yield (t-1.ha) in organic and low inputs, 2004 and 2005

Conclusion

Networking is useful to study specific traits required for organic farming, such as weed competition, in order to transfer them as selection criteria in breeding programs. A key issue will be the variety registration system, which is not adapted to lines for very low input and organic conditions.

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Differences between spring wheat cultivars in susceptibility to Fusarium caused seedling blight

Timmermans, B.G.H.[1] & Osman, A.M.[1]

Key words: Spring wheat, *Fusarium*, seedling blight, cultivar differences, growth rates

Abstract

Fusarium spp. present on spring wheat seeds can infect seedlings and cause reduced plant densities and higher wheat infestations. In the current project, variation between commercially available spring wheat cultivars in their tolerance to Fusarium seedling blight was investigated in a pot and a field trail. Additionally, initial growth rates of cultivars were measured to investigate possible relations with tolerance. Preliminary analysis shows presence of tolerance differences between the spring wheat cultivars in the pot and field experiment. This difference was relatively robust (experiment x cultivar interaction was not significant). Preliminary analysis also showed a relation between tolerance and initial growth rates of cultivars in the field experiment. The presence of robust differences in tolerance and relations with growth rates of commercially available cultivars form good possibilities for future breeding.

Introduction

Fusarium species are important pests for conventional and organic cereal production. Especially in wet years, they can infect wheat spikes during flowering and cause Fusarium head blight or scab (Birzele *et al.*, 2002) Infection decreases the amount and quality of the yield and can result in high levels of mycotoxins (Parry *et al*., 1995). For organic agriculture a second problem exists: the use of non-chemically treated infected seeds can result in seedling blight and hence lower plant densities (Jones, 1999). These do not necessarily result in lower yields (Gooding *et al*., 2002) but can lead to a delay in canopy closure, and make crops less competitive against weeds. The aim of the current project is to investigate the presence of differences in susceptibility to seedling blight between spring wheat cultivars and if differences can potentially be linked to early development rates of the cultivars.

Materials and methods

Seeds of six spring wheat cultivars (Melon, Lavett, SW Kungsjet, Epos, Pasteur, Thasos) were used containing three Fusarium infection levels (averages 1, 11 and 25%, precise infection levels measured in a Blottertest, De Tempe, 1958). Seeds originated from an organic field that was inoculated with *F. culmorum* in 2004.

Field experiment: Seeds were sown in a field on an organic farm on clay soil (Colijnsplaat, The Netherlands) on 11 April 2007. Experimental set up as randomized block design with four repetitions and 20 m^2 plot size. Percentage of seedling emergence was measured on 29 May (after 1.5 month of hot and dry conditions) by counting six transects of 1 m in each plot. Measurements of above-ground dry matter

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were done in the lowest infection level (1% Fusarium infected seeds on average) on 7 and 18 June, by cutting 0.4 m^2 of all plots at ground level and measuring dry weight after drying at 105°C.

Pot experiment: Seeds were sown in a sandy soil (originating from a former organic grass field) in 5 litre pots at the experimental organic farm Droevendaal, Wageningen University and Research Centre, Wageningen, The Netherlands, on 26 March 2007. Experimental set up was a randomized block design with four repetitions, and each plot contained 20 pots of 5 litre, with 5 seeds sown in each pot (resulting in 100 sown seeds per plot). Pots were watered regularly to maintain optimal moisture conditions for plant growth.

For each cultivar the percentage of lost seedlings per percentage of Fusarium in the seed was determined by calculating the slope of the linear regression line of lost seedlings on the level of Fusarium infection in the seeds. Relative growth rates of dry matter were calculated in the lowest infection treatment (1% infected seed) by nonlinear regression (equation: $W_t=W_0$*exp(relative growth rate*time), in which W_t and W_0 represent weights on time t and 0, respectively). All statistics were performed using GenStat Seventh Edition version 9.1.0.147, VSN Internation LTD, Rothamsted, and R version 2.4.0 (R Development Core Team, 2006).

Results

In field and pot experiments a significant relation ($p<0.001$) between reduction in plant numbers shortly after emergence and Fusarium in seed measured in the Blotter test was found. The difference in plant tolerance to seedling blight was highly significant ($p<0.001$) between pot and field, revealing a general lower tolerance to Fusarium in the pot experiment (Fig. 1).

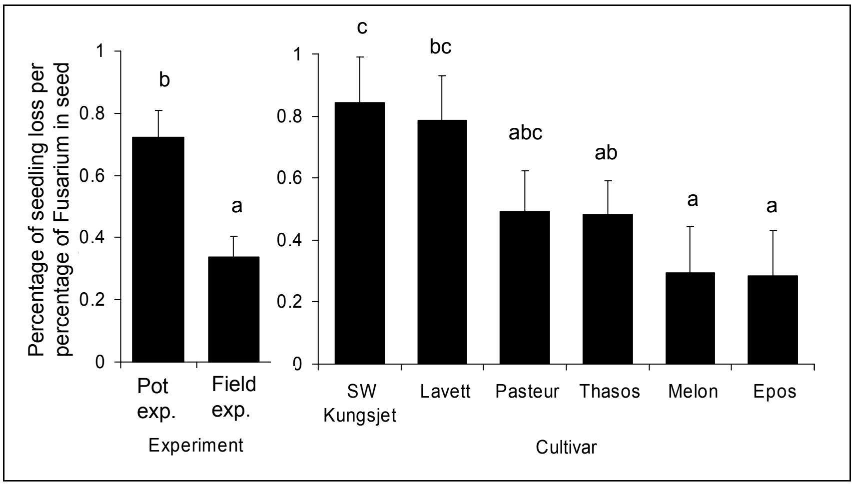

Figure 1: Percentage of lost seedlings per percentage of Fusarium in the seed for the pot and field experiment and for all six cultivars. Error bars indicate standard error of the means, significant letters indicate significant differences (p<0.05).

Differences in tolerance between the six spring wheat cultivars were significant ($p<0.01$, Fig. 1): in both field and pot experiments, tolerance for Fusarium seedling blight was highest for cultivars Epos and Melon, and lowest for SW Kungsjet and Lavett. The cultivar x experiment interaction was not significant, showing the relative robustness of these differences.

First preliminary analysis of the results indicated a correlation between tolerance and the relative growth rate without Fusarium of the cultivars in the field experiment (Fig. 2): the higher the relative growth rate of the cultivars was in the field, the higher the tolerance to seedling blight. In the pot experiment, no significant differences in relative growth rate between the cultivars were measured.

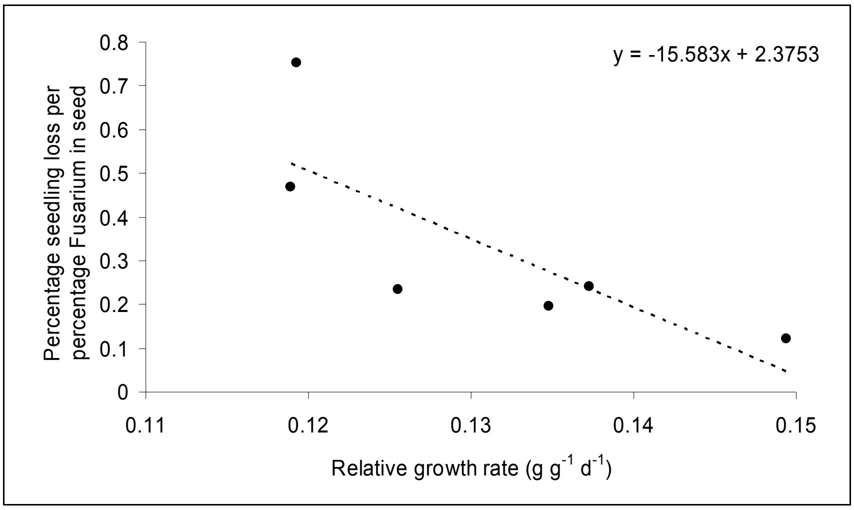

Figure 2: Percentage of seedling loss per percentage of Fusarium in seed plotted against the relative growth rates measured in the low infection treatment in the field, 2007. Broken line indicates a linear trend, equation shown in graph.

Discussion and conclusion

First preliminary analysis of these results indicate significant, and relatively robust differences between spring wheat cultivars in their tolerance to Fusarium caused seedling blight. Results are in accordance with results from previous year (Timmermans and Osman, 2007). Strikingly, Lavett, the cultivar that is most widely used in practice in The Netherlands (Osman *et al.* 2005), was one of the most susceptible cultivars in both experiments. Other authors have mentioned differences in cultivars sensitivity to Fusarium seedling blight for winter wheat, that seem at least partly related to susceptibility to seedling blight (Browne and Cooke, 2005). In the field, an indication was found for a relation between relative growth rates of cultivars and resistance to seedling blight. This relation can potentially be used as a criterion in future breeding; however, further analysis of current and former experiments has to ensure that it is robust in different environments. Plans for near future include combining these results with data measured in former experiments. Also, analysis of two years-measurements on light interception and crop closure (potentially delayed by seedling blight) and measurements on actual weed infestation are to be included.

Acknowledgments

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Disclaimer

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Does Wheat Cultivar Choice Affect Crop Quality and Soil Microbial Communities in Cropping Systems?

Nelson, A.[1], Frick, B.[2], Clapperton, J.[3], Quideau, S.[4] & Spaner, D.[1]

Key words: wheat, soil microbial community, breadmaking quality, organic and conventional management

Abstract

Wheat (Triticum aestivum L.) *cultivars may have differential effects on soil microbial communities and the breadmaking quality of harvested grain. We compared six Canadian spring wheat cultivars under organic and conventional management systems for yield, breadmaking quality and soil phospholipid fatty acid analysis (PLFA) profile. Yields were lower, but protein levels were higher in the organic system. Cultivars differed for quality traits, but all cultivars had acceptable levels for processing. There were small differences in PLFA profiles for cultivars in the conventional system, but none in the organic system. More significant correlations between grain quality and PLFA measures were present in the organic system. Protein levels and breadmaking quality at least equal to conventional systems can be achieved in organic systems. Wheat cultivars differed for grain quality in both organic and conventional systems, and culivars altered the soil microbial profile in conventional systems. Microbes may play a greater role in determining crop quality in organic systems than in conventional systems.*

Introduction

Demand for organic foods has been increasing in Canada, in part because consumers perceive organic foods as having unique and/or superior quality than conventionally produced foods (Yiridoe et al. 2005). Research into the nutritional differences and sensory profiles of organic and conventional products has not yielded consistent results (Bourn and Prescott 2002).

Soil microbial communities play an important role in soil fertility and nutrient cycling, and are affected by production practices. Cropping systems management (organic and conventional) may (Bossio et al. 1998) or may not (Girvan et al. 2003) alter soil microbial communities. Crop cultivar selection can also affect soil microbial diversity (Germida and Siciliano 2001).

Understanding the effects of cultivar choice on soil microbial communities and crop quality may result in production systems with consistently high food quality. Our objectives were to determine the effect of spring wheat (*Triticum aestivum* L.) cultivar choice on soil microbial communities, crop productivity and breadmaking quality in both organic and conventional systems.

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Materials and methods

Six western Canadian spring wheat cultivars (Elsa, Glenlea, Go, Marquis, Park and Superb) were grown in four-replicate randomized complete blocks on two nearby sites (one organically managed and one conventionally managed) in 2005 and 2006 in Edmonton, AB, Canada (55°34´N, 113°31´W). The two sites had similar soil types.

Quality measures on grain included a number of processing measures which relate to final product quality. Protein levels over 12% are considered adequate in western Canada. Flour yield (FLY) is a measure of milling quality. Falling number (FN) indicates the sprouting resistance of the grain, affecting dough quality; grain over 400 has high sprouting resistance. Particle size index (PSI) indicates kernel hardness, with values generally 50-55 PSI. Mixing development time (MDT) is a measure of how long it takes to develop the dough; values between 2-3 minutes are desired. Soil biological biomass, % Gram- and Gram+ bacteria, % fungi, richness, evenness and diversity was determined using phospholipid fatty acid analysis (PLFA) on 5 soil samples randomly removed from each plot during crop growth (Clapperton et al. 1997).

Proc Mixed in SAS v.9.0 was used to analyze the combined experiment as a split plot, with management system as the main plot and cultivar as the subplot, replicated in time (year). The data were also analyzed separately by management system combined over years. For both analyses, years and blocks were considered random and management system and cultivar were considered fixed effects. Pearson correlations were conducted on site-year lsmeans.

Results

Tab. 1: Results of combined and separate statistical tests of breadmaking quality traits of wheat cultivars grown organically and conventionally

Cultivar	Yield ($t\ ha^{-1}$)	Grain protein (%)	FLY (%)	FN	PSI (%)	MDT (min.)
	Conventional					
Conventional mean	5.3	15.1	73	486	52	2.7
F test $_{cultivar}$ (df=5)	***	***	***	***	***	***
SE $_{cultivar}$	0.49	0.20	1	22	1	0.26
	Organic					
Organic mean	2.1	16.9	70	472	49	2.4
F test $_{cultivar}$ (df=5)	ns	***	***	***	***	***
SE $_{cultivar}$	0.77	0.46	1	78	2	0.16
	Combined ANOVA					
F test $_{mgmt}$ (df=1)	*	*	NS	NS	NS	NS
SE $_{mgmt}$	0.53	1.01	1	32	1	0.16
F test $_{cultivar}$ (df=5)	**	NS	NS	*	***	***
SE $_{cultivar}$	0.52	0.94	1	43	1	0.21
F test $_{mgmt*cultivar}$ (df=5)	*	NS	NS	NS	*	NS

NS=not significant (P≥0.10), * significant at P<0.10, *** significant at P<0.01, FLY=Flour yield , FN=Falling number, PSI=Particle size index, MDT=Mixing development time, SE=Standard error

When the management systems were analyzed separately, cultivars differed ($P<0.01$) for all breadmaking quality measures, except yield in the organic system (Table 1). Although cultivars differed for quality measures, most exhibited quality measures falling within accepted standards. However, Glenlea in the conventional system, and Go in the organic system had falling numbers below 400, suggesting these cultivars may have inferior dough under certain management systems.

In combined analyses, management had a significant effect on yield and grain protein. Yields under organic management were about half of those under conventional management. Grain protein levels were 12% higher in the organic system compared to the conventional system. Cultivar was a significant source of variation for all breadmaking quality traits except protein and FLY, with most values within standards.

The interaction of management × cultivar was significant ($P<0.10$) for yield and PSI. Superb yielded more grain than Marquis in the conventional system. Marquis yielded the lowest of the six varieties in both systems.

In the separate analysis for the PLFA measures, cultivar altered ($P<0.05$) % fungi, PLFA evenness and diversity in the conventional system (Table 2). Superb had higher % fungi, PLFA evenness and diversity than the other cultivars. Cultivar did not alter ($P>0.10$) any of the PLFA measures in the organic system.

Tab. 2: Lsmeans of cultivars under conventional management for % fungi, PLFA evenness and diversity from management-separated statistical tests

Cultivar	% Fungi	Evenness	Diversity
Elsa	0.93 b	0.82 ab	2.63 ab
Glenlea	0.90 b	0.80 b	2.61 b
Go	1.02 ab	0.82 ab	2.68 ab
Marquis	0.91 b	0.82 ab	2.68 ab
Park	1.05 ab	0.79 b	2.57 b
Superb	1.37 a	0.85 a	2.81 a

Lsmeans followed by the same letter within columns are not significantly different at the $P<0.05$ level, with Tukey's adjustment. Lsmeans separation was carried out using the pdiff option in SAS.

Correlation analysis suggested some relationships between grain quality and the soil microbial community in both systems, with more correlations in the organic system. Eighteen of 42 correlations were significant in the organic system, and only seven of 42 correlations were significant in the conventional system (data not shown). The % fungi was positively associated with yield under organic management (r=0.9***) and under conventional management (r=0.7**).

Discussion

Protein content of grain is an important factor in breadmaking quality, and was higher in the organic system. Other experiments have reported protein levels in organic systems to be lower (Poutala et al. 1993) or the same (Ryan et al. 2004) as conventional systems. Lower yields and heavy applications of compost for many years prior to the wheat crops in the organic system may explain the higher protein content in organic wheat. However, this experiment demonstrates that it is possible to have similar protein levels in organic and conventional systems.

Cultivars chosen for this experiment differed for some measures of quality as well as yield in both organic and conventional systems. The oldest cultivar, Marquis, yielded lowest in both the organic and conventional system, indicating that breeding has improved yields over the last century. Cultivar choice also affected some measures of the soil microbial community, but only in the conventional system. Management system did not affect microbes. It appears that factors other than cultivar are important in determining microbial community structure in organic systems.

More significant relationships between grain quality and soil microbes in the organic system may indicate that soil microbes play a greater role in determining crop quality in the organic system than the conventional system. The positive correlation between yield and % fungi may be due in part to mycorrhizal fungi (Olsson et al. 1999), as mycorrhizae can benefit plant nutrient uptake and crop productivity.

Conclusion

Yields were lower in the organic system, but protein levels and breadmaking quality at least equal to conventional systems can be achieved in organic systems. Cultivar choice altered grain quality and yield in both systems, but did not have an effect on soil microbial communities in the organic system. Soil microbes may play a greater role in determining crop quality in organic systems than in conventional systems.

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Organic crop production in the tropics

Options for improving soil fertility in the southern part of the Republic of Bénin: Where does Mucuna find its niche?

Akouègnon, G.E.[1], Hoffmann, V.[2] & Schultze-Kraft, R.[3]

Key words: legume adoption, soil fertility, ethno-economics, local knowledge, Bénin

Abstract

Empirical evidence has shown that small-scale farmers can use a non-food, green manure legume as soil-fertilising technology only if it provides immediate benefits other than soil fertility improvement. In the southern part of the Republic of Bénin, however, subsistence-oriented farmers chose Mucuna pruriens *exclusively for soil fertility. In this they had the opportunity to select dual-purpose grain legumes for both soil fertility and food without season loss. The rationale behind this apparently irrational choice lies in the differentiated and economically sound land allocation to* Mucuna *and grain legumes.*

Introduction

The use of green manure (GM) legumes as nitrogen-fixing crops has been advocated as one of the most affordable soil-fertilising technologies for small-scale farmers. In practice, however, resource requirements of GM technology often conflict with the short-term objectives of this target group. Small-scale farmers cannot afford to grow GM legumes simply for the sake of soil fertility unless the seeds of the legumes are edible or in a few cases where GM legumes could be used primarily to combat noxious weeds (e.g. *Imperata cylindrica*) (Douthwaite et al. 2002).

In order to address the trade-off between soil fertility and food concerns, Schulz et al. (2003) have suggested the development of biomass-rich varieties of local grain legumes. However, the soil fertilising effect of these varieties is potentially lower than that of GM legumes because of their grain yields, which entail a substantial removal of nutrients from the system. On the whole, the search for niches susceptible to solving the "GM vs. grain legumes dilemma" remains the cornerstone of promoting soil-fertilising legume options that can be accepted by small-scale farmers.

Study area, materials and methods

The study was conducted from 2000 to 2002 in 4 villages, representative of the major landscapes and land use systems prevailing in southern Bénin. These villages were Agbassakpa (07°04' N, 02°26' E) located on a peneplain built on the Precambrian crystalline basement with ferruginous soils (Luvisols); Azozoundji (07°08' N, 02°03' E) and Zomondji (06°09' N, 01°09' E) located on the plateaux locally called *Terres de*

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Barre with ferralitic soils (Nitosols); and Djregbe (06°41’ N, 02°61’ E) on the costal plain with very poor quartz sand soils (Regosols).

The choice of the villages was based on the need to represent the existing land use intensification gradient: Land fallowing (3 to 5 years) was still practised in Agbassakpa and Azozoundji, but hardly in Zomondji and not at all in Djregbe. Access to mineral fertilisers was restricted in all 4 villages. The length of the growing period ranges from 211-270 days, rainfall is bi-modally distributed averaging 1,100 mm a^{-1}. The farming system is rain-fed and maize-based.

In each village, 8 legume options comprising 5 GM species and 3 food grain legume species were introduced to farmers. The introduced GM species were *Aeschynomene histrix* (accession I.12463), *Centrosema molle (syn. C. pubescens*) (I.152), *Mucuna pruriens* and *Pueraria phaseoloides* (commercial varieties), and *Stylosanthes guianensis* (I.15557) while the food grain legume comprised *Arachis hypogaea* (69-101), *Glycine max* (TGX 1448-2E), and *Vigna unguiculata* (IT84D-449, Mawuwena).

Researcher-managed demonstration plots were established in each village. These were in addition to individual trials that were freely designed and managed by volunteer farmers. Seeds were distributed free of charge and based on the participants’ choices. To monitor farmers’ experimentation process and legume diffusion pathways, both quantitative and qualitative methods were used. The number of adopters was counted seasonally, the areas planted with the introduced legume options were mapped, measured and reasons for adoption, re- or dis-adoption were assessed using periodic workshops, field days and focus group discussions. The rationale behind the utilisation of the species was assessed by eliciting the local soil taxonomy and the value, i.e., yield potentials, attributed to the fields planted with the introduced species. To get a more systematic picture of the comparative advantage of the technology options that were introduced, the ethno-economic values of the legume fields were included in the cost/benefit calculations involved. This was done using the Partial Budget Analysis (PBA) of legume utilisation (Bellon & Taylor 1993). Because of their food advantage, preference of grain legumes over GM legumes was taken as the baseline scenario. Therefore, in-depth analysis (PBA, soil taxonomy etc.) was made only in cases where GM legumes were preferred to grain legumes. The information used in this article is derived from the last data collection in 2002, 4 seasons after the first seed distribution.

Results and discussion

In Zomondji, farmers’ preferences were clearly for the grain legumes. The soil-fertilising effect of Mucuna and *P. phaseoloides* was acknowledged, but the species were not chosen because of land constraints. Also Djregbe’s farmers were more in favour of grain legumes, because of their food property. In contrast, Agbassakpa’s and Azozoundji’s farmers favoured the GM legume options in addition to the grain legumes (Table 1). The GM legumes were evaluated according to their “leaf size”, “aggressiveness of growth habit” and “soil covering speed”. As a result, Mucuna was preferred to every other species, which were qualified either as “second Mucuna” (*P. phaseoloides*) or simply as “small-leafed” species. The weed suppressing property of Mucuna was acknowledged, not as a primary advantage but just as a further confirmation of the “strength of Mucuna”. The grain legumes varieties were judged according to their grain yield and not for their soil-fertilising effect, which became the exclusivity of Mucuna.

Tab. 1: Intensity of utilisation of the introduced legume options after 2 years of experimentation

Legume	Azozoundji (N[a]=125)		Agbassakpa (N[a]=90)	
	No. of users	Average area (m²) per user (% of afs [c1])	No. of users	Average area (m²) per user (% of afs[c2].)
Aeschynomene. histrix	8	169.2 (3.9)	1	225 (0.8)
Arachis. hypogaea	116	114.7 (2.7)	87	212.4 (0.7)
Centrosema molle	0	0 (0)	0	0 (0)
Glycine max	121	341.9 (8.1)	43	264.5 (0.9)
Mucuna pruriens	108	244.5 (5.8)	43	287.5 (1,0)
Pueraria. phaseoloides	0	0 (0)	0	0 (0)
Stylosanthes guianensis	1	138 (3.2)	16	261 (0.9%)
Vigna unguiculata	112	(n.a.[b])	17	635.3 (2.2%)

Notes: [a]: Total number of participants; [b]: n.a.=non available; [c]: afs: Average farm size comprising all types of fields including fallows. In Azozoundji, afs [c1]= 4229,5 m²; in Agbassakpa, afs [c2]=28970,3 m².

The maps of the legume fields show that the species were planted along the local soil fertility gradient, respectively on fields classified as *Fangle*, *Kunxo* and *Sisa* as defined in Table 2.

Tab. 2: Local soil taxonomy in Agbassakpa and Azozoundji

Soil category	Category subset	Suitability for crops	Fertility level	Need of fertiliser
Fangle	Fangle	Potentially for maize	Potentially fertile	2 seasons of grain legume to get smoother
Kunxo	Fertile	Maize	Fertile	No need
	Middle fertile	Maize/grain legume rotation	Middle fertile	Grain legume rotation
	Poor	Only grain legume	Poor	Mineral fertiliser
Sisa	Sisa	No crop	Exhausted	Not worth of fertilisation

The grain legumes were grown either on *Fangle* or *Kunxo* while Mucuna was planted on *Sisa* soil. How could farmers choose Mucuna while having the option to use cowpea (*Vigna unguiculata*) - the grain legume that traditionally has been most used for soil fertility in both villages? In the light of the negative rate of return (-42.7%) yielded by a shift from cowpea-maize to Mucuna-maize rotations (Table 3), farmers' choice of Mucuna appeared irrational. However, considering that the *Sisa* fields allocated to Mucuna cannot sustain cowpea, the opportunity costs of Mucuna is to be equated to zero, at least according to farmers' perceptions. Thus, the Mucuna technology becomes more profitable than that of cowpea: the marginal rate of return with a replacement of cowpea by Mucuna would then be 397.7% (data not shown).

Tab. 3: Partial budget analysis of a maize crop after Mucuna (MM) and cowpea (CM) in Azozoundji

Item	Mucuna/Maize (MM)	Cowpea/Maize (CM)
Gross farm benefits		
1 Average grain yield of subsequent maize on Sisa soils for CM and other soils for CM (kg/ha)	1,500	750
2 Price (FCFA[a])/kg)	112	112
3 Gross margin gate benefits (FCFA/ha) (1x2)	168,000	84,000
Variable input costs (FCFA/ha)		
4 Land preparation	25,500	8,625
5 Opportunity costs for lost season	129,716.54	0
6 Total variable input costs (4+5)	155,216.54[(d)]	8,625[(e)]
Net benefit		
7 Net benefit (kg/ha) (3-6)	12,783.46[(b)]	75,375[(c)]
8 Change in net benefits with a shift from cowpea to Mucuna soil fertilising technology [[(b)] – [(c)]]		-62,592
9 Change in total variable input costs with a shift from cowpea to Mucuna technology [[(d)] – [(e)]]		146,592
10 Marginal rate of return (%) (100 x 8 ÷ 9)		-42.7

Note: [a]: Franc de la Communauté Financière Africaine: 656 FCFA =1 Euro

Conclusions

Smallholder farmers can choose GM legumes to improve poor soils that are not suitable for the production of food crops. In the Republic of Bénin, these potential GM niches were found in non-sandy areas, where land is moderately available, i.e., scarce enough scarce to impose a shifting cultivation based on soil fertility taxonomy.

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Effect of green manure rotation, biol and cultivar on the production of organic spinach (*Spinacea oleracea*)

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Key words: Biol, green manure rotation, spinach, *Spinacea oleracea*

Abstract

Two cultivars (Open Pollination OP and hybrid) were evaluated in a rotation with green manure (Crotalaria juncea) and four biol concentrations (0, 20, 40 and 100%) on organic spinach crop. A statistical complete randomized block under factorial design was used. The yield was highly statically significant for the rotation with green manure (24.3 t/ha), biol (25.8 t/ha) and the interaction of rotation x cultivar (25.2 t/ha), where the production of the OP was superior to hybrid, when green manure was used. High yields obtained when green manure in rotation and high biol concentrations were used, justifies its wide and common use, especially with small farmers, improving the spinach organic production efficiency even when an OP cultivar was used.

Introduction

Organic agriculture in Peru involves more than 100 000 small farmer families. Organic agriculture aims to obtain high nutritional quality food with environmental respect, preserving soil fertility and genetic diversity (Alvarado 2004).

Crop rotation is an antique practice used to increase yields, keep soil fertility in a natural way and as a strategy to prevent pest and diseases. Several authors define it as sequence of different crops, associated or not, in a tract of land for limited time and not necessarily repeated in the same order or a crop sequence system in a specific area (Altieri 1999), therefore the succession in the time it's the most important in the system to maintain soil fertility.

An adequate planning of crop rotation allows attending soil requirements efficiently and can be started using green manure or fodder crops with great contribution of biomass and nitrogen (*Fabaceae*), to generate crop fertility conditions (Kolmans & Vásquez 1996). Therefore rotations can not be carried out of a random, because it can also generate negative effects, such as sorghum root allelopathic exudates that affects yield (Altieri 1999).

Organic fertilizers are obtained directly or indirectly from plants or animals during the rotting process, and they are an important source of essential nutrients, organic matter, humus substances and plant growth regulators. ***Biol*** is a popular name of a liquid organic fertilizer, which is obtained from a biodigestor (anaerobic fermentation of manure, green plants in closed recipients). Different micro organism are in charge to transform these organic materials in humic substances and a sort of amino acid, vitamins, AIA, gibberellins and mineral complex from the non humic fraction of the organic matter. Biol has become very popular across Latin America, especially among

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small producers in order to easy to produce, low costs and better effects. Biol is used in many crops, with soil or foliage applications and variable concentrations.

This study was aimed to evaluate the organic production of spinach (*Spinacea oleracea*) in an organic plot depending on three factors: rotation with green manure (*Crotalaria juncea* L.); biol effect and the response of two cultivars of spinach, one open pollinated (OP) and a hybrid.

Materials and methods

The essay was conducted between at the *El Huerto* (Vegetable Research Program) of the Universidad Nacional Agraria La Molina (UNALM) in Lima, Perú. The average temperature varied between 13º C and 19ºC with an average of 16º C and a relative humidity of 87%, finding within the optimal temperature range (13-18ºC) for the crop (Ugás et al 2000).

The characteristics of soil presents low levels of CE (0.72 dSm^{-1}), moderately alkaline (pH 8), low organic matter content (1.8%), gritty and frank texture, average levels of CIC, but high content of phosphorus and potassium, characteristics suitable for the cultivation of spinach.

Materials

Seeds: Viroflay cultivar seeds (open pollinated OP) were used, and Quinto hybrid.

Biol: Obtained by a 10 m^3 capacity biodigestor, from Bioagricultura Casablanca in Pachacamac, with the following characteristics (Table Nº 1).

Tab. 1: Biol analysis from a biodigestor. Pachacamac, Perú

CE dS/m	pH	Solid g/l	Organic matter g/l	N mg/l	P mg/l	K mg/l	Ca mg/l	Mg mg/l	Na mg/l
15.3	8.2	23.6	5.4	980	121	6760	220.4	53.4	542

Source: Soil and Fertility laboratory UNALM

Pest control: It was used yellow traps, colored glue traps and oil to control white fly (*Liriomyza huidobrensis, Bemisia tabaci*), ash to control black worms (*Agrotis spp*), as well as water cultural control for root rotting (*Fusarium spp*).

Study Factors

Rotation. The spinach was planted in two adjacent plots: one where the last crop harvested was corn (*Zea mays*) and the second where the preceding crop was crotalaria (*Crotalaria juncea*) incorporated to the soil.

Cultivar. Two spinach cultivars (*Spinacea oleracea L.*) were used: Viroflay, open-pollinated (OP) and Quinto (hybrid).

Biol concentrations. Three biol concentrations were used in foliar application: 20, 40 and 100% plus a witness (without application).

Treatments and experimental design. The combination of three factors: rotation, cultivar and biol, lead to 16 treatments. It was used statistical complete randomized block design with factorial arrangements. The averages were confirmed by the Duncan test (Alpha = 0.05) using the test of least squares (Alpha = 0.05) when working with the interactions between different factors

Results

Growth. The OP cultivar obtained the largest size, over the hybrid cultivar when rotation with green manure was used. Both cultivars (hybrid and OP) obtained larger sizes when biol concentration increased (fig. 1).

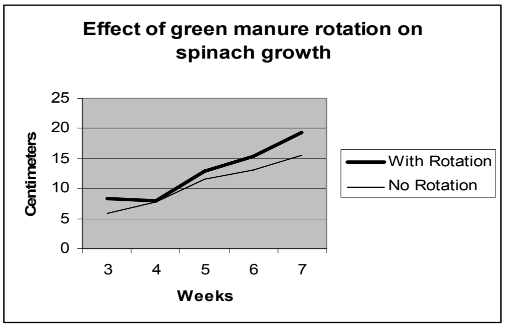

Figure 1: Effect of green manure rotation on spinach growth

Yield. According to single factors (TABLE Nº 2), highly statistically significant differences were found for green manure rotation and higher concentrations of biol factors; these factors were superior to the cultivar factor (hybrid and OP), being decisive in improving yields of organic spinach crop. Under this conditions, the effect of the type of cultivar (hybrid or OP) was less important that biol and rotation effects.

Tab. 2: Simple effects and interactions of rotation with green manure (*Crotalaria juncea),* biol and cultivar on spinach yields (*Spinacea oleracea*).

Treatments	Yields (t/ha)
Rotation	
Without Crotalaria (WC)	17.97 b
With Crotalaria (C)	24.29 a **
Cultivar	
Viroflay (OP)	19.44
Quinto (Hyb)	22.82 (ns)
Biol (%)	
0	15.47 b
20	20.26 ab
40	22.99 a
100	25.80 a**
Rotation X Cultivar	
WC x OP	13.65 b

Treatments	Yields (t/ha)
WC x Hyb C x OP C x Hyb	22.29 a 25.24 a 23.34 a**
Rotation x biol	n.s
Cultivar x biol	n.s
Rotation x Cv x biol	n.s

* Significant for P<0.05 ; *** significant for P<0.001

Interaction factor was highly significant only with the combination of rotation with cultivar, even when OP cultivar was used. Other double or triple interactions were not significant. These results confirm the superior effect of the rotation with green manure over foliar fertilizer (biol) and type of cultivar.

Discussion and Conclusions

Results demonstrated that in organic spinach crop the rotation with green manure is a major factor than cultivar (hybrid /OP) or organic foliar fertilizer (concentration of biol). The best response of the cultivar OP was obtained when used rotation with green manure, demonstrating it is a valuable factor to obtain better yields in organic spinach crop. Hybrid cultivar did not obtain higher yields, because the specific nutrition and environment requirements are achievable only with chemical inputs (Arroyo 2005). In Argelia, in desert conditions, the production of spinach under unfavorable conditions was greater with OP than the hybrids (Gutierrez & Tapia 2006). The rotation with green manure (*Crotalaria juncea*) showed that at the same environmental conditions OP can be more efficient reaching higher yields than hybrid. Biol concentration increased the yield, gaining maximum efficiency when 100% foliar concentration was used (23.37 t / ha). Biol effects are consistent with other essays like pickles (*Cucumis sativus*), where higher yields were obtained with biol 50% (25.7 t/ ha) in an out-of-season planting and green beans (*Phaseolus vulgaris*) where the highest yields (17.9 t/ ha) were obtained with 100% of the foliage biol (Barrios 2001). Therefore spinach yields can be explained by the effect of simple factors (Rotation or cultivate biol concentration) independently and by the interaction of double rotation with green manure x cultivar. When not using green manure in the rotation, the yield was increased only by the effect of cultivars.

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Organic matter addition in organic farming – Impact on root development and yields in maize and cowpea over dry seasons

Sangakkara, U.R.[1], Bandaranayake, P.S.R.D., Dissanayake, U. & Gajanayake, J N.

Key words: Organic matter, WHC, Roots, Maize, Cowpea, Yields

Abstract

Organic matter and its proper management are vital in tropical organic farming to maintain productivity. A field study thus placed rice straw or Gliricidia leaves on the soil surface or the material was incorporated into soil. The impact of these treatments on soil moisture, root development and yields of organically grown maize or cowpea were evaluated in an Asian dry season. Incorporation increased soil moisture retention in the soil and hence induced better root growth, culminating in higher yields. The impact was greater in maize, especially with Gliricidia leaves. The benefits of incorporating organic matter in dry seasons for tropical organic farming are presented.

Introduction

The availability of organic matter in tropical Asian farming systems is low and is generally of poor quality (Katyal et al., 2001). Management of the available organic matter is thus important to derive maximum benefits (Giller et al., 2006). Incorporating organic matter within conventional farming systems showed stimulation of root growth (Sangakkara et al., 2004). Similar studies within a tropical organic system have not been reported. However Ball et al. (2007) report this effect in temperate conditions. Hence a field study evaluated the impact of different methods of placing two common tropical organic materials on water holding capacity of the rooting zone of a tropical organic system. The impact on root growth and yields of two common tropical crops (maize – *Zea mays* and cowpea *Vigna unguiculata*) was also determined over a minor season when the crops are subjected to moisture stress.

Materials and methods

The experiment was conducted on an organic farm located in the intermediate zone of Sri Lanka, at Kurunegala (83°N, 79°E, and 116 m above sea level) in the minor season of 2005 lasting from May to August. The soil of the site was an Ultisol, with an organic C content of 1.89 ± 0.44% and N content of 38 (± 1.99) $mg.kg^{-1}$ and a sandy loam texture. Rainfall received in this season was 214 mm and the mean temperature was 31°C ± 2.33 °C. With the onset of the rains in May, land was prepared, plots of 3 x 2 m demarcated. Soils were sampled at 12 locations to a depth of 30 cm at intervals of 0 - 10, 10 – 20 and 20 – 40 cm using a core sampler and Water Holding Capacity (WHC) was determined. Thereafter, leaves of *Gliricidia sepium* (C:N ratio 21.4) and rice straw (C:N ratio 39.8) were either applied to the surface or incorporated into the top 40 cm manually. The rate of addition was equivalent to 5 Mt dry matter per ha. The control treatment had no organic matter. Thus the experiment had 5 treatments replicated four times within a randomized block design.

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At 14 days after adding organic matter, soils of all plots were sampled again to the same depths and WHC was determined. Seeds of either maize or cowpea (Var Ruwan or Arlington respectively) were planted at the recommended spacing and maintained organically. At flower initiation of both crops, core samples were obtained from two locations per plot from the depths of 0 – 20 cm and 20 – 40 cm, roots washed and total lengths determined by the grid method to calculate root length densities (RLD). Seed yields were determined at crop maturity. The data was subjected to statistical analysis using a GLM model and significance of treatment differences were determined using LSD values.

Results and Discussion

The WHC of the soils prior to adding organic matter declined significantly with depth (i.e. 18.2, 16.5 and 15.1% (S.E. 2.11, n= 12) at depths of 0 – 10, 10 – 20 and 20 – 40 cm respectively. This clearly indicated the more compact soil structure within the root zone on this organic farm.

Organic matter increased WHC of soils when compared to the control (Table 1). Incorporation of the material increased the beneficial impact to a greater extent, especially when rice straw, was added. This is due to the slower decomposition of this material with its greater C:N ratio, when compared to the leguminous Gliricidia leaves. The lower increase in WHC on the surface is due to the faster breakdown of the material, especially Gliricidia leaves. However the importance of organic matter in enhancing WHC of tropical soils was clearly evident as shown by Olness and Archer (2005), who stated that a 1% increase in soil C enhances WHC by 2 to >5%, depending on the soil texture.

Tab. 1: Water holding capacity of soil as affected by organic matter and its method of application

Organic matter	Method of addition	WHC (%)	
		0 – 20 cm	20 – 40 cm
Rice straw	Surface	19.5	18.6
	Incorporated	20.2	19.8
Gliricidia	Surface	19.2	16.5
	Incorporated	19.9	19.1
Control		17.5	16.3
SE mean (n=40)		0.41	0.84

Organic matter stimulated root development (RLD) of both species (Table 2). The interaction between organic matter and the method of addition was also significant. The greater beneficial impact was observed with maize, which has a fibrous root system when compared to the tap root system of cowpea. This can also be attributed to the more drought tolerance of cowpea and its deep rooting ability. Surface application of rice straw enhanced RLD of maize, especially in the top layer of soil and more than in cowpea (Table 2). The beneficial impact was also greater than when Gliricidia was applied to the surface. This again is due to the slower breakdown of straw. In contrast, the differences in the RLD in cowpea in the two soil depths were not as greater as in maize when the organic matter was applied to the surface. Incorporation induced better root development in both soil layers, especially with rice straw. Although the RLD of both species in the top layer of soil was lower when the organic matter was incorporated, there was an overall stimulation of roots within the soil profile due to incorporation. This can clearly be related to the better WHC of the lower soil layer when the organic matter, especially straw was incorporated.

Tab. 2: RLD of maize and cowpea as affected by organic matter and method of addition

Organic matter	Addition	Root Length Density ($cm.cm^{-3}$)			
		Maize		Cowpea	
		0 – 20 cm	20 – 40 cm	0 – 20 cm	20 – 40 cm
Rice straw	Surface	25.6	12.8	14.5	12.7
	Incorporation	22.4	20.7	10.1	10.6
Gliricidia	Surface	23.1	10.4	11.4	9.3
	Incorporation	19.6	18.0	10.5	10.1
Control		15.6	12.8	9.4	8.5
LSD (p=0.05)	Material	0.031	0.027	0.018	0.037
	Incorporation	0.004	0.018	0.006	0.033

Organic matter increased seed yields of both species over the control, irrespective of the type and method of addition (Table 3). This clearly highlights the role of organic matter in organic farming, especially in the dry seasons when crops are subjected to soil moisture stress. The beneficial impact was greater in maize than in cowpea in this season, due to the greater susceptibility of the cereal to moisture stress.

Incorporation of the organic matter increased yields significantly, and again the impact was greater in maize. This is due to the better root distribution in the soil profile due to incorporation. A positive correlation could thus be established between RLD and yields for maize ($Y = 14.254Ln(X) - 83.396$ ($r^2 = 0.8845$) and cowpea ($Y = 9.521Ln(X) - 56.55$ ($r^2 = 0.7906$). The greater increase in yields with increasing RLD in maize also highlighted the greater beneficial effect of adding organic matter on the cereal, by the stimulation of root development, which could be related to enhanced water holding capacity.

Gliricidia increased yields to a greater extent than rice straw, especially when incorporated. The higher N content in the leaves and the more rapid breakdown would provide N, which is limiting in tropical cropping systems to the growing crops, especially maize. In contrast, cowpea could fix atmospheric N and hence is less benefited by this organic matter.

Tab. 3: Impact of method of addition of organic matter on yields of maize and cowpea

Organic matter	Addition	Seed yield kg ha^{-1}	
		Maize	Cowpea
Rice straw	Surface	1145	596
	Incorporation	1390	690
Gliricidia	Surface	1215	648
	Incorporation	1485	815
Control		885	480
LSD (p=0.05)		48.51	10.11

Conclusions

The field study highlights the importance of organic matter and its method of addition for crop growth and yields in tropical organic farming in the dry seasons. Organic matter stimulated root growth which in turn could enable the crop to enhance water use efficiencies. The use of material with a lower C:N ratio also accrues more benefits than straw, which is commonly used in tropical organic farming.

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Harmonizing *Jhum* (Shifting Cultivation) with PGS Organic Standards in Northeast India: Key features and characteristics of *Jhum* for process harmonization

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Key words: Shifting cultivation, *jhum*, PGS, Northeast India

Abstract

Shifting cultivation, known as 'jhum' in Northeast India is widely distributed upland slash and burn agricultural system. Efforts to address jhum remained challenging tasks, more so due to its shortening cycle but continued livelihoods dependency for a large population of upland communities. With organic foods gaining popularity, harmonizing jhum with Participatory Guarantee System (PGS) organic standards may provide enhanced opportunities for improved livelihoods and environmental security in Northeast India. The paper explores these opportunities and focuses on the features and characteristics of jhum that would require in meeting the PGS organic standards.

Introduction

Shifting cultivation**,** locally known as ***jhum*** is a widely distributed form of agriculture in the upland areas of Northeast India. The practice involves site selection, slash and burn, followed by mixed cropping for a year or two and fallowing for certain years for recuperation of the land. In spite of various efforts of the government to address and contain *jhum*, over 443,000 families of upland rural communities of the region continue to partially or wholly depend on 'jhum' for their livelihoods, with total areas affected by the practice estimated between 1.73 to 13.81 million ha (NEC 2006). *Jhum* in Northeast India, including its variants such as *alder-based jhum* in Nagaland, *bun* cultivation in Meghalaya continue to attract diverse opinions. Its critiques call it as an inefficient and wasteful form of agriculture, while others see this as diversified livelihood system that ensures sustenance along with conservation of associated rich cultural heritage. The shortening jhum cycle (the intervening period between fallowing and returning to the same spot for cultivation) from traditional 10 years or more to 4-5 years on an average now is indeed a matter of concern. This is seriously impacting on the local livelihoods and environmental security in many pockets of the region.

However, given the farmers' knowledge and continuing adaptive innovations by responding to complex agro-ecological and socioeconomic dynamics, this system of farming with appropriate cycle provides the best options for sustainable use of land due to its inherent strengths and the institutions governing the practice. Harmonizing jhum with Participatory Guarantee System (PGS) would strengthen jhum as an agricultural and adaptive forest management practice based on scientific and sound ecological principles, particularly where the climate and land gradients are uniquely suitable primarily for jhum. PGS is a complementary system of organic guarantee that builds the organic movement, educates farmers and consumers and grows the domestic market for organic produce. In fact, such a parallel domestic certification system will end up facilitating the growth of Third Party Certified farms in India,

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thereby strengthening and increasing India's place as an Organic exporter (Khosla, 2006). The objective of the present study is to explore these possibilities and opportunities of harmonizing shifting cultivation practices (jhum) with the PGS organic standards for securing improved livelihoods and environmental stability in Northeast India. The PGS organic certification and assurance system could be particularly suitable for the marginal farmers and shifting cultivators of the region.

Materials and methods

Materials for this paper are drawn from the output of a two-day stakeholders' consultative workshop held in Shillong during July 14-15, 2007. The workshop was attended by academicians, scientists, government agencies, NGOs, rural development workers, farmers' representatives and international research and development agencies to consider why and how *jhum* in Northeast India could be harmonized with PGS organic standards. The key features and characteristics of *jhum* that would be considered for harmonizing the practice with PGS standards were identified and qualified, which form part of the results of this paper. The concepts and implementation modalities were discussed with farmers, which received wide acceptance if organically produced crops could ensure higher and assured income.

Results and Discussion

The National Programme for Organic Production (NPOP) in India includes fallow lands for promotion of organic farming (GoI, 2005). Jhum cultivation practices ensure such fallow lands where PGS organic standards can be applied. For this purpose the following minimum characteristics ought to be met, besides other standards such as taking of pledge by the farmers, maintenance of diaries, etc. as required under PGS.

- *Zoning of PGS jhum*: The area for PGS jhum to be clearly demarcated and protected from non-organic non-PGS area, involving community institutions.
- *Jhum cycle*: At least 9-10 years jhum cycle with 8 years of fallowing and 1-2 years of cropping; in alder-based *jhum* with well-spread periodically pollarded trees, a minimum cycle of 4 years with 2 years fallowing and 2 years cropping.
- *Site selection*: The PGS jhum sites to be as per local jhum regulations, at least 400 m from major water source; 50 m from main road; not community or government forest reserved area; not primary or pristine forest.
- *Jhum clearing*: Precaution exercised by rationalizing land clearing based on availability of seeds/planting materials, and availability of labour for weeding; trees not clear-felled but looped branches, retaining as many standing trees.
- *Burning & fire management / precaution against fire*: Well established fire line maintained before burning; no destruction of adjacent biodiversity-rich forest by fires from jhum; no crop residues burnt; strong community fire management.
- *Labour*: No child labour employed; men and women share equal work-burden.
- *Seeds / planting materials*: Only local / indigenous seeds used; seeds exchange with other farmers prior to sowing as per local customs; seeds of local species of trees / fruit trees also sowed/planted along with jhum crops; no GMOs or HYV hybrid seeds used; if required, seeds treated only as per PGS organic standards.

- *Agronomic practices*: Well balanced/mixed agro-biodiversity planted or maintained; no tillage; no over planting of nutrient-exhaustive crops; very good mix of nitrogen fixing plants/crops, occupying at least 50% of the crop area; no serious or alarming attacks of pests and diseases; no chemical pesticides used.
- *Soil & water conservation practices*: Good soil and water conservation practices using both agronomic (through indigenous crop mix) and mechanical measures (using locally available materials or traditional good practices) maintained; no visible gully formation or other evidences of soil erosion in the field.
- *Weeding & weed management*: Removed weeds used for mulching; no germinating local tree species destroyed during weeding.
- *Pest management*: Integrated pest management (IPM) practiced; if required, organic pesticides used along with promotion of traditional preventive measures.
- *Harvesting & packaging*: Bags and containers used to harvest and transport jhum organic produce are clean and uncontaminated; used locally available uncontaminated leaves and bamboo baskets for packaging while transporting.
- *Crop residues*: Crop residues left in the field; no burning of crop residue.
- *Fallow management*: A minimum of 8 years of fallow periods maintained in a typical system; and 2 years in a pollarded-alder-based system.
- *Soil chemistry*: Soil properties maintained by appropriate crop mix cultivation, soil and moisture conservation practices, maintenance of at least 8 years fallow.
- *Soil flora and fauna*: Soil faunal and floral population maintained, including soil microbial status ensured by recycling of crop residues and optimum fallowing.
- *Biodiversity in the fields*: Crop biodiversity and biodiversity of fallow areas maintained or enhanced; live hedges maintained as jhum boundaries; *jhumscapes* appear with jhum as islands in the midst of enhanced forest cover.
- *Productivity & food security*: The overall practice is conservation farming with improved land productivity and enhanced food security and income.
- *Land tenure & social equity*: Equitable land access to all members of a given village; effectively prevents unequal or skewed privatization of common property resources, harmonizing with traditional system of social equity.
- *Conversion period*: Suggested period is 12-36 months for general fallow land; a fallow land with a period of 8 years or more may have shorter conversion period.
- *Packaging materials*: Local materials made of leaves, bamboo baskets, etc.; no plastic or non-biodegradable materials used.
- *Markets*: Need for establishing a network of markets and well-established supply chain for organically or naturally produced food crops from Jhum PGS.
- *Pricing and advertising support*: Initially market support for pricing and transport; also support for advertisement of 'niche' crops and consumer education.

However, successful initiation of jhum PGS would require partnership endeavour of the farmers, indigenous community institutions, government agencies and participating NGOs preferably through demonstrative pilot projects. Policy adoption on jhum PGS along with building of market network for organically produced 'niche crops' from jhum and consumer education and awareness would go a long way in grounding and popularizing jhum PGS in Northeast India. Meanwhile, the proponents of *jhum* PGS would have to prove that the organic and ecological standards meet those of NPOP (GoI, 2005) or as described by Khosla (2006) and ECOVIDA (2004).

Conclusions

The people of Northeast India represent a fascinating variety of cultures. Jhum plays an important cultural role in local customs, besides ensuring agro-biodiversity conservation and offering livelihood security to rural upland poor. It would be unfortunate if developmental programmes based on misjudged opinions about jhum suppress this unique form of agriculture. A balanced approach to development which also recognizes the merits of jhum is needed so that this remarkable form of organic farming persists into the 21st century. With appropriate PGS policy adoption and harmonizing jhum with PGS organic standards would enable jhum to be sustainable conservation and ecological farming practice.

Recent studies from the Eastern Himalayas showed that the practice represents enormous diversity of cultivation systems with farmers' ingenuity to local resource management (Kerkhoff and Sharma, 2006). It is widely recognized that several highly productive and sustainable agroforestry systems have their origins in local shifting cultivators' responses to the need to reduce or improve fallow cycles of shifting cultivation (Cairns, 2007). These collectively represent new hopes for shifting cultivation and harmonizing jhum with PGS organic standards could be a rewarding option of translating these hopes and dreams into realities.

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What can organic agriculture contribute to sustainable development? – Long-term comparisons of farming systems in the tropics

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Key words: long-term experiments, system comparison, production systems, tropics, sustainability

Abstract

Despite the high demand for sound data on the agronomic, ecological and economic performance of organic agriculture in developing countries, systematic comparison of organic and conventional farming systems has not so far been carried out. The Research Institute of Organic Farming (FiBL), together with its partners, is presently establishing long-term comparisons of farming systems in various agro-ecological and agro-economic contexts to study the different parameters that are essential for sustainable development. To date, three study areas have been selected: (a) a sub-humid area in Kenya where farming is subsistence-oriented; (b) a semi-arid area in India where cotton is produced for the export market; and (c) a humid area in Bolivia where perennial fruits and cacao are produced for the domestic and export markets. The key elements in these comparisons are replicated long-term field trials. These are complemented by farm surveys and short-term trials under on-farm conditions. This network of comparison of farming systems in the tropics is expected to (1) put the discussion on the benefits and drawbacks of organic agriculture on a rational footing; (2) help to identify challenges for organic agriculture that can then be addressed systematically; (3) provide physical reference points for stakeholders in agricultural research and development and thus support agricultural policy dialogue at different levels.

Introduction

In Europe and North America, considerable research has been carried out on organic farming and its impact. The advantages of the organic system in terms of both ecosystem conservation and economic performance have been demonstrated by numerous studies (Pimentel et al. 2005, Offermann and Nieberg 2000, Stolze et al. 2000). An important contribution in this regard has been made by the DOK trial (DOK = (bio)dynamic, organic, conventional), conducted in Therwil, Switzerland, and now in its 28th year (Mäder et al. 2002). Organic farming is now also being promoted by non-governmental organizations (NGOs) in tropical countries, and farmers' groups are adopting organic methods of cultivation to improve their food security and their income (Kilcher 2007). So far, however, there have been no systematic studies examining the efficiency of organic farming methods in the tropics compared to conventional approaches with regard to achieving economic, social and environmental objectives (Parrott and Kalibwani 2006). Whether and how organic farming can contribute to

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development in low-income tropical countries is of interest not only to producers' organizations, but also to research institutes, development organizations, national authorities and international donors.

The Research Institute of Organic Agriculture (Forschungsinstitut für biologischen Landbau – FiBL), together with its partners, has set itself the task of establishing a network of long-term comparisons of farming systems to investigate the contribution of organic farming to enhancing food security, combating poverty and conserving tropical ecosystems.

Research questions

In the long-term comparisons of farming systems run by FiBL, organic farming is compared to conventional production with a view to addressing the following questions:

- How does organic farming influence yield and yield security, especially in years with extreme climatic conditions such as droughts or floods? What impact does it have on product quality and shelf-life?
- How does organic farming influence agro-ecosystem stability and availability and quality of natural resources, especially soil fertility, energy resources, biodiversity and beneficial organisms?
- Do organic products create value-added that generates higher incomes?
- How does organic farming affect the living standard of the farmers?
- How efficient is the organic farming system with regard to nutrient and energy use, and in terms of capital and labour requirement?

Methodology

Central to FiBL's comparison of farming systems in Africa, Asia and Latin America are replicated field trials reflecting the crop rotations and cultivation methods currently practised in the given locality (see also below). These trials are geared towards addressing agro-economic and environmental research questions over a longer period and investigating processes of change. Straightforward analysis of economic feasibility (gross margin) can also be carried out. In a second step, the same parameters are also compared in on-farm trials in conditions that reflect actual practice, but in a shorter time-frame. As part of this, the experiment is repeated for all farming techniques on every holding involved. To complete the picture, farm-level comparison of socio-economic aspects such as income structure and living standard is also carried out (Eyhorn et al. 2007). In regions where there are numerous organic holdings, farms are selected for study on the basis of random sampling. In locations where organic farming is not widespread, pairs of organic and conventional holdings operating under comparable conditions are selected for study. Case studies are also carried out to illustrate the process of conversion and its impact on the environmental, economic and social situation over a longer period (Lee and Fowler 2002). The data base obtained from the field and on-farm trials and surveys is subsequently made available for organic sector development in the region in question, and especially for agricultural training and extension, for market development and policy consultation.

Locations

FiBL and its partners are developing sites for long-term comparison of farming systems in three countries:

In Kenya, investigation centres on largely subsistence-oriented cultivation of maize and vegetables in sub-humid conditions. The farming methods – conventional and organic, at two levels of intensity in each case – were applied for the first time in March 2007. Local partners are the Institute of Insect Physiology and Ecology (ICIPE), the Tropical Soil Biology and Fertility Institute (TSBF-CIAT), the Kenyan Agricultural Research Institute (KARI) and the School of Environmental Studies and Human Sciences of Kenyatta University (KU).

In India, a comparison of farming systems based on cultivation of an export product – cotton – is being set up in a semi-arid region. Soya and wheat, another two important agricultural products in this region, are also included in the investigations. The trial consists of one organic, one biodynamic, one conventional and one GMO system, and operations commenced in the 2007 cotton season. The main local partner is a cotton trading company (bioRe India). Appraisal of research partners is currently under way.

A third site is currently under development in a humid region of Bolivia. In this case, the crop that the trial will focus on is a long-standing export product, cacao, cultivated in agroforestry systems. Planting of the trial site will be carried out in April 2008. The following institutions have joined forces to form a network of partners: Promoción e investigación de productos andinos (PROINPA), Instituto de Ecología de la Universidad La Paz, Asociación de organizaciones de productores ecológicos de Bolivia (AOPEB), El Ceibo.

Strategic objectives

FiBL is developing this network for long-term comparison of farming systems because:

- the debate on organic farming in southern countries needs to be put on an rational basis;
- it will provide governments and donors in southern countries with support for making strategic decisions and developing action plans;
- it will help to identify challenges for organic farming in southern countries and address them systematically;
- it will provide decisive results-based support for developing organic farming in the region in question, as demonstrated by the experience of the DOK trials in Switzerland in the 1970s and 80s.

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Green manuring for tropical organic cropping – A comparative analysis

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Key words: green manures, application, soils, yields, seasons

Abstract

Green manuring is an essential component of tropical organic farming. Field studies evaluated the use of three legumes as in situ or ex situ green manures, along with a nonlegume green manure and a control to ascertain their impacts on soil properties and yields of maize and mung bean grown in major (wet) and minor (dry) seasons. In situ green manuring, especially with legumes, had the most beneficial impact on soil properties, while with ex situ methods, the use of leaves alone improved soil properties. Yields were increased to a greater extent by green manuring in the minor season, and the in situ system proved to be more beneficial. In ex situ green manuring, greater benefits were obtained by the application of leaves alone. The impact of different green manures and their application methods is presented.

Introduction

Green manures are an ideal method of sustaining soil fertility in the tropics (Joergensen, 2002, Fageria, 2007), and in organic farming, for both soil fertility and microbial activity (Palm et al., 2001). Many studies in Asia (e.g. Katyal et al., 2001) highlight the value of green manures, although no studies report the benefits of *ex situ* or *in situ* application of the same material in comparison to that of only *ex situ* green manures on tropical upland crops. Field studies were carried out to compare how green manures grown *in situ* and *ex situ* affected selected soil properties and yields of maize (*Zea mays*) and mungbean (*Vigna radiata*) cultivated in the major and minor seasons of tropical Asia, in contrast to application of only *ex situ* manures.

Materials and methods

The study was carried out at the Experimental Station (418 m above sea level, 8°N, 81°E) of the University of Peradeniya, Sri Lanka, located in the mid-country intermediate zone, over the period October 2004 to August 2005, to encompass the major (WET) and minor (DRY) season corresponding to the Northeast and Southwest monsoons. The soil was an Ultisol (Rhodoult) with a sandy clay loam texture. The site received 722 mm and 236 mm of rainfall in the major and minor seasons and the me an temperature and humidity were 29°C + 2.3°C and 69.5 + 2.33%

The experiment had 9 treatments per species (maize and mungbean), namely ex situ application of gliricidia (Gliricidia sepium) or tithonia (Tithonia diversifolia) leaves, or twigs and leaves, *in situ* or *ex situ* application of crotolaria (*Crotalaria juncea*) or sesbania (*Sesbania rostrata*), and a control with no green manures, replicated three times in a randomized block design.

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The land was well prepared manually in August 2004 and March 2005 on adjacent blocks, with 18 plots of 2x2 m demarcated per replicate. Seeds of crotalaria or sesbania were broadcast on the selected plots for the two crops, and populations of these two species were maintained in an adjacent block for *ex situ* green manuring. In early October 2004 or May 2005, with the rains of the major and minor seasons, the biomass of the two planted green manures were estimated and the selected green manures were applied *in situ* or *ex situ* to the plots at a rate equivalent to 4 t/ ha of dry matter. The *ex situ* green manures – gliricidia and tithonia leaves or leaves and twigs, and sesbania or crotalaria *ex situ* were obtained nearby. C:N ratios of samples were determined. At 15 days after incorporation, soils of the plots were sampled to a depth of 30 cm using cores and analyzed for pH, bulk density, water holding capacity, and soil N by standard techniques as described by Anderson and Ingram (1993). Thereafter, seeds of maize (Var Ruwan OPV) or mungbean (Var MI5) were planted and maintained as per local recommendations without any chemical inputs. Seed yields were determined at crop maturity. The data was subjected to analysis of variance using a general linear model.

Results and Discussion

Sesbania and crotalaria had the highest N contents (Table 1) and the lowest C:N ratios, which are important in green manures. The inclusion of twigs, which is done by most tropical farmers in *ex situ* mulching, reduced N content and increased the C:N ratios of gliricidia and tithonia. Furthermore, tithonia had the lowest N contents and hence the highest C: N ratios thus indicating its inability to provide N to plants in organic systems, although it is known to provide P to crops (Cong and Merkcx, 2005).

Tab. 1. Nitrogen and C: N ratios of the selected green manures

Green manure	N %	C:N ratio
Gliricidia leaves	3.25	18.4
Gliricidia leaves and twigs	2.91	20.9
Crotalaria juncea plants	4.08	14.8
Sesbania rostrata plants	4.56	14.1
Tithonia leaves	0.58	25.7
Tithonia leaves and twigs	0.45	29.4
Probability (n=24)	0.018	0.009

Green manures had no significant impact on soil pH, although bulk density declined significantly when compared to the control (Table 2). *In situ* green manures reduced bulk density to the greatest extent. In *ex situ* mulching, leaves and twigs reduced bulk density more than when leaves alone were added, because of the higher lignin content of the former. The WHC followed the same trend as bulk density, and there was a significant positive correlation (r= 0.76*) between these two variables. Soil N was increased significantly by the legume green manures when compared to the control and tithonia. Again, *in situ* green manuring had a greater significant impact and also the use of leaves alone of gliricidia. This illustrated the benefits of *in situ* green manuring for enhancing soil properties and N. If *ex situ* manuring is adopted, the use of leaves alone would develop a better soil for organic farming

Tab. 2 Selected soil properties at planting as affected by green manures in wet (S1) and dry (S2) seasons, Es = addition *ex situ*, IS = addition *in situ*

Green manure	Ad.	pH (1:2.5 H_2O)		Bulk density $Mg.m^{-3}$		WHC %		Soil N (% Dry wt)	
		S1	S2	S1	S2	S1	S2	S1	S2
Gliricidia L*	Es	6.14	6.23	1.24	1.25	18.4	18.7	2.15	2.02
Gliricidia L & T	Es	6.25	6.39	1.22	1.21	19.9	19.2	2.04	1.98
Crotalaria	Is	6.46	6.52	1.18	1.21	20.2	19.6	2.24	2.15
	Es	6.38	6.27	1.21	1.24	18.5	19.3	2.14	2.05
Sesbania	Is	6.34	6.18	1.19	1.23	19.8	18.7	2.21	2.11
	Es	6.15	6.22	1.23	1.25	18.6	19.1	2.11	1.99
Tithonia L	Es	6.50	6.58	1.29	1.31	19.5	19.4	1.76	1.77
Tithonia L & T	Es	6.24	6.43	1.24	1.25	18.2	19.8	1.62	1.65
Control		6.15	6.13	1.35	1.36	15.6	14.8	1.58	1.54
Probability (p=0.05)		0.049	0.057	0.038	0.024	0.046	0.018	0.021	0.017

*L & T refer to leaves and twigs respectively

Green manures enhanced yields of both crops, especially the lower yields in the minor dry season, which could be attributed to the enhancement of soil water holding capacity. The legume material when grown *in situ* had a greater beneficial impact. In *ex situ* green manuring, the use of leaves alone had the greatest beneficial impact. Tithonia, although it provides P to plants, could not have the same impact on yields as N is the most limiting nutrient in most tropical soils (de Costa and Sangakkara (2006).

Tab. 3. Yields of maize and mungbean (kg ha^{-1}) in major and minor seasons as affected by green manures and method of application

Green manure	Addition	Maize		Mungbean	
		Major	Minor	Major	Minor
Gliricidia L	Ex situ	3251	2471	956	674
Gliricidia L & T		2433	1958	825	615
Crotalaria	In situ	3998	2941	999	701
	Ex situ	3704	2665	921	756
Sesbania	In situ	3790	2781	1001	795
	Ex situ	3410	2485	954	741
Tithonia L	Ex situ	3041	2104	825	642
Tithonia L & T	Ex situ	2534	1917	758	542
Control		1844	1452	458	329
Probability (p=0.05)		0.038	0.027	0.005	0.019

Thus, the study highlighted the importance of green manuring for tropical organic cropping. Legumes, especially as *in situ* green manures, had a greater beneficial impact, especially in the minor dry seasons. If *ex situ* green manuring is adopted, the use of leaves is the best option rather than the common practice of adding the entire shoot.

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Population Density and Distance to Market Does not Influence the Farmers' Use of Organic Manure

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Key words: Organic manure, socio-economic-ecological-modeling, integrated soil fertility management, Savannas, Nigeria.

Abstract

This study developed and employed a socio-economic-ecological-modeling (SEEM) framework in its analyses. The SEEM is made up of four resource use domains of high/low population density and high/low access to market and two agro-ecologies in the savanna of Nigeria. Data used comprises a sample of 320 farm households in northern Nigeria. The pattern of organic manure use varied slightly and insignificantly across agro-ecological and resource use domains. The major finding of the study is that the resource use domains made use of same amount of organic manure. The level of organic manure use is, however, below the recommended levels for the cereal-based production systems in the study area. Policy that encourages the intensity of manure use and crop-livestock integration is recommended to support integrated soil fertility management practices in the study area.

Introduction

Population pressure increases, shortened fallow cycles, cropping intensification, inaccessibility and low output pries and concerns about agricultural sustainability and self-sufficiency have combined to contribute to increased demand for integrated soil fertility management of the agricultural resource base. Following this situation, organic manure in the form of animal manure becomes one of the principal sources of nutrients for soil fertility maintenance and crop production. Also, there is need to investigate the present level of use of organic manure in order to knowledge gap by agro-ecologies using the methodologies of resource use domains which are importance drivers of agricultural intensification and commercialization (Manyong et al. 2003). Hence, this study assessed the socioeconomic and ecological interactions in organic manure use in northern Nigeria.

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Materials and methods

This study was conducted in the savannas of northern Nigeria - the northern Guinea savanna (NGS) and the Sudan savanna (SS) agro-ecological zones (AEZ) represented by the Kaduna and Kano States as benchmark areas, respectively (Manyong et al., 2003). The *length of growing period* (LGP) was adopted in stratifying sample by global agro-ecological zoning (FAO/IIASA, 2000). The LGP is 150-180 days for the NGS and 90-150 days for the SS. Kaduna State lies between latitudes $9^0\ 04^/$ to $11^0 50^/$ N and longitude $6^0 09^/$ to $10^0 41^/$ E. Kano State lies between latitudes $10^0 33^/$ to $12^0 37^/$ N and longitude $7^0 34^/$ to $9^0 25^/$ E. The NGS and the SS were chosen because these two zones support the highest concentration and density of livestock in Nigeria (Thornton et al., 2002; Manyong et al., 2003).

Four socio-economic resource use domains of the clusters of similar resource and farming conditions, resulting from a combination of high and low population density areas and high and low market access areas were generated through a geo-spatial mapping estimated using the Arcview© software - a GIS software. In deriving the population factors, a rural population density of less than 100 people per square kilometer was estimated and identified as low population density (LP) while a population density of 100–500 people per square kilometer was estimated and identified as high population density (HP). Anything otherwise was defined as an urban population. Also a proximity of 20 km radius to a town or city was defined as high market access (HM); anything otherwise was defined as low market access (LM). These domains reflect differences in opportunities and correspond to agricultural intensification, which is in turn strongly influenced by population density and access to markets (Devendra and Pezo, 2002). A total of 20 farm households were randomly selected from the pool of villages generated by the GIS by using the random number table that resulted to 320 farm households from 16 in the study area. The coordinates of the geo-referenced 16 villages were verified using a hand-held Magellan© 330 geo-positioning system (GPS) instrument during the ground verification/truthing exercise. Data analysis involved the use of descriptive and inferential statistics.

Results and Discussion

The use of manure is a well established practice in the agricultural system in the study area. Ninety percent of the farmers used manure, though at low intensity of use. The mean manure use in the study area is 1850 kg ha^{-1}. This represents 382 percent increase over the 485 kg ha^{-1} reported by Manyong et al. (2003). The results thus show higher level of intensification in organic fertilizer use in the study area. Also, there was higher level of organic fertilizer use (or intensification) of 1870 ± 1170 kg ha^{-1} in the SS compared to the of 1830 ± 1570 kg ha^{-1} in the NGS. However, the averages are still insufficient to meet the animal manure of 3–5 tons ha^{-1} required to maintain cereal grain yields in the region (Bationo and Mokwunye, 1991, Chianu and Tsujii, 2004). Analysis of means difference show that there was no significant difference in use of manure in the two agroecological zones, and by socioeconomic/resource use domains. It should be emphasized; therefore, that increased use of organic fertilizer is required to meet the challenges of increasing human population, low agricultural productivity, high land use intensity and expansion of agriculture to marginal lands.

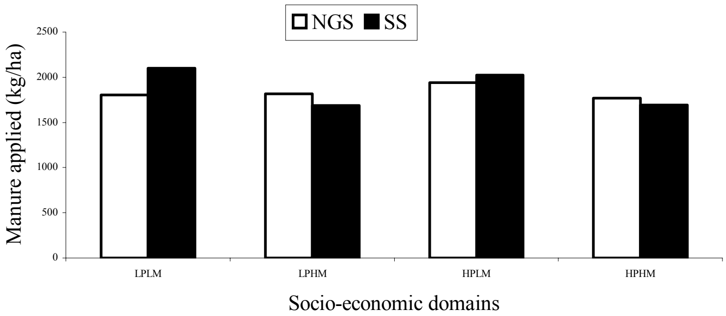

Figure 1: Manure use by socio-economic domains

Conclusions

The extent of manure use varied widely across socio-economic resource use domains. The low population density and low market access (LPLM) socio-economic domains had higher intensification (2100 kg ha^{-1}) in manure used in the SS compared to the 1803 kg ha^{-1} of the NGS (Figure 1). Given the socio - economic domains of low population, the difference observed in the intensification levels (reduction) of manure use per hectare (1685 kg ha^{-1}), when we moved to the LPHM in the SS, could be explained for the difference in the access to the market. While there are differences in the manure used per hectare across the socio-economic domains, the low market access areas intensified more in manure use as hypothesized, than the high market access area, perhaps because of the greater grassland and availability of fodder for animal to generate manure as well as high livestock density in the area.

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Organization of a Sustainable Agroforestry Model for Small Farmers in the Montes de Oro Region, Puntarenas, Costa Rica

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Key words: organic coffee, Costa Rica, small farmers, bird diversity, farming systems

Abstract

The Montes de Oro Region, in the Puntarenas Province, Costa Rica, is a marginal agricultural area with coffee production as the main activity. The region faces a number of social and economic problems, worsened by the reduction in forest areas, increase in soil erosion, absence of sustainable land production alternatives and heavy dependence to imported pesticides.

This project looked to protect the region's biodiversity and to contribute to mitigate the negative environmental effects through the implementation of organic coffee production systems, integrating ecological, social and economic factors to offer sustainable and profitable production alternatives. Six components were looked at: associated crops, establishment of shade trees and windbreaks, fertilization, studies of bird diversity and improved coffee processing systems. We present the results of a three year study case.

Introduction

In spite of the low international coffee prices, coffee production in Costa Rica is still an important commercial activity. Its contribution to the national Gross Internal Product during the last years has been around 15%, and it represents approximately 4% of the total exports. About 91% of the coffee production is concentrated in small or medium size farms and the activity offers employment to more than 300.000 people during harvesting time (ICAFE, 2004).

The Montes de Oro region, in the Puntarenas Province, Costa Rica, is a marginal agricultural area with coffee production as the main activity, although during the last years there has been a strong migration of farmers to cities, in search of better job opportunities. The region faces a number of social and economic problems, worsened by the reduction in forest areas, increase in soil erosion, absence of sustainable land production alternatives and a heavy dependence to imported pesticides.

The objectives of the present project were: to protect the region's biodiversity and to contribute to mitigate the negative environmental effects through maintenance or implementation of organic coffee production systems, integrating ecological, social and economic factors to offer sustainable and profitable production alternatives.

The project worked on 6 components: 1) associated crops, 2) establishment of shade trees using fruit and native forest trees 3) establishment of windbreaks 4) fertilization 5) studies of bird diversity and 6) improved coffee processing systems.

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Sustainable Production Model Components

1) Associated crops

A survey was carried out among 149 farmers belonging to ten localities to identify the crops more frequently intercropped with coffee. According to the survey, the main crops associated to coffee plantations are tomato, sweet pepper, dry and green beans and corn. Farmers said to prefer these crops as they are well known, have a safe market and are easy and fast to produce. However, it also has to do with tradition and the lack of knowledge about other promising crops and improved varieties. Due to these results, farmers were trained on new technologies used in organic vegetable production (greenhouse, seedling production, pest control, improved varieties and soil conservation practices).

The project also participated in an interinstitutional effort to organize a vegetable gathering center for the region. The main market problems identified in the survey were: high cost of transport (43%), intermediaries (15%), lack of markets (13%), low and unstable prices (8%), bad roads (6%), poor farmers' organization (5%) and other factors (10%). Farmers were asked to suggest how to improve the crop market. They are well aware that a change in attitude is necessary and that they should organize themselves to access safer markets, obtain better prices and reduce production costs; however, they pointed out the need of more efforts from the local authorities.

2) Establishment of shade plants.

The use of shade trees benefit coffee plantations in various ways: they enhance fauna diversity, improvement of ecological conditions of the production unit and produce goods of immediate usage (Benzing 2001).

Shade plants were produced in the Cedral Farmers' Association nursery. A total of 8,400 shade trees were distributed during two years among farmers of Montes de Oro for 77.6 ha of coffee with shade. The tree species planted were *Leucaena*, *Gliricidia sepium*, *Albizia adinocephala*, *Erytrina poeppigiana*, *Casia* and *Alnus jorullensis*; of this 1,934 were fruit trees (avocado, various citrus species, macadamia and soursoup). The introduction of shade and fruit trees had various purposes: diet improvement within the population, an alternative income for the farmers, and the protection of water springs.

3) Establishment of windbreaks.

Windbreaks are formed by one or more lines of plants of the same or of different plant species which cover different height structure, planted parallel and perpendicular to predominant wind. The use of windbreaks reduces eolic erosion, protects crops, animals and water springs, and helps prevent pasture from drying out during summer.

A total of 42.500 trees were established for 37.000 m of windbreaks, with 367 ha protected at 5 years after planted, when maximum growth of the trees was expected. Different arrangements of the following tree species were used: *Cassuarina equisetifolia*, *Eucalyptus* spp., *Eugenia jambos*, *Coutorea latiflora* and *Cupressus lucitanica*.

4) Fertilization

With the aim of reducing the high costs of fertilization without affecting grain quality and production, four fertilization alternatives were evaluated, together with a generalized application of Bocashi (5 ton ha-1): two annual applications of a physical mixture of N, K and B at a cost of US $60 ha-1 yr-1; 2) two annual applications of a physical mixture of N, K, Mg and B at a cost f US $66 ha-1 yr-1; 3) two annual applications of a physical mixture of N, K, at a cost of US $47 ha-1 yr-1; 4) two annual applications of a physical mixture of the formula 18-5-15-6-2 (600 kg ha-1 yr-1) at a cost of $100 ha-1 yr-1.

All of the fertilizer alternatives had higher productions than the conventional fertilizer scheme accounting for an increase of 8 – 10% for alternatives 1 and 3, and of 18% for alternative 2. In conclusion, it is possible to reduce production costs without affecting yield.

5) Bird diversity

A study was carried out to evaluate bird diversity and abundance in two areas of Montes de Oro. The first area (1300 masl) was located in the very humid premontane life zone, dominated by coffee plantations, cattle farms, secondary forest and border of harvested forests. The second area (1000-1450 masl) corresponded to the montane life zone.

A total of 151 bird species was found in the study area. Ten species were exclusive to the limit between the premontane and montane forest, i.e. they were not present in coffee farms. From the 141 species found in the zone where coffee is grown (premontane forest), 28 species were never registered in coffee plantations, while the rest (80%) were observed in coffee and surrounding farms. The 28 species not registered in coffee plantations were insectivorous and frugivorous birds, dependent of the forest for feeding, or that occasionally come out the forest but need native fruits for their nourishment (Stiles y Skutch 1989).

The number of birds found in coffee farms was similar to that of the surrounding zone; however, bird diversity was higher in the surrounding areas than in the coffee farms. It is recommended to plant native fruit trees within the coffee plantations to attract bird populations. The recommended tree species are: *Citharexylum caudatum* (Verbenaceae), *Ficus pertusa* (Moraceae), *Trichilia havanensis* (Meliaceae), *Ocotea* and *Nectandra* spp. (Lauraceae), *Conostegia xalapensis* (Melastomataceae), *Dendropanax arbore* (Araliaceae) and *Sorocea trophoides* (Moraceae). It was also suggested to increase the number of shade trees within the coffee plantations to increase insect population for insectivorous birds.

6) Coffee processing

A Compact Ecological Processing Unit (UCBE) was purchased to process the organic coffee. This unit reduces the water required for processing from 800 l to only 11 l (for 258 Kg of coffee), also reducing contaminations and costs of treatment of residual waters. In addition, there is a significant reduction in energy consumption, since there is no need to use the main plant to process the small amounts of coffee produced at the beginning and end of the harvesting season.

The use of the new unit also reduced the time from depulping to storage from 10 days in conventional processing to 3 days, which increases the grain yield and quality. The size of coffee yard was increased in order to use solar energy for drying the coffee beans thus reducing signifficantly the use of wood during coffee processing. All these improvements resulted in the CoopeMontes de Oro processing plant being granted with the ISO14000 certification, which implies an improvement in environmental protection and quality.

Conclusions

Farmers were receptive to the improvements suggested. Vegetable production increased in diversity, quantity and quality. However, the establishment of a vegetable gathering centre was never achieved.

New agroforestry practices were introduced: a) windbreaks, which resulted in the protection of 367 ha of crop land, b) water spring protection, which will assure water availability for farmers living downstream, c) shade trees, which improve nutrient cycle, represent a long term cash crop, benefit fauna diversity, and farmers' nutrition.

From a total of 250 farmers from Montes de Oro, Puntarenas, 10 % went into organic coffee and are certified by ECOLOGICA; their production was sold at $200/100 kg of roasted coffee in 2006; 80% sell their coffee as fair trade with a price of $131/100 kg; the rest of the producers are conventional, and their production is paid at $80/100 kg.

With this project, the Montes de Oro farmers' lifestyle was improved.

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Study the effects of conventional and low input production system on quantitative and qualitative yield of *Silybum marianum* L.

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Keywords: *Silybum marianum*, production system, planting time, seed yield, quality.

Abstract

This investigation was carried out in the spring of 2005 – 2007 in the Research Station of Rangelands in Hamand - Damavand region of IRAN to study the effects of conventional and low input production systems on seed yield and sylimarin percentage of Silybum marianum L. This experiment was done in split-split plot based on randomized complete block design with 3 replications. Treatments were 2 production systems (Conventional and Low input system) in the main plots, 3 planting time (25 of March, 4 and 14 of April) in the sub plots and 2 seed types (Improved and Native of Khoozestan) in the sub-sub plots. Results showed that there was a significant difference between production systems. The highest height (125.8cm) and number of capitols per plant (10.4) were obtained in conventional system. While other traits including capitol diameter (7.028cm), number of seed per capitol (125), 1000 seed weight (25.006g), seed yield (1888.072kg/ha), silymarin percentage (%7.711) and silymarin yield (150.443lit/ha) were recorded in the low input system. Results showed that because of using vermicopmpost and its effects on plant growth in low input system, highest seed yield and silymarin yield were obtained in this treatment. Seed planting in the first time of planting (25 of March) had the same effect on growth and yield. Highest values were recorded in the first time of planting (25 of March). Also, improved seed caused more seed and silymarin yield. Results showed that for getting highest seed and silymarin yield, using improved seed and low input production system is necessary. Also, according to the climatic condition, seed must be planted as early as possible. In this investigation, the best time of planting is 5 March).

Introduction

Siybum marianum is native of the East Mediterranean and Asia Minor, and is one of the most frequent medicinal herbs grown in Iran (Anonymous, 2003). The pharmaceutical industry uses the content of flavonolignans (silybin, silymarin, silydianin and silicristin) in the seeds, which have a hepato-protective effect. The most important its constituent is Silymarin that is used widely in pharmaceutical industry (Omer *et al*., 1995). Medicinal plants production is mainly dependant on ecological condition. In this respect, using correct production system is crucial. In Iran, there are more than 7500 plant species which most of them have valuable active substances. One of the most important of them is *silybum marianum*. Recently its cultivation has started and several drugs have produced from its silymarin (anonymous, 2003). This is very important to reduce chemical drugs and increase individual health. The

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question of the right planting time of Milk thistle in relation to its yield and silymarin content has been subject of discussion. Although it is stated that Milk thistle should be sown in autumn, but it is dependant on ecological condition and objective of production. There are no studies on spring cultivation of Milk thistle in these regions. One of the problems in Hamand region is finding out the adaptability and correct production system. In low input production system, less energy and chemicals is used. So, such systems are accordance with principles of sustainability and ecosystem health (Sharma, 2002). Milk thistle is a long day plant and planting time has major effects on seed yield and silymarine percentage (Omer *et al.*, 1990). So, by choosing correct time of planting, plant density and production system, growth and development will accordance with optimum temperature and solar radiation in the local region and subsequently seed yield and silymarin percentage will increase. Objective of this investigation is to find out the suitable production system, seed type and planting time of Milk thistle to exploit its yield potential for its recommendation to the farmers of Hamand region.

Materials and methods

Field study was carried out in the spring of 2005-2007 at the Rangeland Research Station of HAMAND - DAMAVAND region at east part of Tehran province in IRAN. The soil of the experimental plots was loamy in texture, rich in nitrogen, available phosphorus and medium in potassium with slightly alkaline in reaction (table 1).

Tab. 1: Physical and chemical characteristics of soil in experiment site

Texture	OC%	Total N%	Available P (ppm)	Available K (ppm)	pH
Silty Loam	0.5	0.05	20	349	7.6

Treatments were two levels of production system (Conventional and Low input system), 3 times of planting (25 of March, 4 and 14 of April) and two seed type (Improved seed and Native seed of KHOOZESTAN). In conventional production system, chemical fertilizers (according to the soil test and fertilizers recommended by Research Institute of Soil and Water for the region) and chemical herbicides were used. While, in low input system, 50% of the fertilizers amount in the conventional system were applied and weeds hoed only by hand. Also, 15 ton/ha vermicompose were used in low input production system. The experiment design was split - split plot with three replications. There were 6 rows with 5m long and 3m width in each plot. Plots were irrigated at 7 days intervals. Final harvest was taken from two central rows ($2m^2$) by hand. Harvesting was started when seeds in capitols matured and silks were appeared in the capitols. Then, seeds were dried in the oven at $75^{O}C$ for 48 hours. Silymarine of seed was extracted at the laboratory of IA university of Roodehen.

Statistical analysis

Data ware subjected to statistical analysis using ANOVA, a statistical package available from SAS. Means comparisons were done by Duncan multiple range test at 5% level.

Results

There were significant differences in all measured traits in response to production systems. Results show that the highest number of capitol per plant (10.4 capitol/plant) and height (125.8cm) were obtained from the conventional production systems. (Table1). These results are supported by previous studies (Omer et al., 1990). The highest capitol diameter (7/1cm), seed number per capitol (125 seed), 1000 seed weight (25.1 g), seed yield (1888/1 kg/ha), silymarin percentage (%7.7) and silymarin yield (150.4 lit/ha) were obtained from low input system. Integration of chemical fertilizers and vermicompost improved soil composition and caused better condition for plant growth and development. This is related to the higher soil biology activities, better soil composition and nutrient availability in the soil (Sharma, 2002). Among the various levels of planting time, the highest yield and silymarin percentage were obtained from the first level of planting time (25 of March). In regards to seed type, the highest seed numbers per capitol and silymarin percentage were obtained from native seed of KHOOZESTAN. But, in other traits, improved seed had better results and significantly was better. The results of this investigation showed that using low input system and improved seed are essential for obtaining the highest seed yield and silymarin percentage. As it is clear in the table 1, farmers in the Hamand region, must start to plant milk thistle at the time which ecological condition allow them. So, 25 of March is the best time. In the low production system, quantitative and qualitative yield is more than conventional system and, of course, expenses will decrease and incomes will be more. This is the thing that farmers and ecologists are looking for it.

Tab. 2: Mean comparison for quantitative and qualitative characters in milk thistle

Treatment	Height (cm)	No. of seed per flower	1000 seed weight (g)	Seed yield (kg/ha)	Silymarin %
Conventional system	125.8 a	10.4 b	17.5 b	1099.5 b	5.9 b
Low input system	94.5 b	125 a	25 a	1888.1 a	7.7 a
25 March	127.2 a	132.4 a	26.6 a	1868.7 a	8.6 a
4 April	111.8 b	112.8 b	20.1 b	1462.2 b	6.7 b
14 April	91.7 c	98.8 b	17 b	1150.5 c	5.1 c
Improved seed	130.3 a	126.7 a	25.1 a	1832.3 a	6 b
Native seed	90.2 b	102.6 b	17.4 b	1155.4 b	7.6 a

*Means with similar letters are not significant at the 5% probability level (Duncan test).

Discussion

The results of this investigation showed that using low input system and improved seed are essential for obtaining the highest seed yield and silymarin percentage. As it is clear in the table 1, farmers in the Hamand region, must start to plant milk thistle at the time which ecological condition allow them. So, 25 of March is the best time. In the low production system, quantitative and qualitative yield is more than conventional system and, of course, expenses will decrease and incomes will be more. This is the thing that farmers and ecologists are looking for it.

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Integrating pigeonpea in maize based farming systems may increase food production and alleviate poverty

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Key words: multifunctional crops, intercrops, cash crops, gender, food security

Abstract

Pressure on natural resources implies that millions of farmers in semi-arid eastern and southern Africa face very low and declining crop yields. Major natural constraints are the nitrogen and phosphorus supply together with insufficient and highly variable rainfall. This article addresses the possibilities for improved soil fertility, increased productivity and income opportunities among smallholders in semi-arid eastern and southern Africa through the integration of improved pigeonpea in maize-based cropping systems. Specifically farmers' experiences with cultivation and integration of pigeonpea in maize-based cropping systems are discussed. This includes how the integration of pigeonpea affects the livelihood situation of rural smallholders – male as well as female in terms of increased food security, increased income, improved gender equity in access to resources etc. While many 'blessings' of integrating the multi-purpose crop pigeonpea in maize-based cropping systems are confirmed, it is also shown that socio-economic and biophysical diversity must be taken into account when evaluating impact of pigeonpea on livelihoods of different groups of farmers.

Introduction

Growing population, unequal distribution of and increasing pressure on natural resources in Africa implies that cultivation takes place on more and more marginal land, causing millions of farmers in semi-arid Eastern and Southern Africa to face low and declining crop yields. Coupled with removal of fertilizer subsidies in the early 1990is, the constraints of limited nitrogen and phosphorus supply together with insufficient and variable rainfall are being felt by an increasing number of farmers. Hence, farmers are especially looking for biological alternatives to establish cropping systems characterized by high production capacity and stability in order to obtain cash income opportunities and food security but too little emphasis has been put on developing such alternatives.

Intercropping of maize and grain legumes is a common practice in many areas in Africa although the rationale behind is not always clear. Pigeonpea is a multipurpose leguminous shrub, which thrives on poor soils. It is grown with the aim of increasing household cash income and for food, fodder, firewood, and soil fertility improvement. There is an increasing international market for pigeonpea grain. Thus, maize

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intercropped with long-duration pigeonpea has emerged as a highly productive system with multiple beneficial effects on the farming systems. Consequently, these cropping systems are widespread in some areas of eastern and southern Africa. Intriguingly, however, few kilometres away pigeonpea may not be found without apparent socio-economic, cultural, or biophysical causes to explain the change.

The objective of this article is to present results from a multidisciplinary and participatory on-farm study in Malawi and Tanzania. The overall theme of the study is to investigate the possibilities to improve soil fertility, increase productivity and income opportunities among smallholders in semi-arid eastern and southern Africa through the integration of pigeonpea in maize-based cropping systems.

Throughout the research, it was assumed that the agronomic results could be interpreted through a socio-economic prism and that yields of each component of the intercropped crops of maize and pigeonpea may be affected by the composition, size and gender of the farming households, as well as these households access to farmland.

Materials and methods

In Tanzania, maize is a major food crop, grown and consumed as stable food by the majority of the population in Tanzania. Half of all Tanzanians are considered to be basically poor and the poorest sections of the rural population are mainly found in semi-arid and remote areas. Between 12-15% of all rural households in Tanzania are female headed (World Bank, 2000). In Malawi over 90% of the total cultivated land area is planted to maize, mostly by resource poor smallholders. Eighty percent of the rural population is farming less than one hectare (Anon, 2003) which causes many families to live on the edge of hunger. Forty percent of the families with less than 0.5 hectare are female headed (Anderson, 2002).

In Tanzania, clusters of villages were selected in Babati district and Gairo Division, Kilosa District, Morogoro Region. In Malawi, two extension planning areas (EPA) were selected, each containing several villages. Nyambi EPA is located within Kawinga Rural Development Projects and Machinga Agricultural Development Division. Ntonda EPA is located within Blantyre Rural Development Projects and Blantyre Agricultural Development Division.

A total of more than 80 farmers were selected, equally distributed at the four research locations, based on their willingness to be involved in research. The selection was done at group meetings with farmers and based on (i) size of landholding, (ii) type of land tenure, and (iii) gender.

The agronomic performance of local and improved pigeonpea genotypes was studied at trial plots fully managed by farmers under farmers' conditions. Data are included from the two cropping seasons of 2001-2002 and 2002-2003, which means that the crop yields from total of 640 plots are included in the data analysis. These data are presented as means over the two years.

The data were analyzed by multiple regression analysis using a general linear model via the SAS GLM procedure. Open-ended questions were evaluated by calculating the mean response using the LSMEANS procedure after having identified the major categories represented by the answers. Comparison of the means for the individual treatments was done using a Waller-Duncan *t*-test.

Results and Discussion

Productivity measured as grain yield showed tremendous differences both in sole maize and in maize grown together with three pigeonpea genotypes. Maize yield decreased ($P<0.05$) in the order Babati>Ntonda>Gairo>Nyambi. However, pigeonpea grain yield followed an order of Ntonda>Babati>Nyambi>Gairo.

The importance of pigeonpea in producing protein is illustrated as the highest nitrogen yield is obtained in some of the areas with the lowest maize yield. Inclusion of the other crop parts only enlarges these differences as the differences in nitrogen content accounts to the residues also. This is important, as large proportions of the residues are re-circulated.

Across all environments, maize yields tended to decrease ($P=12$) in female-headed households compared to male (data not shown). Maize yields even further decreased at households headed by single parents or females. In contrast, the pigeonpea grain yields were unaffected ($P=0.69$; data not shown) by gender of household head, although the pigeonpea grain yields of single parent/female headed households tended to be higher than for the other types of households.

In the literature it is often argued that female farmers are less productive than male farmers in relation to maize yields because women have less access to chemical inputs and technical know-how than men. The current study shows that women's productivity in relation to other crops than maize, such as pigeonpea, in some cases can be even higher than that of men without access to special inputs.

Across all environments, the access of households to land influenced maize yields ($P=0.12$) and pigeonpea yields in particular ($P=0.006$) (data partly shown in Fig. 1). Clearly those households with most land obtained the highest maize yields. However, pigeonpea showed exactly the opposite effect; favoured by the households with small land access.

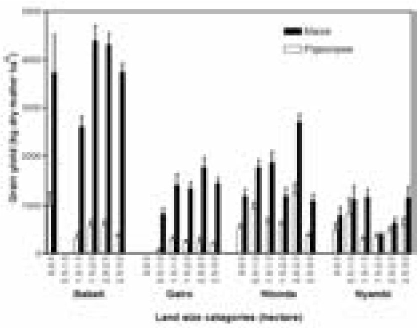

Figure 1: Relation between land size and mean grain yields from four sites of maize and pigeonpea over two consecutive cropping seasons. Bars represent ±SE; n varies depending on category.

The data yields no clear indication of why grain yield of pigeonpea should be higher at the smaller holdings. However, as there is no relation ($R^2 = 0.08$) between land size and household size, it is hypothesized that the lower pigeonpea grain yields at those households with the largest land holdings can possibly be sought in constraints in seed availability at planting; a common feature for many of the trial farmers and also reported elsewhere (Snapp et al., 2002).

Labour constraint during weeding of the crop is well known to reduce maize yield but pigeonpea yield is not affected by a few weeks delay in weeding which gives farmers more flexibility in coping with the agricultural tasks during peak seasons. The present data confirm that household size has no effect (P=0.55) on grain yield of pigeonpea but significantly affected (P=0.01) maize grain yield (Fig. 2).

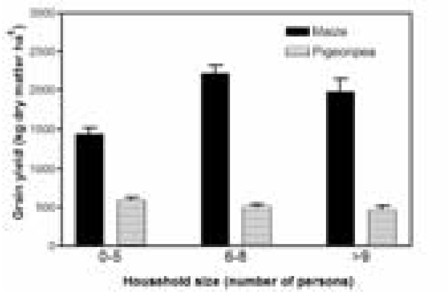

Figure 2: Relation between household size and mean grain yields of maize and pigeonpea over two consecutive cropping seasons. Bars represent ±SE; n=480 for pigeonpea and 640 for maize.

Conclusions and perspectives

Integration of pigeonpea into the maize based farming systems in all cases significant increased total productivity of food and fuelwood and it generated a potential high-value cash crop. In perspective, there is effective market demand for both whole grain as well as processed pigeonpea products from Eastern and Southern Africa in several global markets. Further a local market for green pods is rapidly developing in the larger cities. A significant backup must however be created to make a market-approach a realistic strategy for resource-poor farmers despite the multifunctional advantages of pigeonpea.

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Plant Products as Biopesticides: Building On Traditional Knowledge Of Vrkshayurveda: Traditional Indian Plant Science

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Key words: Biopesticides, traditional knowledge, sustainable agriculture, vrkshayurveda

Abstract

Today there is a global search for alternatives to chemical pesticides and as part of this process there are various efforts to test the use and efficacy of natural products for pest control and crop protection. Our Centre has been involved in exploring the traditional knowledge regarding the use of natural products for pest control and crop protection. As part of this effort, we have looked at the traditional folk practices prevalent among farmers as well as information from classical literature on the subject drawn from Vrkshayurveda (traditional Indian plant science). Following this, we have carried out experiments for standardizing and field testing promising natural products by determining the precise range and kind of pests controlled by them, determining the optimum concentration where they can be effective against pests without being harmful to useful organisms and predators as well as studying their mode of action. Subsequently, we have also developed storage forms of various of these products by using methods based on Ayurveda. Studies on the stability and shelf life of these products are also being carried out through an insect rearing laboratory. Finally, we have also set up village based biopesticides units where a range of these products are being prepared thus providing valuable inputs to sustainable agriculture and a means of livelihood to rural women and farmers.

Introduction

Vrkshayurveda literally means – "The Science of Life of Plants". There is a vast body of literature on Vrkshayurveda both in Sanskrit and our regional languages. It encompasses areas such as collection, selection and storage of seeds; germination, sowing, various techniques of plant propagation, grafting, nursing and irrigation; testing and classification of soil and selection of soils suitable for various plants/types of plants; manuring; pest and disease management/preventive and promotive care to build up disease resistance and to cultivate healthy plants; nomenclature, taxonomy, description and classification of plants to suit varied purposes; favourable and unfavourable meteorological conditions for various operations related to cultivation (such as sowing, harvesting) and use of plants as indicators of weather, water, minerals, etc. A series of publications brought out in recent years provides an overview of varied aspects of Vrkshayurveda, covering – a general introduction to this area, plant propagation techniques, nomenclature and taxonomy and pest control and disease management in Vrkshayurveda (1-2).

The Centre for Indian Knowledge has been involved in doing a lot of work relating to Vrkshayurveda for the past several years (3-6). This has included survey and

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collection of literature on Vrkshayurveda, shortlisting techniques and recipes for specific problems and testing out prescriptions of Vrkshayurveda in practice. Our Centre has been working with several plant products and also experimenting to test the efficacy of these plant products against different pests in farmers' fields.

Standardisation of Use

Over the last ten years our Centre has carried out a large number of experiments and tests to standardize the use of plant products for pest control. Even though a large number of anecdotal accounts and field reports are available a lot of rigorous work needs to be carried out before we can state that the efficacy of use of a plant product has been convincingly demonstrated. Based on these experiments, we have tested out practically the utility of a large number of plants and their extracts for different pests, crops and diseases. Some of the plants for which we have carried out such tests are neem, garlic, onion, persian lilac, turmeric, ginger, tobacco, papaya, leucas, pongam, tulasi, aloe, custard apple, vitex, sweetflag, poison nut, calotropis etc. Farmers are used to pesticides which are packaged and available from the shelf. Even though farmers realise the importance of using plant products as alternatives to chemical pesticides, the widespread use of these plant products will take a while to become very popular. One of the ways by which they can be popularised is to process it and make it available to the farmers in a readily usable form.

Materials and Methods

Ayurvedic approach to produce Storage Forms : Subsequently, we commenced a project for the preparation of storage forms of biopesticides based on ayurvedic principles. This work was taken up with an objective to prepare storage forms of biopesticides with increased shelf life. The Centre has a good expertise in the area of vrkshayurveda and ayurveda and hence we thought it would be best to take up processing of these plants along ayurvedic principles. The shelf life (i.e. the period for which they can be stored without loss of biological activity) of some ayurvedic preparations are as follows Swarasa or juice (3 – 4 hours), Kashayam or water extract (24 hours), the storage forms are - Churna or dry powder (6 – 12 months), Thailam or oil extract (1 – 3 years), Arkam or distillate (1 – 5 years), Asava / Arshta or fermented extracts (3 – 5 years)

Results and Discussion

Experimentation with the Storage Forms : After initial trials with 60 preparations the number of preparations taken for detailed experimentation were narrowed down to 25 preparations. The biopesticides that were prepared were tested out in experimental plots laid out in the CIKS experimental farms as well as in farmers' field. However, we have not carried out comparisons of these preparations with commercially available storage forms of biopesticides. A list of thirteen of these products that have been tried out and found to be effective are given below.

Table 1: Selected promising biopesticides, d = days, m = month, w = week

Name of the Preparation	Croptested	Effective Against	Shelf Life
Adathoda kashayam	Paddy Vegetables	Leaf folder, bacterial leaf blight, *Helminthosporium* leaf spot	3 m
Pudhina kashayam			
Thriphala kashayam	Paddy, Ladies finger	Bacterial leaf blight and *Helmintho sporium* leaf spot,	3 m
Andrographis kashayam	Vegetables	Aphids and borers in brinjal, ladies finger	3 m
Sida kashayam			
Prosophis kashayam	Paddy	Bacterial leaf blight, *Helminthosporium* leaf spot, Blast	3 m
Barley *Sesamum* Horsegram kashayam	Vegetables	Acts as fruit yield enhancer	3 m
Cow's urine arkam & Sweet flag arkam	Paddy, Ladies finger, Chilli	Bacterial leaf blight, *Helminthosporium* leaf spot, vein clearing disease, fusarium wilt,	6 m
Garlic arkam	Paddy	Leaf folder, bacterial leaf blight, *Helminthosporium* leaf spot	6 m
Neem seed extract	All crops	Leaf folder, aphids, Jassids, fruit borer and stem borer	1 m
Five leaf extract	All crops	Jassids and borers	1 w
Garlic, Ginger, Chilli extract	All crop	Hoppers and borers	3 d

Conclusion

Summing up we present below some of the special features and highlights of our efforts

1. A large amount of literature has been collected and processed to identify traditional practices relating to plant protection from folk practices of farmers, reported field practices and the classical textual literature of vrkshayurveda.
2. We have tested and standardized the use of several practices looking into detail at some identified plants, which were listed earlier.

3. We have experimented with and standardized storage forms of thirteen these natural products, which can be prepared based on the ayurvedic approach.
4. Using the technologies that have been developed we have set up village based biopesticide units in nine different locations in Tamil Nadu. It serves multiple purposes of providing safe and tested plant products as biopesticides for organic farming using technologies that can be practiced and transferred to women farmers who maintain these units.
5. Simultaneously, we have set up an insect rearing laboratory where we test out the mode of action of these products as well as the shelf life of these biopesticides.

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Use of Tharu Ethnobotanical Knowledge for Organic Insect Pests Management of *Cucurbita pepo* L. cv. 'zucchini'

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Key words: Ethnic community, plant resources, pesticidal plants, farmers' field experiment.

Abstract

Tharu ethnic communities are rich in ethno-botanical knowledge on the utilization of plants for various proposes to fulfil their daily needs. They have precise knowledge about distribution, abundance, cultural practices, pest management, harvesting, and proper use of these plant resources. Gurau of Tharu communities and elderly people have sound knowledge on medicinal and pesticidal plants. Information on twenty-four locally available plants having pesticidal value, have been collected from the Tharu communities of Dibya Nagar and Meghauli VDCs, Chitwan. Out of them four of the most promising plants were selected to test their efficacy in farmers' field conditions. In order to assess the effectiveness of plant materials on insect pests of vegetables, a farmers' field experiment was conducted in Dibya Nagar during the summer of 2006. The plants selected to test efficacy against insect pests of Zucchini are Azadiracta indica, Justicia adhatoda, Persicaria barbata, and Artemisia indica. Plant extracts made from fresh green leaves of the selected plants at a concentration of 1:5 were applied at seven days intervals. It was found that A. indica had most promising effect on the pests, followed by P. barbata. However, all other treatments had positive effect. Similarly, the research result indicated possibility of using plant materials towards development of organic pest management methods.

Introduction

Ethno-botany deals with study of the relationship between people and plants and refers to the study of how people of a particular culture and region make use of plants. The term 'Ethno-botany' was first used by Harshberger (1896) who defined it as "the study of relationship that exits between people of primitive societies and their plant environment". A modern definition given by Nancy Turner (1988) is that "ethnobotany is the science of peoples' interactions with plants".

Tharu are a culturally and linguistically diverse ethnic group that lives along the Indo-Nepal border in the region known as Tarai. There are almost 1.2 million Tharu in Nepal, and smaller numbers live in the adjacent areas of India. In the last census, Tharus appear as one of the ethnic minorities of Nepal (Krauskopff, 1999). Tharu population is mostly found in rural plain areas near by the riverbanks. Their livelihood depends on agriculture livestock and fishing in natural water bodies like rivers, streams, lakes etc.

Organic pest management consists of a range of activities that support each other. Most of management practices are long-term activities that aim at preventing pests and diseases from affecting a crop. It includes several activities to minimize the pests' population, including use of botanical plant products.

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Zucchini (*Cucurbita pepo* L. cv. zucchini) is becoming popular in Nepal. It is rich in Vitamin B and C and minerals. It can be grown from terai to the mid hills in Nepal. Red pumpkin beetle (*Aulacophora foveicollis*) is the most important pest. Zucchini is also susceptible to powdery and downy mildew and fruit fly.

The majority of Tharu farmers cannot afford to purchase pesticides. Nepal is rich in ethno-botanical knowledge and botanical pesticides. However, a detailed study of the use and effectiveness of botanical pesticides is required.

Materials and methods

There were mainly two parts of this study. The first part of this study included collection of information on Tharu ethnobotanical knowledge on pest management and second part of the study included a farmer's field experiment.

Questionnaires for the semi-structured interviews were prepared to collect the information on Tharu ethnobotanical knowledge, especially on pest management.

Dibya Nagar and Megauli Village Development Committees (VDCs) of Chitwan district were purposively selected for this study to have better Tharu ethnobotanical knowledge as most Tharus live there. For the selection of key informants, one preliminary survey was carried out in these sites through field visit and using semi-structured questionnaire. Twenty informants from different villages of the Dibyanagar and twenty informants from Meghauli VDCs were selected based on information of preliminary survey. Designed questionnaires were pre-tested with five informants.

A total of forty household surveys were made from both VDCs. Family members were encouraged to participate during the process of information collection. Due care was given to collect reliable information from the informants using cross-questioning and triangulation. Two verification meetings were organized to validate collected information.

A list of twenty-four locally available pesticidal plants was prepared based on the information collected from the household survey and verification meetings. From this, the four most promising plants, based on pair-wise ranking, were selected to test their efficacy in the farmers' field experiment.

The farmer's field experiment was conducted in a Randomized Complete Block Design (RCBD) with five treatments and five replications in the farmers' field.

A primary solution was prepared with one kg of plant leaves by pulverizing them over the stone grinder. One litre of water was added to the resulting slurry, and then this mixture was screened through the thin muslin clothes. The solution was then mixed in the ratio of 1:5 of the primary solution and water. The resulting solutions were sprayed over zucchini plants in seven day intervals. Biological information such as scale of pest damage and total marketable yield were recorded. The effectiveness of plant solutions was categorised as the severity of leaf damage in the scale of 1-5 in the descending order.

Results from farmers' field experiment were analyzed using MSTAT-C software package. Duncan's Multiple Range Test (DMRT) was used to measure the significant differences among the treatment means.

Results

Tharus have rich knowledge on distribution, abundance, cultural practices, pest management, harvesting, and proper use of the plant resources. Based on the information collected from the household survey and information verification meetings, information on 24 locally available pesticidal plants has been collected. Four most promising plant species have been selected from these 24 plants for the farmers' field experiments to test the efficacy of selected plant species over insect pests of zucchini. Pair-wise preference ranking, one of the Participatory Rural Appraisal tools, was used to select these four plant species.

The plants selected to test their efficacy against insect pest of Zucchini were Neem (*A. indica),* Asuro (*Justicia adhatoda*), Bisundari (*P. barbata*), and Artemisia (*Artemisia indica*).

Tab. 1: Mean of plant height (cm), number of leaves per plant, number of insects per plants, scale of damage and production (ton/ha.) of zucchini in farmers fields in 2006.

Treatments	Plant height	No. of leaves	No. of insects	Scale of damage	Production
Asuro	9.332[a]	7.302[ab]	3.050[a]	2.872[ab]	8.40 [bc]
Bishunhari	9.292[a]	7.732[ab]	2.900[a]	2.702[b]	11.40[ab]
Titepati	9.430[a]	7.500[ab]	3.550[a]	2.884[ab]	9.30[b]
Neem	9.318[a]	8.052[a]	1.650[a]	2.584[b]	15.90[a]
Control	8.818[a]	6.662[b]	3.650[a]	3.306[a]	4.20[c]
CV	8.92%	12.38%	62.03%	12.94%	36.52%
SEm	0.3685	0.4123	0.8211	0.1661	1.607
$LSD_{0.05}$	1.105	1.236	2.462	0.4981	4.818

Means followed by the same letter for each treatment are not significantly different at 5% (P = 0.05) level according to Duncan's multiple range tests.

Discussion

Based on the analysis of variance and Duncan's multiple range tests, Neem (*A. indica)* has been found most effective followed by Bishunhari (*P. barbata*) in terms of controlling damage by insect pest and increasing total marketable yield.

Some of the parameters such as the height of plant and number of insects were found to be insignificant among the treatments (P= >0.05). Similarly, the observation for parameters such as numbers of leaves, scale of damage and production were found significantly different (P=<0.05) among the treatments. Effect of differnet treatments on height of plants and number of insects were found to be non significant.

From this experiment, it is found that Neem (*A. indica)* possessed the most promising effect on insect pests of zucchini plants. However, all other treatments resulted some sorts of positive effect for the management of insect pests of zucchini.

The results are in accordance with Neupane (1999) reported that Neem has insecticidal, repelling, antifeeding, growth inhibiting, fungicidal, and nematicidal properties, and can control larvae and adult of chewing and sucking insects, including insect pests of cucurbits.

Conclusions

Tharu ethnic communities of Nepal are rich in ethnobotanical knowledge on the utilization of plants of pesticidal value and their use for pest management. Neem (*A. indica*) has been found most effective followed by Bishunhari (*P. barbata*) in term of damaged by insect pest and total marketable yield among four selected and 24 locally available pesticidal plants.

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Knowledge transfer and dissemination

Organic Pilot Farms in North Rhine-Westphalia (Germany)

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Key words: on-farm research, participation, inter- and transdisciplinarity

Abstract

Since 1993, research, advisory service and practice work together in the German Federal State of North Rhine-Westphalia (NRW) on solutions for selected issues of plant cultivation and animal husbandry with practical relevance for organic farmers. The project that is funded by NRW and the European Union entails demonstration and optimisation of selected organically operating farms and their methods of production as well as professional advice. The project is coordinated by the Institute of Organic Agriculture and executed in cooperation with the Chamber of Agriculture and contributes effectively to the expansion of Organic Agriculture (OA) in NRW.

In this successful participatory and interdisciplinary cooperation between practice, extension service and research, 30 farms that are distributed all over NRW and integrate a wide range of different types of production in their typical local region are involved in developing the research questions, executing experiments and discussing results. Solutions are assessed and optimised on farm level and demonstrated in the practice of major farms in order to secure the knowledge transfer in extended agricultural practice. The feasibility of the methods is immediately assessed by practitioners and transmitted to colleagues.

On-farm research - a transdisciplinary approach

Aims

The project 'Organic Pilot Farms in North Rhine-Westphalia' was initiated in 1993 by the Ministry of the Environment and Conservation, Agriculture and Consumer Protection in NRW to strengthen and establish OA in NRW. Decentral on-farm research, demonstration, extension and transfer of knowledge are the basis of this project. Agricultural science (University of Bonn), extension service (Chamber of Agriculture) and private organic farms cooperate aiming to increase scientific knowledge and to improve quality of advisory services by creating places for demonstration and discussion on practical farms in the region to transmit scientific results directly into agricultural practice. The technical, ecological and economic feasibility of Organic Farming (OF) systems is demonstrated to enhance the willingness of conventional farmers to convert to OF, an approach that meanwhile is pursued in the Netherlands as well (Brinks 2003).

Concept

'An increase of inter- and transdisciplinary approaches in agricultural sciences' was already requested in the memorandum 'Research for a Sustainable Agriculture' of the Federal Agency for Nature Conservation (BfN 2001). The memorandum 'Future Perspectives of Agricultural Science and Research' of the German Research

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Foundation (DFG 2005) is consciously oriented on practicability. An improved exchange between theory and implementation into practical use is recommended. This concept, which has been pursued in the project 'Organic Pilot Farms in North Rhine-Westphalia' for more than one decade, has proved to be serviceable and successful in an evaluation through the German Federal Agricultural Research Centre (FAL) and is international basis in all CGIAR Centres.

The concept is based on private organic farms, so-called 'Pilot Farms', which are distributed all over NRW integrating a wide range of different farm types, from vegetable growers to livestock breeders, in their typical local region. Additionally, they had been selected for innovation and competence in communication, the main issues for daily collaboration. Pilot Farms provide sites for factorial field experiments, supported by demonstration fields in which scientific results are proved and displayed under different regional and climatic conditions and, if necessary, modified for the integration into the individual farm. All decentral scientific trials and demonstration fields are available for regional advisory services of the chambers of agriculture and the organic growing associations. Thus, the Pilot Farms are essential places of exchange for scientists, advisors and practitioners.

The schedule of the project is:

- ***Research***
  On Pilot Farms factorial field experiments on questions of interest for the practice are conducted by scientists of the University of Bonn and the Chamber of Agriculture NRW, in close cooperation.
- ***Knowledge Transfer***
  entails conversion and use of scientific results under practical and site specific conditions as well as enhancement to practicable procedures.
- ***Demonstration***
  The technical, ecological and economic producibility is demonstrated decentral as an advice both for conventional farmers with interest in converting to OF and for farmers already working organically.

Research needs are detected in direct dialogue with the agricultural practice, problems of current interest can be continuously incorporated in scientific work. Pilot Farmers are intensively involved in raising the research questions implementing the experiments as well as discussing the results. This inter- and transdisciplinary approach, which had also been successful and essential in cooperations between science and practical farmers in the United States (Wuest et al. 1999) and in the Netherlands (Langeveld et al. 2005), opens a panel of relevance control for scientists. Research separated from practical interest can be avoided.

Through intensive and long-lasting cooperation between practice, extension and research an efficient work on relevant scopes and a direct knowledge transfer of scientific results into practice are provided immediately. The farmers themselves contribute to spreading knowledge directly from farmer to farmer in their own diction.

Communication

Researchers, advisers and Pilot Farmers meet several times a year (cp. Thompson & Thompson 1990). During the growing season field trials and demonstration plots can be used for advisory services. New strategies are presented and discussed on field inspections that are open for all interested farmers irrespective of their mode of farming. In wintertime results get reviewed with all participants together in project meetings. Details get well thought-out and new demand is mutually ascertained in thematic working groups (arable crops, potatoes, vegetables, dairy cows, poultry, pigs). Research deliverables are published in annual reports of all experiments, on the website www.leitbetriebe.oekolandbau.nrw.de and in practitioner-oriented journals, too.

Participatory research and knowledge transfer

Developing new cultivation strategies is an open, participatory process of all project partners. The following examples give an insight in the chances of transdisciplinary cooperation:

Indirect weed control

The use of morphological variation of winter wheat (*Triticum aestivum* L.) cultivars as a tool for indirect weed control was applied as a disciplinary project of agronomy. The results substantiated that weed suppression and shading ability through crop cover, crop height and leaf inclination (planophile vs. erectophile leaf inclination) were inversely correlated (Eisele & Köpke 1997). Out of these results an interdisciplinary research group, founded by the German Research Foundation (DFG), was arranged at the University of Bonn. Later on transdisciplinarity became subsequently workable in the EU-Project 'Strategies of Weed Control in Organic Farming, WECOF' and finally the results were presented to farmers in demonstration fields on Pilot Farms (Neuhoff et al. 2005).

Underseeds in potatoes

To minimise erosion and nitrate leaching the suitability of different underseeds in potatoes (*Solanum tuberosum*) were tested in the late 1990's. These promising approaches had been reviewed very critically by practice until two Pilot Farmers in cooperation with an adviser of the Chamber of Agriculture in NRW started to use this strategy in practice. They reported less weed infestation and better harvest conditions by a reduced amount of clods. With increasing interest these positive statements were followed by their colleagues. An examination of different underseeds under practical site conditions was requested. From 2005 to 2007 in fifteen factorial field trials and in seven demonstration plots distributed all over NRW amongst others *Raphanus sativus*, *Sinapis alba* and *Fagopyrum esculentum* were undersown in potato stands in order to control weed infestation after senescence of potato shoots. Different sowing dates were tested. Weed dry matter as well as the density of *Chenopodium album* were reduced mainly by oil radish and early sowing combined with the last mechanical treatment (ridging). Buckwheat able to suppress weed growth efficiently is suggested to be used in vegetable production (Stumm & Köpke 2007). By presenting the prosperous results in several articles and on conferences, mostly by a researcher together with a convinced Pilot Farmer, underseeds in potatoes became an accepted strategy to reduce weed infestation after senescence of potato shoots in practice.

Conclusions

The transdisciplinary cooperation in the project 'Organic Pilot Farms in North Rhine-Westphalia' was distinguished on an international conference for its applied operation method and the efficient knowledge transfer (Lange & Lehmann 2005, while scientists can only present conclusive results. As shown in the example *Underseeds in potatoes*, the presentation of results in articles and on conferences by researchers together with a convinced practitioner who demonstrates that he is ready to bear the financial risk of the new method has become a central issue to develop confidence of practical farmers into the feasibility of new strategies.

Acknowledgments

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The development of an international *curriculum* on organic farming in China

Pugliese, M.[1] & Gullino, M. L.[1]

Key words: China, education, standards, academic institutions, teaching, learning

Abstract

The project "Organic farming: social, ethical, economical, scientific and technical aspects in a global perspective" was founded by European Commission within the framework of Asia Link programme. The specific objective was the development of a curriculum on organic farming suitable to the Chinese educational framework, and the development of relevant learning and teaching tools supporting the implementation of the developed curriculum within the Chinese partners' institutions. It consisted of four major components: seminars, visits abroad, PhD student mobility and summer schools. The developed curriculum *consist of six major components for a total of 30 credits: a core course on organic farming (8 credits); four specific courses in biological system management of pests, diseases and weeds, soil quality management, organic animal production, and food quality and food safety (20 credits); and approximately 2 credits for experimental learning on farms. Direct target groups of the project activities were professors and associate professors, postgraduate and graduate students. The project indirectly addressed also private and public industries, non-governmental and governmental organisations. The project lasted 24 months, starting from December 2005.*

Introduction

Decades of intensive and extensive agriculture aimed at guarantee food security for a growing population, have lead in China to extremely negative impact on the environment (e.g. water eutrophication, soil salinisation, loss of soil fertility, aquifers' depletion, water pollution, overproduction of wastes), due to the overexploitation of natural resources (e.g. soil and water) and the excessive use of chemical fertilisers and pesticides. As an example, in the areas of intensive agriculture where up to 5 cropping cycles can occur in the same year on the same soil, the total annual quantity of nitrogen released into the soil goes beyond 1,500 Kg per hectare (Gullino *et al.,* 2006). Agriculture based on obsolete production patterns has also direct impact on the commercialisation of agricultural products, both nationally and internationally. Chinese agriculture is still characterised by low quality of food products. While the production and demand of organic food is rapidly increasing in China (Willer and Yussefi, 2007) due to the raising awareness of consumers about health and environmental issues, the national agriculture production is not yet ready to give a full positive response to this demand. The lack of capacity to produce added value products and the consequent limited access to foreign markets is perceived as a lost opportunity to increase Chinese farmers' income and ameliorate living standards in rural areas. At a production level, the lack of updated technical and scientific know-how among local

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technicians and extension agents is perceived as one of the major barriers towards the adoption of organic agricultural practices. There is an urgent need to create new profiles of professionals, with updated skills, able to locally support the structural and capacity changes sought by the Chinese government. To properly tackle the whole situation, the Chinese Government is, *inter alia*, planning measures aimed at strengthening scientific research and education in agriculture and giving national research a greater international profile. China gives great attention to the development of high-quality universities and to the introduction of new innovative curricula, while acknowledging the "historical" role of national academic institutions in providing essential technical and scientific information which base reliable and effective policy measures upon (Clini *et al.,* 2008). In this framework, there is a perceived need for Chinese academic institutions – in their recognised role of support to policy makers - to develop and disseminate a better understanding of organic farming as an essential mean to promote sustainable agriculture, in terms of environmental protection, food safety, and higher market opportunities.

Activities

The project "Organic farming: social, ethical, economical, scientific and technical aspects in a global perspective" was founded by European Commission within the framework of Asia Link programme. The specific objective was the development of a curriculum on organic farming suitable to the Chinese educational framework, and the development of relevant learning and teaching tools supporting the implementation of the developed curriculum within the Chinese partners' institutions.

The project was coordinated by Agroinnova of the University of Torino in Italy, in collaboration with Tuscia University in Italy, University of Bonn in Germany, Wageningen University in The Netherlands, and four Chinese Universities, i.e. China Agricultural University in Beijing, Zhejiang University in Hangzhou, North East Agricultural University in Harbin and Qinghai College of Animal Husbandry. The proposed partnership built upon existing collaboration on organic farming between European and Chinese Universities.

Among the activities implemented there are: the stabilishment of a Scientific Committee, with experts from each project partners institution and the applicant; the development of electronic tools, i.e. seven newsletters and a website (www.bioasialink.net) for project outcomes dissemination; the design of a curriculum in organic farming suitable to the particular educational needs of the Chinese partner institutions and of China in general; the development of proper teaching materials and manual supporting the future implementation of the curriculum on organic farming; the organization of three seminars and one academic conference in Beijing and Hangzhou aimed to facilitate the dialogue between universities and stakeholders (i.e. governmental authorities, private companies, NGOs, etc.). Many students and professors were involved in the activities. Among them, 12 Chinese professors spent three-months in European Universities for research and academic activities, 12 Chinese PhD students spent one-year in European Universities whithin a three years PhD programme and 8 European PhD students spent up to 4 months in Chinese Universities for research. Two two-weeks summer schools in Europe for 32 Chinese and 16 European students were organized.

Curriculum development

After two years of discussion the partners involved in the project defined the main topics and contents of the *curriculum*, according to Chinese partners requirements. The *curriculum* address scientific, technical, social and economical aspects of organic farming, on a “from field to table” basis. A total of 30 credits will include a 4 weeks on-farm internship. The *curriculum* has six major components: a core course on organic farming with twelve courses for a total of 8 credits; four specific courses in biological system management of pests, diseases and weeds, soil quality management, organic animal production, and food quality and food safety for a total of 20 credits; and approximately 2 credits for experimental learning on farms. The topics treated in the core course include principles, standards and philosophical and historical development of organic farming, environmental assessment of organic farming, strategies and technologies for organic food production, certification and labelling, marketing, case studies in organic farming and excursions to organic farms. The core course would be further on integrated in the first semester of a MSc course, while the specific courses would be integrated in a second semester according to the different needs of different academic institutions.

Conclusions

The synergic role provided by different Universities involved in the project represents a strong effective effort toward the development of organic agriculture. In Europe a strong effort is given to Universities involved in organic farming and many courses started since 2001 in several EU members like Italy, Norway, Germany, Denmark and United Kingdom (Francis, 2004; ENOAT, 2004). This project represents the first step towards the development of a sino-european *curriculum* on organic farming, and it would provide the basis for the development of well-trained and skilled technicians on organic agriculture in China.

Acknowledgments

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Dissemination of Organic Agricultural Information: The Role of Key Communicator Networks in Rural Bangladesh

Sarker, M.A[1], & Itohara, Y.[2]

Key words: Dissemination, organic agricultural information, key communicators, communication networks and rural Bangladesh

Abstract

The study was attempted to measure the role of the key communicators in the dissemination of organic agricultural information in the Tangail district of Bangladesh. The findings of the study revealed that there are six key communicators who are actively working in disseminating organic agricultural information among the ordinary farmers. Among these six key communicators, one is high communicator who usually provide advice and information to ordinary farmers as well as other key communicators. Thus identifying these key communicators from a community, the development organization can train up them and use them successfully in the promotion of organic farming in rural Bangladesh.

Introduction

Need of agricultural information is the basic necessity for the farmers as it plays a pivotal role in enlightening them, raising their level of knowledge and eventually help in their decision making process regarding farming activities. Effective communication between scientific information sources and the farmers is the key to economic progress of an agro-based nation. In Bangladesh, the Department of Agricultural Extension (DAE) is bridging the gap between research organizations (scientific information sources) and the farmers in order to promote sustainable agriculture and socio-economic development of the people in the farming community (DAE, 1999). However, unfortunately DAE and other government organizations have no active initiative to disseminate organic agricultural information among the farming community (Rahman and Yamao, 2007). According to IFOAM (1996), NGOs are the initiator of the organic agricultural movement in Bangladesh and 138 NGOs jointly have formed the Forum for Regenerative Agriculture Movement (FORAM). Among these NGOs a few leading NGOs are continuing their efforts in expansion of organic agriculture among the ordinary farmers, which started in the early 1980s. Thus adopter organic farmers mostly need to depend on NGOs and local progressive farmers for receiving organic information. A study of Sarker and Itohara (2007) showed that organic farmers in Bangladesh usually receive organic farming related information from friends and relatives, model farmers and opinion leaders who are treated as the key communicators. **The key communicators** are progressive farmers, input dealers, friends and community members who care about organic agriculture and have a desire to help the organic farmers to provide them with the most useful information. They gather information from the NGO and other information sources regarding their perceptions, questions and/or opinions about the organic agriculture, at the same time they spread information back to the organic farming community creating a partnership

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with the NGOs and other organizations. The research of Kashem and Halim (1991) showed that farmers pay more credibility to advice and information received from the model farmers, opinion leaders and other fellow farmers rather than any other sources. Thus it is essential to identify those key communicators and their needs for training to best optimize their role as the helping hands of the extension workers in promoting organic farming in Bangladesh. Keeping in mind this reality the present study was carried out by the researchers.

Materials and methods

The Tangail district of Bangladesh was purposively selected, and the study was conducted at Pirojepur village under Madhupur *upazila* (sub-district). The necessary data for the study was collected from 60 organic farmers out of 320 organic farm families of the study area. The key communicators regarding the dissemination of organic agricultural information were identified by using the sociometric method as suggested by Giles (1974), Young (1996) and used by Manohari (2002). At first six communicators were identified through a focus group discussion (FGD) where the organic farmers and the field staff of PROSHIKA (a leading NGO in Bangladesh) were the participants. In the next step the respondents were asked to give his/her first, second and third preferences in the order of his or her inclination to any of those three persons by whom he or she was influenced in the regards to organic farming. For one's preferenence of first, second and third choices the weightages were 3, 2 and 1 respectively. Thus the sociometric scores for one key communicator were calculated by using the formula: $SS= (3X N_1) + (2XN_2) + (1XN_3)$; [where, N_1= Nr. of respondents gives the 1st choice; N_2= Nr. of respondents gives the 2nd choice and N_3= Nr. of respondents gives the 3rd choice].Further the key communicators were categorized into 3 distinct categories based on the ascending order of cumulative percentage of sociometric scores. Key communicators having the cumulative percentage upto 25 were considered as low communicators, where they were treated as medium communicators within the range of 26-75 cumulative percentage. At the other end, key communicator with cumulative percentages of more than 75 were treated as the high communicator. In additon a sociogram was made, to show the communication networks that exist among the organic farmers of the study area while the basis was the first preferences of the respondents.

Results

Tab. 1: Communicators' profile based on sociometric scores

Key communicators	Preference by nr. of respondents			Sociometric scores	%	Cumulative %	Category
	1st	2nd	3rd				
1	1	-	1	4.0	1.1	1.1	Low
2	2	1	2	10.0	2.77	3.87	Low
3	3	8	3	28.0	7.73	11.60	Low
4	6	12	17	59.0	16.29	27.90	Medium
5	10	16	19	81.0	22.38	50.27	Medium
6	38	24	18	180.0	49.73	100	High

Total	60	60	60	362.0	100		

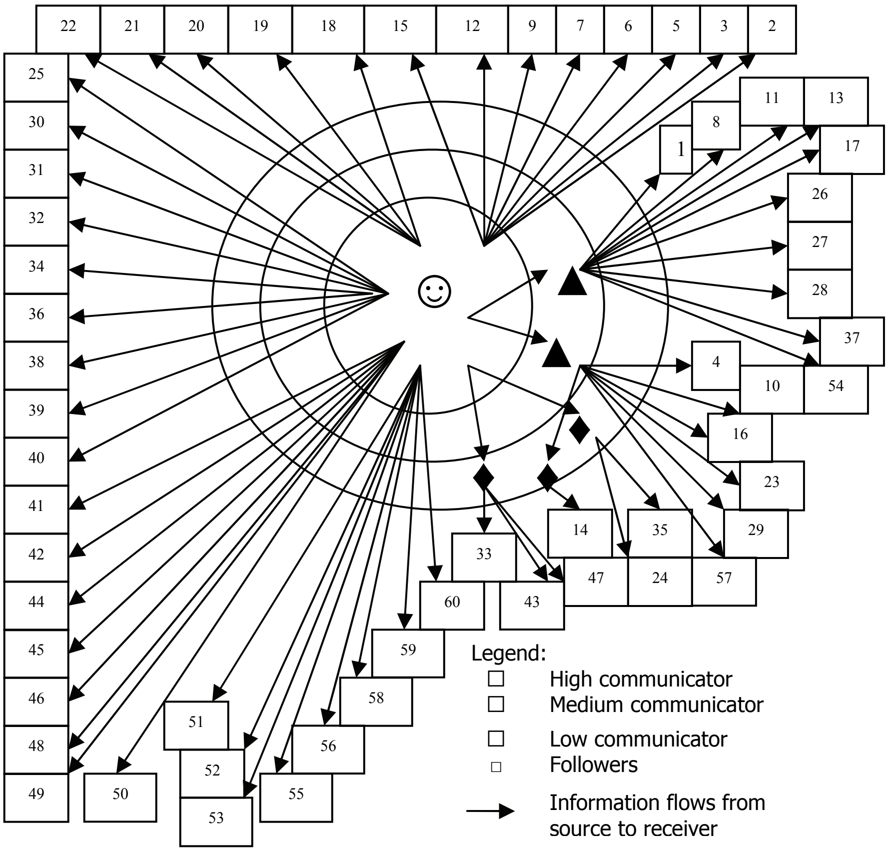

Figure 1: Communication networks exist among the organic farmers of the study area

Discussion

It was evident from table 1 that out of six identified key communicators, three of them belong to the category of low communicator while two of them belong to medium and only one person belongs to high communicator categories respectively. Findings showed that these 3 low communicators' cumulative percentage of sociometric scores ranged between 1.1–11.60. While two of them were identified as medium communicators and their cumulative percentage ranged between 27.90 – 50.28. This is because the majority of the respondents consult them either as 2nd or 3rd liking and a very few of them consult as their 1st liking for receiving organic advice and information. On the other side only one communicator was identified as high communicator with the 100 cumulative percentages of sociometric scores. This is because the majority of the respondent farmers consult him as their 1st preference for organic agricultural information followed by 2nd and 3rd preferences. The researchers further came to know that this identified high communicator is a highly educated person and doing organic agriculture with the guidance of PROSHIKA since the beginning of organic farming in this area. Thus he has expertise and all other ordinary organic farmers consult him regarding organic farming when needing information.

It is clearly understood from figure 1 that not only the ordinary organic farmers consult with the high communicator, moreover all the medium communicators and two of the low communicators also consult him regarding various aspects of organic agriculture. Thus the role of the high communicator is proved as the highest contributing factor in the dissemination of organic agricultural information. The role of the medium communicator is also recognized as important from the study as ordinary farmers as well as one low communicator also consult one of the medium communicator for organic advice and information. The researchers also came to know that PROSHIKA employed only one Technical Worker (TW) who has a four year diploma in agriculture (not a bachelor degree from a university) is assigned to promote organic farming in the 3 villages of Madhupur sub-district *(*PROSHIKA, 2006)*.* It is barely possible for him to meet the information needs of all the organic farmers of the 3 villages. Thus PROSHIKA focused on identifying the key communicators and used them for disseminating organic agricultural information among the ordinary organic farmers which eventually saved expenses for the extra manpower.

Conclusions

From the above study it can be concluded that the concerned Government and Non-Government agencies should concentrate their highest efforts in identifying the key communicators and developing their capacity which ultimately affords the greatest benefit to the organic farming community with proper flow of information at all times as well as to shrink the expenses of the organization.

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Socio-psychological characteristics of farmers in the adoption of organic farming practices in coconut based homesteads of humid tropics

Sherief, A.K.[1], Anilkumar, A.S.[1], Sakeer Husain, A.[2] & Jayawardana, J.K.J.P.[3]

Key words: homestead, socio-psychological characteristics, adoption, organic farming

Abstract

A study was conducted to find out the socio-psychological characteristics of farmers in the adoption of organic farming practices in coconut-based homesteads of the humid tropics. Multistage random sampling technique was followed to select 105 'coconut based homestead farmers' in Thiruvananthapuram district of Kerala state, India. A pre-tested structured interview schedule was administered to elicit data. The study revealed that the farmers' socio-psychological characteristics such as education, innovativeness, risk orientation, market perception, self-confidence, information seeking behavior, awareness, knowledge and attitude towards organic farming practices have significant correlation with their adoption behaviour.

Introduction

Kerala, a southern state of Indian subcontinent of humid tropics is characterized by predominance of small holdings called homesteads. A homestead is an operational unit in which a number of crops, major one being coconut, are grown with or without livestock, poultry and fish, mainly for the purpose of satisfying the farmers and his families basic needs. These homesteads constitute more than 30 per cent of the total cultivable area and about 85 per cent of these holdings have a size of less than 0.5 ha. Coconut, the major crop of small and marginal homestead farmers, enjoys a distinct place in the economy of Kerala. About 2.5 million farmers are earning their livelihood directly or indirectly from coconut cultivation.(Nampoothiri. (2001).

A major share of coconut production comes from small and marginal farmers in the State. There is a potential for promotion of organic farming among these farmers who are now unable to convert to commercial agriculture.(Pradeepkumar, et.al (2004). However in certain areas especially in the plantation horticulture adjacent to homesteads, continuous use of chemical fertilizers and its impact results in increased soil acidity, imbalance of major and micronutrients and degradation in soil biological properties.(Parthasarathi, (2002) The situation demands application of cost-effective organic nutrient sources, which helps in improving the soil fertility and productivity.

Adoption of any agricultural practice depends on the socio-psychological characteristics of the farmers.(Sherief, A.K.2002). Organic agricultural practices are no exception to this. The present study was conducted to find out the socio-psychological characteristics, which influence the adoption of organic farming practices in homesteads of humid tropics by the coconut based homestead farmers.

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Materials and methods

The study was conducted in the Kalliyoor, Venganoor and Kuzhuvilam panchayats of Nemom, Adhiyannoor and Chirayinkeezhu blocks respectively in the Thiruvananthapuram district of Kerala state. Multistage random sampling technique was administered to identify 105 coconut based homestead farmers. Based on judges rating, fourteen socio- psychological characteristics of farmers were selected. These include age, experience in coconut cultivation, education, livestock possession, trainings attended, innovativeness, risk orientation, market perception, self confidence, environmental orientation, information seeking behaviour, awareness on organic farming practices, knowledge on organic farming practices, and attitude towards organic farming practices. The data were collected with a pre-tested, structured interview schedule. In order to examine the relationship and rate of dependence of the selected fourteen independent variables on adoption of organic farming practices, correlation coefficient was tested and analysed.

Results

The socio-psychological characteristics of coconut based homestead farmers and their relationship with adoption of organic farming practices are depicted in Table1.

Tab. 1: Correlation between socio-psychological characteristics with adoption of organic farming practices

SI No	Independent variables	Correlation coefficient (r)
1	Age	0.0995
2	Experience in coconut cultivation	0.1167
3	Education	0.4834**
4	Livestock possession	0.1179
5	Training attended	0.0711
6	Innovativeness	0.3717**
7	Risk orientation	0.2730**
8	Market perception	0.8952**
9	Self confidence	0.5256**
10	Environmental orientation	0.0747
11	information seeking behaviour	0.4383**
12	Awareness on organic farming practices	0.3589**
13	Knowledge on organic farming practices	0.9468**
14	Attitude towards organic farming practices	0.5867**

** significant for P<0.001

A close observation of Table 1 reveals that education, innovativeness, risk orientation, market perception, self-confidence, information seeking behavior, awareness, knowledge and attitude towards organic farming practices have positive and significant correlation with adoption of organic farming practices. Among these factors, knowledge about organic farming practices, market perception, attitude towards organic farming practices, and self-confidence have more influence on the adoption.

Discussion

Education helps an individual to acquire more knowledge, understand the techniques better and strive to get accurate information for use in farming. This may be the reason why farmers' education level has positive and significant influence on the adoption of organic farming practices. The farmer innovativeness showed positive and significant influence on the adoption. Innovative farmers are progressive in outlook and are always keen in updating their farming practices. Hence they tend to seek changes in their farming practices. Further, the farmers who are willing to take risk in farming always have a propensity to attempt new technologies without hesitation. This may be the reason for the positive significant relation of adoption with risk orientation. Furthermore, having realized the upward market trend of organic produce, farmers are motivated to adopt organic farming practices to reap an early reward. Hence the positive relationship of market perception to adoption of organic farming practices.

It is observed from the study that the self confidence had positive and significant relationship with adoption. Self confidence makes farmers to develop ability to face risks and seek new information. Self confidence level of farmers, determines the decisions for adopting organic farming practices. This might be the reason for a significant and positive relationship between self confidence and adoption. The information seeking behaviour also had positive and significant relationship with adoption. In this era of digital and communication technology, farmers can gather information through various information sources. Authentic information from reliable sources might have facilitated higher level of adoption.

The correlation coefficient between awareness and knowledge on adoption of organic farming practices were found to be positive and significant. With the increase in awareness and knowledge on the degradation of environment and higher level of pesticidal toxicity in food, farmers develop favorable attitude towards organic farming through their own experience which led to the higher level of adoption. Similarly, attitude exhibits positive and significant correlation with adoption. High level of awareness and knowledge might have contributed to the farmers to change their attitude. This implies that farmers with positive attitude tend to adopt organic farming practices more quickly than the farmers with negative attitude.

The socio-psychological characteristics of the farmers such as age, experience in coconut cultivation, livestock possession, trainings attended and environmental orientation had no significant correlation with adoption of organic farming practices, showing no significant influence on the adoption of organic farming practices.

Conclusions

In humid tropics like Kerala in India, homestead farming has been one of the survival strategies of the farmers in coconut based homesteads. Adoption of organic agricultural practice in these homesteads greatly depend on the socio-psychological characteristics of these farmers It is evident from this study that the socio-psychological characteristics of farmers like the education level, innovativeness, risk orientation, market perception, self-confidence, information seeking behavior, awareness, knowledge and attitude towards organic farming have high influence on the adoption of organic agriculture in coconut based homesteads in Kerala. Among these factors, knowledge about organic farming practices, market perception, attitude towards organic farming practices, and self-confidence have more influence on the adoption. Hence efforts should be made to create more knowledge and understanding among the farmers about the organic farming practices, its advantages and marketing possibilities, which inturn will develop more positive attitude, and improve the self-confidence of the farmers, leading to increased adoption of organic farming practices in coconut based homesteads of humid tropics.

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Cross-disciplinary and participatory research methods: What can we learn?

Cross-Disciplinary Analysis of the On-Farm Transition from Conventional to Organic Vegetable Production

Jackson, L.[1], Smukler, S.[2], Murphree, L.[3], Yokota, R.[4], Koike, S.T.[5], & Smith, R.F.[6]

Key words: Soil, cropping systems, organic transition, regression trees, canonical correspondence analysis

Abstract

This farm-scale analysis of the three-year transition to organic from conventional vegetable production tracked the changes in crop, soil, pest and management on two ranches (40 and 47 ha) in the Salinas Valley, California. Many small plantings of a diverse set of cash crop and cover crop species were used, as compared to only a few species in large monocultures in conventional production. The general trends with time were: increase in soil biological indicators, low soil nitrate pools, adequate crop nutrients, minor disease and weed problems, and sporadic mild insect damage. Some crops and cultivars consistently produced higher yields than others, relative to the maximum yield for a given crop. Differences in insect and disease damage were also observed. These results support the value of initially using a biodiverse set of taxa to reduce risk, then later choosing the best-suited varieties for optimal production. The grower used some principles of organic farming (e.g., crop diversity, crop rotation, and organic matter management), but also relied on substitution-based management, such as fertigation with soluble nutrients, initially heavy applications of organic pesticides, and use of inputs derived from off-farm sources. The organic transition was conducive to both production goals and environmental quality.

Introduction

In California, large scale vegetable producers are starting to adopt organic practices to meet the growing market demand (Giles, 2004; Klonsky, 2004), and are now distributing produce to national and international marketplaces. Research on the transition to organic production by conventional, large scale growers requires methodology that represents decision making options at the whole-farm scale. Agricultural transition periods require adaptive management to meet production goals in an environmentally-sound fashion. Frequent and repeated sampling is needed to capture changes in management, yields, and other biophysical responses, and as a result, organic transition periods have rarely been studied under the conditions of dynamic decision-making on the scale of actual farms. Using indicator variables in

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large-scale studies, e.g., yield, nutrient content, pest damage indices, and soil properties, along with multivariate statistics, can show the linkages between management factors, environmental conditions, and crop performance. The outcomes of multi-year, multidisciplinary studies can generate hypotheses regarding factors that optimize the success of the transition to organic production.

An instructive organic transition occurred in the Salinas Valley, California, where one of the USA's largest cool-season vegetable production companies converted two ranches according to the California Certified Organic Farmer guidelines (Smukler et al., ms. submitted). Our cooperative research partnership jointly designed a project to monitor the temporal and spatial progress of the organic transition across the ranches. Each ranch was surrounded by conventional vegetable production that typically uses more than 150 kg of synthetic nitrogen (N) fertilizer per crop, frequent application of pesticides, and intensive hand labor for weeding, thinning, and harvesting.

On the two ranches, a network of 81 points was sampled at nearly every crop and cover crop harvest for a set of indicators for crop productivity, pest pressure, and soil status for 2.75 years. The design provided a large data set and a variety of different conditions that were conducive to analysis by multivariate methods, i.e., Classification and Regression Trees (CART) and Canonical Correspondence Analysis (CCA) to describe ecological relationships but also suggest pathways for management improvement (McCune and Grace, 2002).

Materials and methods

The project began in June, 2000, at the onset of the three-year period required for organic transition by the California Organic Food Act and National Organics Program on two ranches owned by Tanimura and Antle, Inc. Sampling ended in March, 2003, at a common end point prior to planting the crops for the spring season. The ranches had been divided into management blocks many years before. Three transects were established across 9 of these blocks (6 at Storm Ranch and three at Daugherty Ranch), for 27 permanent transects. The soil type is mainly Salinas clay loam.

The grower recorded all management operations, e.g., Intensive tillage, direct seeding of vegetables, and drip irrigation. Cover crops were usually planted once every year. Compost (C:N=18) was applied at least once per year. Pelleted chicken manure fertilizer (2.5-2-2.5) was applied prior to plantings (1100 kg ha^{-1} supplying 28 kg N ha^{-1}). Then a soluble fertilizer (6.0–0.4– 0.2) was applied multiple times through the drip tape during each crop growth cycle. Total application rates ranged from 25 kg N ha^{-1} for baby greens to 244 kg N ha^{-1} for celery. Several organically certified pesticides were used during the transition. Weather data were from a nearby station.

Along each transect, three sampling plots were evenly placed at least 35 m apart, for 81 plots in total on the 27 transects (54 at Storm Ranch and 27 at Daugherty Ranch). Soil samples were taken in June, 2000, and again in March, 2003, before organic certification. This composes the soil properties data set. In addition, throughout the transition, crops and soils were sampled within one week of harvest of each transect. This composes the crop and soil monitoring data set. At each sampling, soil cores, aboveground biomass and harvestable yield, and weeds were sampled, and presence/absence of damage by insects or disease was noted. For analytical procedures, see Cavagnaro et al. (2005) and Smukler et al. (ms submitted).

Analysis of variance (ANOVA) tested for year to year changes in relative yield, and soil biological activity, as well as by growing season during the transition period. Log linear models tested for differences in the categorical data for presence/absence of shoot damage by insects or disease, or for root disease. Recursive regression trees (CART) explored the relationship between management and relative yield, and damage to crops from insects, and disease for all crop taxa excluding cover crops. CCA examined how soil properties changed in the different transects.

Results

Crop performance increased over the three-year period based on relative yields, (observed yield of each crop divided by the observed maximum yield ever measured for that crop during the three year period, expressed as a percentage). During the most intensively cropped season, which was the summer, there was a significant increase in relative yields from 45% in the first year to 62% in year three. CART regression trees showed that: 1) Most of the variation in relative yield was explained by crop selection. The red leaf and green leaf lettuces had higher relative yields than romaine. 2) Different cultivars also showed different levels of performance, e.g., for baby greens, cilantro, frisee, and parsley. 3) Some management blocks were prone to lower relative yields, suggesting specialized needs for improving inputs.

Insect damage, measured by presence/absence, increased from an average of 3% during the summer of the first year, to 66% in the second summer, but then decreased in the summer of the third year to 28%, reflecting general trends in outbreaks in the region. Similarly, fall and spring damage increased from year one to year two, decreasing in year three. The crops that were most damaged were broccoli, endive, frisee, green leaf, radicchio, and romaine, while the least damaged crops were cilantro, escarole, baby greens and parsley. The lettuce aphid was the most important pest, especially in year two on romaine, and high applications of Bt and other organic pesticides were relatively ineffective. CART regression trees showed that: 1) Higher dew point (>13°C) and thus higher relative humidity, was a factor that contributed to insect damage. 2) Under these moister conditions, the most enclosed blocks were more likely to experience severe insect damage, compared to edge blocks near conventional production or paved roads. 3) High solar radiation and higher drip irrigation were also associated with higher pest damage especially for certain taxa.

There was an increase in leaf disease symptoms from the summer of year one, where 3% of the samples were infected, to the summer of year two, where 27% of the samples, followed in the summer of year three by a decrease to 7%. Red leaf and romaine lettuces had more incidences of leaf diseases than any of the other crops. The most important foliar disease was downy mildew of lettuce, forcing in year two, three romaine plantings to be disced before harvesting.

An indicator of weed pressure was the percentage of sampled plots containing weeds. For the Storm Ranch, in 2000, 2001, and 2002, respectively, 27, 39 and 16% of the plots contained weeds. For Daugherty Ranch, this was 4, 11, and 18%, respectively.

Over the three year transition period there was a trend towards greater soil biological activity. Soil microbial biomass carbon (C) at 0-15 cm depth increased ~25% during the most biologically active times of the year, which is the mild wet fall and spring, over the three-year period. Arbuscular mycorrhizal colonization was only 2.8% of the root length, but more than doubled to 6.8% by year three. By the second year, soil nitrate pools were very low, yet when N contents of each crop were compared with reported stringent critical deficiency values most were well above the critical value.

While mean values of soil C or N for the ranches did not change between the onset and the end of the transition period, there were significant changes in other soil parameters particularly between individual management blocks. Mean Olsen P, soluble K, and EC decreased, while pH increased. CCA analysis showed that changes in pH and EC were driven largely by higher silt, and amounts of Biolizer fertilizer and drip irrigation. Higher soil K was associated with higher amounts of chicken manure pellets. Thus, management blocks responded differently to the organic transition due to both soil characteristics and inputs.

Discussion

The transition from conventional to organic production was successful at a large scale even in a region dominated by conventional agriculture. Tanimura and Antle Inc. showed a distinct learning curve in relation to both nutrients, i.e., increased soluble fertilizer additions, and pest management, i.e., decreased use of organic pesticides. Overall, their management resulted in improved soil biological indicators, generally adequate plant available N with reduced soil nitrate, and a gradual increase in relative yields with time. The continued organic production at this site, and the expansion to other sites, suggests that it is economically viable.

Many organic growers manipulate plant species richness and evenness within the constraints of managing supply for market demand, as one of the main sets of allowable tools for farm management (Zehnder et al., 2007). This study shows that this may have benefits for mitigating risks associated with low yields and insect damage, and is best addressed through adaptive management.

Conclusions

These results demonstrate that some of the strategies that were developed by small-scale organic producers can be applied to larger-scale production to achieve a more sustainable agricultural intensification, which has far reaching implications as the demand for organic production increases.

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How to promote innovation and interdisciplinarity in organic food and farming research evaluation

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Key words: Research evaluation, Criteria and procedures, Innovation, Interdisciplinarity, CORE Organic.

Abstract

The development of organic food and farming research calls for system-oriented, innovative, interdisciplinary approaches. The process of evaluating research proposals is a crucial step towards this objective. Based on the EU CORE Organic pilot call for joint transnational research projects, we analysed to what extent the evaluation criteria and procedures implemented address this issue. Feedback on the experience of the target groups involved in this call was gathered and discussed in relation to findings from the literature. Our results show that interdisciplinary and innovative aspects could be better addressed, and evaluation criteria more clearly defined and delimited. This entails reshaping the main criteria and developing more suitable evaluation categories and sub-criteria. We also suggest creating mechanisms to enable funding of a few "risky" research projects, to facilitate entry of newcomers to the arena, to promote exploratory research projects and to support longitudinal interaction among applicants and assessors.

Introduction

As a cornerstone of knowledge production, research evaluation is the subject of considerable debate in the scientific arena. Based on our experience with the CORE Organic project and its associated pilot call for joint transnational research projects, we aim to bring this debate to the forefront of the organic food and farming (OFF) research arena. CORE Organic, an acronym for "Coordination of European Transnational Research in Organic Food and Farming" was initiated as a part of the European ERA-net Scheme, which is intended to step up cooperation among national research activities. One of the objectives of CORE Organic is to enhance the quality, relevance and utilisation of resources in European research in OFF. Research in organic farming, advocating a holistic approach, is still a relatively new research domain. This calls for strong integration of disciplinary perspectives and for development of specific methodologies to assess new research targets (Rasmussen *et al.*, 2006). Our objective is to assess to what extent the evaluation criteria and procedures used for the CORE Organic pilot call address these issues, particularly their suitability for promoting interdisciplinary and innovative research projects. Drawing on feedback of experience from the target groups involved in this call and analysis of the literature, we suggest some pathways to improve research evaluation

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procedures, arguing that improvement of evaluation procedures would also improve the quality of research in this field.

Materials and methods

In September 2006, eleven EU partners from CORE Organic launched a pilot call for transnational research projects in OFF. The following three thematic areas were chosen: animal health management, quality of organic food and innovative marketing strategies. 38 research proposals involving research consortia of at least three partner countries were submitted for selection. A panel of nine experts was selected for a consensus-building process. Evaluation was implemented with a set of 19 sub-criteria, aggregated into six main criteria. The scientific expert panel recommended the 17 projects that scored best in the evaluation to the Governing Board of CORE Organic, which then selected 8 projects[1] with the aim of matching the national priorities given by the 11 participating countries, covering the three thematic areas, and involving as many relevant partners as possible. The survey and assessment of the evaluation procedure consisted of a feedback evaluation exercise involving the different target groups that took part in the pilot call, including the expert panel, the Governing Board members, the national call contact persons and the applicants.

Results and discussion

The pilot call used a combination of classic criteria such as “scientific quality”, “choice of methods”, “relevance to the call”, and more specific ones such as “trans-national linkage”, “interdisciplinarity of the consortium” and “innovative research” (Table 1, left column). The experts’ survey showed that the proposed set of evaluation criteria fulfilled the expectations of most target groups involved in the CORE Organic pilot call, and that the participants were, on the whole, satisfied with the procedure. However, it emerged from the survey that the criteria used for evaluation should be better defined, and that developing more specific sub-criteria could allow a better balance between “scientific quality and robustness” and “interdisciplinary and innovation” (see Table 1, right column). Furthermore, the current list of sub-criteria already contains three criteria dealing with different aspects of interdisciplinarity. The fact that they are assigned to different main categories may weaken their significance. Meanwhile, some applicants and experts still suggest that major improvements should be undertaken in the evaluation procedure concerning the issues of interdisciplinarity and innovation. The fact that it is difficult to promote innovative research, and especially interdisciplinary research, is not new in science. The intention to advance knowledge by calling into question the current understanding, with its attendant paradigms and assumptions about quality criteria, usually suffers in a conventional peer review process known for its conservative and risk-minimising characteristics (Hacket and Chubin, 2003). Large pluri-disciplinary panels are acknowledged to be more efficient in evaluating interdisciplinary research.[2] When the peer panel comprises a healthy balance of the disciplines involved in the proposal, the panel system allows broad representation of divergent judgements and conflicting validation norms (Porter and Rossini, 1985). Furthermore, this system allows open debate about criteria assessments; this, when combined with a rough rating-scales model, is acknowledged to bring support to controversial innovative and interdisciplinary projects. From this

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[1] For a description of the projects see http://www.coreorganic.org/research/index.html

[2] A panel of 8 to 12 experts has been shown to be a good number.

perspective, a low level of agreement among reviewers on a peer panel is not an indication that the assessment lacks validity or legitimacy (Langfeld, 2001). Rather, it may indicate that the panel is highly competent because it represents a wide sample of the various views on what constitutes good and valuable research. The challenge, then, is to find a diverse set of experts that encompasses the various facets of a set of proposals, and to avoid duplicative perspectives. It can be assumed that the following prerequisites were met in the CORE Organic pilot call: each expert had basic knowledge of OFF, had been involved in OFF research projects that mobilised interactions with other disciplines (systemic and interdisciplinary approaches), and possessed expertise in at least one of the three identified topics. Both a rough rating scale and open decision-making process were used and low inter-reviewer agreement was achieved. Nevertheless, it seems that innovation in OFF needs to be strengthened. We suggest that a specific mechanism should be implemented in the evaluation process in order to allow a few “risky” research projects to be funded, *i.e.* to give temporary credibility to innovative work. At the same time this could facilitate the entry of newcomers into the arena and promote exploratory research projects. This procedure could be extended to projects which show a strong interdisciplinary dimension but a certain methodological weakness. As a gate-keeping mechanism, a later assessment step could also be implemented, consisting for example of a tutorial on the ongoing research.

At the same time, considering research evaluation as a negotiation and knowledge creation process, we advocate stronger longitudinal interaction among the applicants and assessors. This would not only generate competence, but also create a communication base that increases the number of people capable of conducting interdisciplinary evaluation with rigour (Klein, 2006).

Conclusions

Criteria and procedures used in the CORE Organic pilot call were judged as relevant by most of the stakeholders involved. However, the assessment process could be improved. Further work should focus particularly on refining criteria, devising mechanisms to allow funding of a few “risky” research projects, and allowing longitudinal interaction among the applicants and assessors.

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Tab. 1: Evaluation criteria for the selection of organic food and farming projects used in the CORE Organic pilot call and suggestions for improvements.

Evaluation criteria	Comments and suggestions for improvements
1 Scientific Innovation	This is the place to assess aims, hypotheses, novelty, new ideas, cross-disciplinary approaches, and knowledge of the literature. The experts have to apply their own ratios and weightings between all these aspects and summarize them into two simplifying criteria. More sub-criteria should be
1.1 Innovative research	
1.2 Scientific quality	
2 Methodology	Contains diverse criteria, *methodology* corresponding more to scientific quality, and others linked to dissemination. They should be considered apart, and criterion 2.3 may include
2.1 Choice of methods	
2.2 Plan for publication	
2.3 Plan for knowledge	
3 Consortium	Heterogeneity and overlapping definitions of the sub-criteria: “skills” of the individuals and groups to handle the research and “practical capacity” of the consortium to handle the project. *Interdisciplinarity of consortium* is not explicitly defined. The fact that different aspects of interdisciplinarity are assigned to different main categories weakens their significance
3.1 Qualification of consortium	
3.2 Complementary expertise	
3.3 Interdisciplinarity of	
3.4 True cooperation	
3.5 Trans-national linkage	
3.6 Scientific networks	
4 Project Management	These sub-criteria are considered difficult to judge by the experts. Additional types of skills and experts (management and organizational experts) should be included.
4.1 Project management	
4.2 Research plan	
4.3 Financial requirement	
5 Relevance	This criterion should include assessments of knowledge users. This is supported by the literature and by the experts, who state that assessing *Societal Relevance* is difficult for them.
5.1 Relevance for OFF	
5.2 Relevance to the call	
5.3 Societal relevance	
6 Added Value	Difficult to address this criterion that tries to assess the “emergent” components of the partnership.
6.1 Added value for EC	
6.2 Trans-national aspects	

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Learning in context – improved nutrient management in arable cropping systems through participatory research

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Keywords: Participatory research, sustainability, organic farming, nutrient management, organic fertilisers

Abstract

Participatory research (PR) provides opportunities to build knowledge relevant to site-specific farms conditions. This study used a PR approach to develop nutrient management strategies in stockless organic farming. A thorough problem identification process was carried out and the problem prioritised was how to combine preceding crop effects with fertilisation strategy in crop rotations. On-farm fertiliser (biogas digestion residues, chicken manure and meat-bone meal) experiments were conducted in spring wheat and winter rapeseed. Significant yield responses were achieved in spring wheat, up to 1200 kg ha^{-1}, and they were higher than in rapeseed. The implications of the results for nutrient management at crop rotation level are discussed.

Introduction

Learning in context is a process of gathering information and developing knowledge relevant to specific situations, such as site-specific conditions on farms (Eshuis & Stuiver, 2005). Participatory research (PR) is a tool to address relevant problems and facilitate technology transfer (Poudel *et al*., 2000). Sustainable practices need to be implemented on farms by farmers and can be improved by involving farmers in the research process. The background to the present project was the lack of knowledge on sustainable nutrient management strategies in stockless organic farming, since low nutrient use efficiencies (NUE) have been reported (Olesen *et al.,* 2007). Studies on optimal combinations of crop rotations and fertilisation strategies that include preceding crop effects and manuring are scarce. Participatory research was considered to be a suitable approach to address the complexity of nutrient management at the cropping system level. A PR project was started in 2006 and will end in 2008. Some of the results are reported in this paper.

Materials and methods

A group of six farmers with similar organic production systems in southern Sweden were selected to form a PR group together with an advisor and a researcher. In PR, identification and prioritisation of a common problem is central (Fujisaka, 1989). In this project, although we had specific funding for nutrient management studies we initiated a broad process of problem identification and used communication facility tools such as drawing problem-trees and solution-trees of high complexity to highlight biological

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and socio-economic issues. Each of the six farms was thoroughly described by the farmer, and problems and future possibilities of the individual farms were discussed and documented.

The cropping systems on the farms consisted mainly of spring cereals, one-year clover-grass green manure (GM) leys, winter rapeseed and green peas. The nutrient management strategies differed among the farms, from a strategy of no inputs of nutrients from outside the farm except N_2 fixation to inputs of nutrients replacing outputs and further on to 'inputs to get high yields'. Different kinds of manure and organic fertilisers based on food industry waste products were used.

Field experiments were conducted on the farms in 2006 and 2007. The experiments were managed in cooperation between the farmers and the local Agricultural Society. Here we briefly describe two fertilisation experiments in 2007 on two sites: spring wheat (*Triticum aestivum* L.) trial on a loam and winter rapeseed (*Brassica napus* L.) trial on a medium clay soil. The experimental plots were arranged in a randomised block design with three replicates. The following fertiliser treatments were included: Biogas digestion residues (0,8% total-N), chicken manure (2,1% total-N), and meat-bone-meal (9,5% total-N). In the spring wheat trial two intended rates, 50 and 100 kg total N ha^{-1}, of the organic fertilisers were applied in spring. In the winter rapeseed trial the organic fertilisers were spread in early spring 2007 in the standing crop with the intended N rate of 120 kg total-N ha^{-1}. Winter rapeseed was sown with 48 cm row distance in early September 2006.

Results

The relative importance of external inputs of organic fertilisers compared with N_2-fixing crops in the rotation was identified in the PR process to be a key issue for the farmers. The PR group was aware of the difficulty of devising long-term nutrient strategies during a project of three years, but concluded that short-term on-farm fertilisation experiments would be most valuable.

Significant fertiliser effects on yield and N uptake in grain were achieved in a spring wheat trial (Table 1). The intended fertiliser rates were not achieved for chicken manure due to discrepancy between preliminary and final fertiliser analyses. On average the lower fertiliser rate gave the highest NUE. The yield increase in rapeseed due to fertilisation was not significant due to large variation between plots, but was on average 600 kg ha^{-1}. The economic evaluation showed higher economic benefits from fertilisation in spring wheat compared with winter rapeseed. However, the wheat and rapeseed experiments were conducted on two different sites, making direct comparisons difficult.

The PR group discussed implementation of results for the cropping systems on the farms. Optimal fertiliser strategies in the crop rotation were the main focus for discussions. The conclusions can be summarised as follows: 1) Early spring application of organic fertilisers or a high nutrient-delivering preceding crop is crucial for good crop development and high NUE in winter rapeseed. 2) Low and variable NUE of organic fertilisation in rapeseed entail that a combination of a moderate nutrient-delivering preceding crop and a low early fertiliser application may be an advantageous option. 3) Large yield benefits could be achieved by applying organic fertilisers to spring cereals. 4) Low rates of organic fertiliser supply together with N_2-fixing crops in the rotation could be an economically and environmentally benign solution. 5) To get high NUE of organic fertilisers farmer's experiences show great importance of immediate fertiliser soil incorporation. 6) Successful weed management is a requirement for high NUE in the cropping system.

Tab. 1: Yield and protein concentration of spring wheat fertilised with different types of organic fertilisers in one on-farm field trial. NUE = (N in grain of fertilised wheat - N in grain of unfertilised wheat)/total N in applied fertiliser

Fertiliser	Total N in fertiliser ha^{-1}	Yield kg ha^{-1} 15%wc	Protein conc. %	N in grain kg ha^{-1}	NUE %
Unfertilised	-	3630a	11.4	62a	-
Biogas residues	52	4240b	11.9	75b	26
	104	4840c	12.5	90c	27
Chicken manure	33	4060ab	12.2	74b	37
	65	4260b	11.9	75b	20
Meat-bone meal	46	4330b	12.0	77bd	34
	92	4630bc	12.5	86cd	26
p-value		*0.006*	*n.s.*	*0.004*	*n.s.*

Discussion

Farmer PR offers possibilities to learn in context and to build knowledge that could lead to improvements of on-farm nutrient management. However there are drawbacks with the PR approach. It is time-consuming, at least in the short-term perspective, and it could be difficult to obtain funding for PR projects with very open aims. The flexibility and simplicity that are important traits of successful PR could lead to poor scientific validity of research results (Poudel *et al.,* 2000).

Agricultural knowledge stems from different sources and PR combines researcher-advisor-farmer inputs with possibilities to develop and implement cropping system solutions. Field experiments carried out by researchers tend to focus on evaluation of single factors excluding a cropping system context. With the PR approach the experimental design of field trials were formed by the group, with the outcome that locally available fertilisers were used and also that farmer's techniques concerning spreading and incorporation of the fertilisers were followed. The choice to conduct fertiliser trials in both spring wheat and rapeseed reflected the farmer's interests of comparing NUE for different crops in the rotation.

The difficulty with application of organic fertilisers to winter rapeseed observed in this project is consistent with other studies, mainly caused by the large nutrient requirements very early in the season (Rathke *et al.,* 2006). At the same time, it is crucial to avoid spreading manure on wet clayey soils, causing compaction injuries. A favourable preceding crop leaving residual N in the soil profile could consequently be an alternative to fertilisation. The farmers in the group grew GM leys, which could be a suitable preceding crop to rapeseed. Farmer's experience showed however difficulties to establish rapeseed after GM due to dried up soil and attacks of slugs. An alternative could be a pulse crop leaving at least moderate nutrient rich residues. The rapeseed probably needs supplementary fertilisation, depending on inherent soil nutrient-delivery. But then the farmer does not have to completely rely on fertilisation to get an acceptable yield. Furthermore an important lesson learned by the farmers was that it is of the utmost importance to have reliable manure analysis to enable high NUE of organic fertilisers. Ecological sustainability concerning fertiliser inputs was the focus of many discussions in the PR group. Earlier studies have sometimes shown negative nutrient balances in stockless organic farming caused by low or no inputs of fertilisers to the farm (Wivstad *et al.,* 2005). Olesen *et al.* (2007) stressed the importance of applying organic fertilisers to such cropping systems in order to maintain good crop yields and to ensure that crops are sufficiently competitive against perennial weeds. There was general agreement that the nutrient inputs and outputs need to be balanced for long-term on-farm sustainability. In a wider perspective, however, it is not sustainable to deplete non-renewable resources, e.g. phosphorus, to sustain nutrient needs on the farm. More advanced nutrient cycling in the food chain would decrease the need for using nutrient stocks.

Conclusions

* More sustainable solutions for nutrient management could be implemented by PR compared with researcher-managed studies. Different kinds of knowledge are combined in PR, providing a broader multidisciplinary base for decisions.

* Higher NUE of organic fertilisers could be achieved in spring cereals compared with in winter rapeseed.

* A combination of a moderate nutrient-delivering preceding crop and a supplementary fertilisation could be a solution for high NUE in winter rapeseed.

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Research - Teaching Integration in Agroecology and Organic Farming

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Key words: farming systems, agroecology, organic farming, action research, learning landscapes

Abstract

Integration of research and teaching enhances the success of students in both areas, and contributes to preparation of graduates who are capable of handling the complexity of location-specific challenges in farming and food systems. A European Network of Organic Agriculture Teachers (ENOAT) convened a workshop in Italy in 2007 to explore the current state of integration and potentials for further developing this learning strategy in universities. We concluded that integration brings motivation to students and greater relevance to their learning environment, both key issues in providing success in the learning landscape

Introduction

Research results and practical experiences in agriculture and food systems provide the information we use in teaching courses, through journal articles, textbooks, farmer bulletins, and other types of learning materials. Research informs teaching. In addition, our teaching of research-derived knowledge and skills in principles of biological systems, ecosystem structure and function, experimental design and other technical areas influence future research, as these ideas are incorporated by our students. Teaching informs research. There is growing concern among our professionals that these two activities are too often disconnected. Teaching and research are often seen as distinct activities, with different goals, time frames, budgets, and specialists in the university. A workshop of the ENOAT in August, 2007 explored the importance of integrating research and teaching with the goal of improving both functions of the university. In this paper we relate the results of the workshop to future education in organic farming, and draw primarily from the proceedings edited by Caporali et al. (2007).

Methods

Linkages between research and teaching have been studied extensively, especially in education. Barnett (2005) describes the challenges of new linkages between research and teaching in established universities, while Brew (2006) explores how to bridge the research-teaching gap. Integration is more than making faculty assignments to these two activities. Success requires examination of how the university is organized, and

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even goes beyond our concerns about learning to address wider issues such as how economic and political pressures impact design of education (Brew, 2006). She expands on a future vision of institutions where academics and students work in collaboration to better understand the world, and to “develop the strategies, techniques, tools, knowledge and experience needed to solve complex, important, and yet unforeseen problems.” In contrast to Brew’s enthusiasm, Jenkins et al. (2003) conclude that most research evidence does not find a positive correlation between success in research and teaching, but there is potential value if integration is carefully built into courses and curricula. Integration of teaching and research depends on how we define them. Current university organization favors two different, unlinked activities, with separate budgets, faculty assignments, and facilities that do not foster integration (Barnett, 2005). Current consensus is that agroecology describes an academic field of systems study, while organic farming is the application and integration of science with practical farmer experience to design productive systems in the field and meet certification criteria. We have published three models of organization of the agricultural university, contrasting current rigid departments and disciplines with two futuristic plans that lead to a near-total integration of research and teaching under the umbrella of education (Lieblein et al., 2000). These could serve as models for teaching organic farming and agroecology, with the latter defined as the ecology of food systems. The ENOAT workshop focused on finding relevant connections between research and teaching, and on how a well-designed university program could enhance both objectives.

Results

Integration of research and teaching is especially important for the education in organic farming and agroecology because of the complexity of questions and many interactions integral to farming and food system. Understanding systems requires a transdisciplinary strategy for education that involves experiential learning. We have found it essential to tie learning to real world challenges and clients. This links research in the field with learning activities in the classroom. The ENOAT workshop revealed a wide range of opinions on what constitutes research, what characterizes teaching, and what could be gained by better integration.

Tab. 1: Essence of Research as Defined by ENOAT Workshop Participants, 2007.

What is research?	o Activity performed in research centers to find new knowledge o Recombining old knowledge, constructing new connections o Solving practical problems, especially unsolved questions o Organizing experience and knowledge in new contexts o Paid or contract activity with obligations and requirements
What process is used in research?	o Includes individual and group learning o Discovery, experimentation, observation, analysis, synthesis o Working closely with clients is essential to success in systems
What characterizes research?	o Interest, curiosity, creativity o Objectivity and honesty in process and reporting results o Transdisciplinarity and systems focus

Research was viewed as a process of discovery, including combining prior knowledge and experience with new information often found in a new context (Table 1). Some viewed research as defining program priorities and setting in motion a process to solve practical problems. Steps include defining questions clearly, setting up accepted procedures to answer the questions, collecting data, analysis and interpretations, and reporting results. The job is not finished without publication or other dissemination of results. The term multidisciplinary was replaced in discussions and the proceedings by transdisciplinary, preferred because the latter refers to a "transcending" of disciplines rather than a collection of people with multiple talents. Teaching is a prime activity of the ENOAT workshop participants, and we asked what each person considered the essence of teaching. Groups of four discussed their responses and found three key characteristics to report. Responses gathered in a group plenary session are shown in Table 2. As conceptualized and practiced by this group of teachers of organic agriculture, teaching includes transmission of knowledge and interpretation in current and new contexts. The process of learning is complex, and we strive to promote both individual and group learning. One challenge is to stimulate curiosity, guide people through an examination of their own attitudes and preconceived ideas, and build motivation for action. Although there is great importance in building skills and knowledge, teaching should reach beyond these lower order issues to seek applications of what is learned and how this experience will interface with the real world and prepare graduates for the uncertainty and complexity they will face in the workplace and society.

Tab. 2: Essence of Teaching as Defined by ENOAT Workshop Participants, 2007.

What is teaching?	o Sharing, moving, and interpreting knowledge clearly to others o Catalyzing, promoting, and facilitating learning o Disseminating knowledge that can be applied in new contexts
What process is used in teaching?	o Promote individual and group learning o Stimulate curiosity, challenging attitudes, building motivation o Creating new capabilities and stimulating critical thinking skills
What characterizes teaching?	o Focus on skills, facts, theories and principles, and how to apply o Build communication skills, experiences and teamwork o More than merely a cognitive activity, but leads to application

Integration of research and teaching was explored in another workshop session. Participants were asked to envision a future learning landscape with close integration of research and teaching, and to describe what they would see in this landscape. Their ideas are summarized in Table 3. Some of the motivations for learning and aspects of application should be integral to any teaching situation. We found that greater motivation will result from students being a part of generating new information through research. Application of information to practical challenges is valuable.

Tab. 3: Vision of learning environment with integration of research and teaching, defined by ENOAT Workshop Participants, 2007.

Motivation of students and instructors?	o Teachers better prepared, and students more involved o Students are part of knowledge process, serve the community o Students feel teacher's conviction and passions for the topics
Relevance of materials in courses?	o High level of relevance to current topics and applications o Direct participation in research, higher awareness of needed results o Current context compared with past experiences, future situations
Focus of learning in the learning landscape?	o Literature and experience are connected in real world situations o Focus on practical issues, students more curious when involved o Learning process focused on interactions, large systems, context

Lastly, we focused on putting theory into action, and asked workshop participants what students would be better able to do as a result of research-teaching integration. As shown in Table 4, the instructors predicted that students would acquire new knowledge about the research process, better understand themselves and their capabilities, and be ready to deal with complexity. They will also be more in tune with the research process, and will be prepared to deal with whole systems with tools and methods that sort out complexity. We see students as more prepared for action and applications with clients and real problems, as compared to dealing with lower order questions where most of the answers are already known.

Tab. 4: What are students better able to do after graduation as a result of research-teaching integration, defined by ENOAT Workshop Participants, 2007.

What knowledge will be acquired?	o Know how to do research, and how to communicate results o Know and understand one's own limitations and strengths o Understand reality, learn to be flexible, deal with complexity
What will they understand about learning process?	o Know where to look, how to analyze, interpret, conclude from data o Use transdisciplinary and whole-systems thinking o Know how to ask relevant questions, process the answers
What will they learn about action and applications?	o Become open and ready to explore opportunities for practice o Gain ability to moderate among people with diverse views o Gain a broader perspective about potential career choices

Conclusions

We conclude from this workshop that integrating research and teaching at the university level in courses on organic farming and agroecology can bring greater motivation to both students and teachers, and that there is a higher probability of finding answers to society's questions. As compared to a more static and known learning environment, students will be encouraged to explore the unknown, applying their new knowledge and experience to real world situations where the answers may not be known. Dealing with complexity, uncertainty, and change will be important for our graduates, and how we design the learning landscape to best help them cope with that exciting future is the largest challenge facing us as educators. We think that integrating research with teaching will help in the process of both education and research. What they share is the process of learning.

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How do farmers research and learn? The example of organic farmers' experiments and innovations: A research concept

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Key words: Farmers' experiments, Organic farming, Local knowledge.

Abstract

Experimenting, adapting and innovating are central features of farmers' activities all over the world. Farmers hold valuable knowledge about their environment, they actively do experiments, and have their own research traditions. The development of organic farming systems is continually evolving through the experiments and innovations of organic farmers. So far, there has been little attempt to study the nature, characteristics, and factors associated with the experimental processes of farmers in a systematic, comprehensive way. A current research project investigates learning processes of organic farmers in Austria, Cuba and Israel through researching the multifaceted experiments they conduct and the innovations they obtain as possible results. This paper presents the research concept of the project.

Introduction

The history of farming shows how farmers have constantly developed and adapted their farming systems to changing agro-ecological and socioeconomic conditions. Farmers have an intimate knowledge of their local environment, conditions, problems, priorities, and criteria for evaluation, and they are actively engaged in experimentation as a part of their farming routine (Chambers et al. 1989, Rhoades and Bebbington, 1995, Sumberg and Okali, 1997). Organic farming research developed through pioneer farmers and scientists in the 1920s. Formal scientific research activities began in the 1970s through a few private research institutes. Organic farming chairs at universities and organic farming projects at state research institutes were only established later (Niggli and Willer, 2000). Therefore, organic farmers themselves have been responsible for most of the advances and innovations in organic farming, and have always researched topics pertinent to their production systems. Not surprisingly then, organic farmers have become the leaders and experts in this field (Bull 2000; Scialabba and Hattam, 2002). Through investigating farmers' experimental processes, formal researchers can broaden their epistemological base by understanding the importance of observation and experience, as well as tacit knowledge, and by learning from farmers' strategies how to deal with complexity (Hoffmann et al., 2007).

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Objectives

A research project about organic farmers' experiments and learning processes is carried out between January 2007 and December 2008. The objectives of the project are:

• to generate empirical knowledge on the processes by which organic farmers' local knowledge is created (Figure 1);
• to identify and define motives, topics, methods and outcomes of farmers' experiments;
• to understand the factors associated with variation in organic farmers' experiments within and among sites;
• to define the links between organic farmers' experiments and the local agricultural communication systems; and
• to understand the role that experimentation plays as a mode of learning and a strategy to deal with changes.

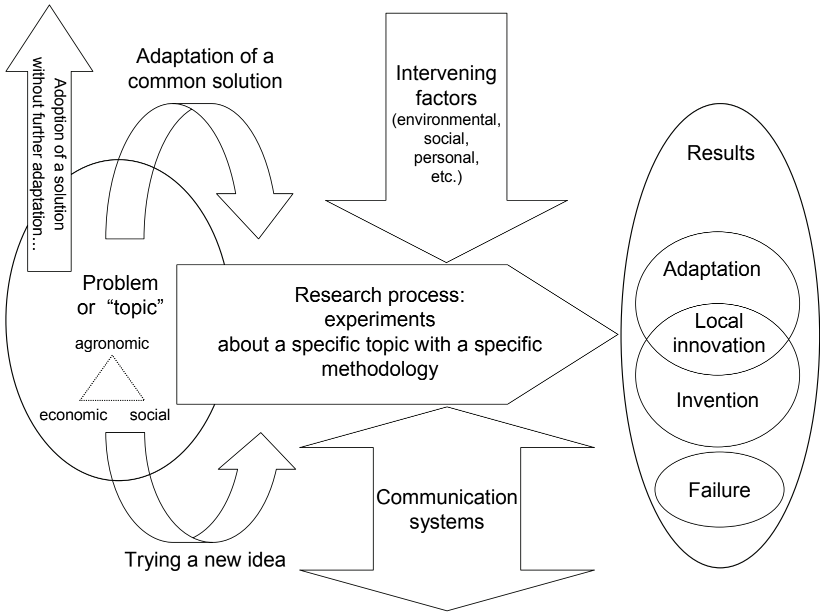

Figure 2: The research process as context to study farmers' experiments

Methods

The research project is conducted in Austria, Cuba and Israel by 3 PhD-students, as well as several master students. The countries were selected to represent organic farmers in i) different environmental conditions ii) different agricultural systems iii) different socio-economic conditions and iv) different phases of the organic farming movement.

The first field research phase of the project was carried out between July and December 2007. In the first field phase, 40 to 50 personal in-depth interviews with organic farmers, as well as several interviews with experts (e.g. advisors of organic farmers' institutions, scientists, etc.) were completed in each country. A purposeful stratified sample, based on maximum variation regarding agricultural zones, farm structure, infrastructural conditions, and types of farmers was applied. Farm walks as well as photographic documentation were realized in the course of the visit on organic farms to complement the interviews. Timelines were used to track changes at the farm level, based on the hypothesis that changes are either triggers for experimentation or the results of experiments.

Recorded interviews were transcribed, coded and analyzed with the help of the software package Atlas.Ti©. This first qualitative analysis is currently going on. Structured quantitative data (sociodemographic and farm data) was stored in an Access Database and facilitates a multivariate analysis with specialized software packages (e.g. SPSS).

Conclusions

Farmers' experiments are one important source of information and knowledge that supports the evolution of agricultural practices and systems (Rhoades and Bebbington, 1995; Sumberg and Okali, 1997). Organic farmers gain practical experience and build up local knowledge by experimenting. Practical experience, accumulated wisdom and traditional knowledge offer valid solutions, tested by time (IFOAM, 2005).

Numerous recent publications draw attention to farmers' experiments and local innovations (e.g. Reij and Waters-Bayer, 2001, Bentley, 2006, ILEIA, 2000), mostly by using case studies of peasant farmers in developing countries. To develop a comprehensive understanding of farmers' research, it is important not only to focus on marginal areas, but to consider diverse social, political and natural conditions. Furthermore, there has been little attempt to look systematically at the nature, characteristics, and the factors associated with the experimental processes of farmers.

Advances and innovations in organic agriculture have so far been done mainly by organic farmers themselves. These processes of experimentation and innovation in organic farming have not yet been assessed scientifically. Understanding which role farmers' experiments play, improves our understanding and knowledge on the complex interactions that organic farmers face in their daily farming practices. Conducting a comparative study about organic farmers' experiments in three different countries permits us to determine the nature of farmers' experimentations. Furthermore the factors associated with variations in the experimental processes, within and among sites are being analyzed. This research contributes to the study of learning processes, and enhances the understanding of the links between organic farmers' experiments and local agricultural communication systems.

Acknowledgments

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Development of organic farming in distant rural Māori communities in New Zealand through successful participatory approaches

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Key words: Participatory research, Māori communities, New Zealand, traditional knowledge, agronomical tools

Abstract

A research partnership was initiated between scientists of Crop and Food Research and rural Māori communities in the Tairawhiti region of New Zealand to help these communities with the transition from extensive agriculture to intensive organic horticulture. Within the project, growers are working together with agricultural scientists, extension specialists and social scientists using participatory approaches, what has proved to be a powerful tool for increasing the relevance and effectiveness of research for these communities. Progress towards original goals has been slower than expected, but mutual trust and developed relationships between the scientists and the community were recognised as the key factor in the project, and both groups were able to learn new and valuable skills. Many hands-on tools and techniques that made a real difference within the context of local organic vegetable cropping were developed and successfully employed.

Introduction

The Tarawhiti district (Fig 1) is a remote and predominantly Māori region with traditionally high unemployment and low rates of economic development.

Figure 1: Tairawhiti district (dark) situated on the East Coast of the North Island of New Zealand

The district covers 8330 square kilometres, almost 5% of New Zealand's total area, with 40,000 ha of rich alluvial river flats, ideal for growing crops with the remainder of the area mainly hill-country, well suited to farm sheep and cattle. The total population of the district is 45,000, a third of which is spread sparsely throughout the rural

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countryside or in small townships along the extensive coastline. In 2000, a joint local and central government taskforce was established to promote the development of the region. They concluded that organic production (already practiced on a small scale by some landholders in the region) represented a viable use of under-utilized Māori land and recommended further research into how organics might be further developed in the district. In addition, around 50 organic, most Māori growers with access to land areas ranging from a half an acre to several hectares, formed the East Coast Organic Producers' Trust (ECOP), based in Ruatoria, Waipiro Bay, Tiki Tiki and Tolaga Bay.

Objectives

The ECOP Trust produced a Strategic Plan which detailed their common agreement to develop their land for commercial organic vegetable production with the goal of increasing employment and improving the well-being of their East Coast community. Together with Crop and Food Research (CFR) an Implementation Plan was developed. ECOP and CFR successfully applied to the Foundation of Research, Science and Technology (FRST) for a programme called "Science for Community Change" was established to aid the development of a profitable and sustainable organic industry on the East Coast using participatory approaches (Kerckhoffs et al, 2006). An additional aim of the project was to improve the ability of scientists to work with rural Moāri communities. The specific goals were jointly finalized (at the start of the project) by ECOP and the science team at a *hui* (formal meeting) in 2003 in Ruatoria: (1) to help East Coast Māori make the transition from extensive agriculture to intensive organic horticulture; (2) to provide scientific, education, and extension services to assist ECOP to develop and implement best organic vegetable farming practices; (3) to design methods to promote beneficial change in rural Māori communities and production systems. ECOP was strongly quided by its original vision to promote values of *tino rangatiratanga*, *kaitiakitanga* and *whanaungatanga* (approximately translated as independence, guardianship, and relationship, respectively) in the East Coast community. There was also a great desire to revive the declining cropping tradition among *Ngati Porou* growers reflected through a mixture of belief in the cultural importance of traditional cropping with a strong desire to provide a positive social and economic example in order to attract back the youth of the community to the region. There was also a strong belief in the health and environmental principles of organics, which are closely aligned to their traditional cropping practiced over many generations.

The project joins ECOP Trust with a team of crop scientists, technicians, a local agricultural consultant complemented by social scientists, and provide agronomic advice to ECOP members while carrying out various organic crop trials on members' land to determine which crops are most appropriate for East Coast conditions. Many (international) students are involved, including several Māori students from the district. The project is also designed to improve the ability of scientists to work with rural Maori communities, and as such ECOP members provide informal and formal advice and training to CFR regarding *Māori tikanga* (protocol and traditions). Most project interaction takes place through workshops and field walks, which are designed in consultation with the local growers and their community with a clear focus on both organics and *matauranga* (traditional knowledge) as guiding principles. Local *hui* (meetings) are held at *marae* (Māori meeting houses) throughout the district (Fig 2). The initial focus was predominantly on many technical soil and cropping issues, like land management and agronomy with topics as soil (fertility), management of weeds, crop selection and winter cover crops. Other topics were subsequently added, and included market access (e.g. interaction with organic wholesalers outside the district), post-harvest and quality issues of their crops (e.g. optimising conditions during curing, storage and transport), 'adding-value' to locally grown products and building viable businesses (including topics like marketing, labelling, food safety). Over the course of the project several topics were revisited to cater for newcomers and for re-newed interest within the original group of growers. Some very practical and hands-on tools are being developed, e.g. a series of cropping calendars (A2-sized wall-planners) for kumara and Māori potatoes (Cropping Calendars, 2006; 2007), the development of a kumara curing cubicle (a low-cost solution to properly cure the kumara after harvest), the development of a mulch-system to enhance kumara growth/yield with additional benefits (e.g. water savings, and weed control). *Hui*, workshops, field-walks and other forms of interaction (e.g. newspapers, radio and TV) are the principal communicating techniques, and are characterized by its interactive and hands-on nature. In addition other scientific information is provided in hand-outs as well as *Te Panui* (newsletters/technical sheets) and on our website of the project (www.panui.org.nz)

Figure 2: Participants of a 3-d hui at Hauiti Marae in Uawa (Tolaga Bay) in August 2007 with topics: "Organic niche markets", "Getting into business" and "Taste of the East-Coast".

Discussion

Despite considerable enthusiasm generated at its inception, the project progressed more slowly than hoped or planned. ECOP's membership had dropped to a current active membership of 10-20 growers, yet at the same time the project has (as planned) attracted other community members not formally attached to ECOP, to its activities. Members of the science team describe an initial slow and sometimes frustrating period of trust-building and the perceived pressure to prove themselves to the growers and the communities involved. During the early stages growers were often reluctant to participate fully in the project, with low attendance at workshops and field-days, which was frustrating as workshops were a costly and time-consuming undertaking involving travel times in excess of 5 hours each way. However, some great achievements have since been made during the course of the project: (1) the emergence (and subsequent empowering) of young Maori entrepreneurs as a result of the exposure of Maori communities to new land use options and market opportunities.

These community leaders are early adopters of the sustainable agricultural practices promoted in this programme and leading others by example. (2) The increased exposure of the science team to *matauranga* (traditional knowledge) and the explicit acceptance by growers and scientists of the need to strengthen and build on mutual experience and understanding. This improved understanding has been instrumental to develop more efficient collaborative research outcomes. (3) The substantial extension of networking beyond ECOP into the wider community, evidenced by wider community participation in *hui* and workshops (29 in total) and field-walks (12 in total); and by individual networking both by Maori growers and scientists. This has significantly empowered local communities into cropping. (4) A major extension of research activity in favour of products targeting high value, niche markets (e.g. promotion of Māori potatoes to the restaurant market, novel products like kumara wine, pickled walnut, and the like). This goes well beyond the original focus on (organic) production of vegetable crops (Māori potato, kumara) alone. The total cropping area has been significantly increased and, on average over the study area, had doubled with many new paddocks now being established for cropping. In addition, the geographic spread of the project has increased the potential of cropping on the East Coast. The volume of produce sold in the East Coast has significantly grown during the period of the programme with niche markets established for many. Both scientists and growers characterize their involvement with the project as profoundly positive. All growers feel the project has greatly improved their ability to grow vegetables commercially. Both parties characterize the understanding, trust, and respect that have developed as crucial and there has been an increasing and ongoing sharing of knowledge amongst all parties (Bruges and Smith, 2007).

Conclusions

In the region the extent of organic cropping has extended along with increased volume of organic produce for the market (within and outside the district). Much more importantly, we have evidence of community development, a much more positive and entrepreneurial spirit, and an expanding level of community interaction with the science team. This reflects substantial capacity building both within the community and within the science team itself. Many meaningful tools and new techniques have been successfully developed by the team and implemented by the local growers.

Acknowledgments

All growers and scientists involved in this project for their shared passion, commitment and dedication. This work is supported by Foundation for Research, Science and Technology (C02X0305). For more information: www.panui.org.nz

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Promotion of Organic Vegetable Production through Farmers' Field School in Chitwan, Nepal

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Key words: Farmers Field School, Biopesticides, Participatory Guarantee System

Abstract

Organic vegetable production is important for economic uplifting of farm community. Research and development activities were carried out to promote organic vegetable production in Chitwan. Activities were carried out in four farmers groups in Chitwan district. Sidhuwa modality of group farming was followed for effective implementation of activities. Farmers' Field School was conducted to evaluate the effect of different organic pesticides on winter vegetables. Different biopesticides had differential effects in yield and disease suppression of winter vegetables but mixture of more than one biopesticide was effective in controlling major diseases and better yield of crops. Thus, this study showed that there is wide scope for use of biopesticides in organic vegetable production. However, this result should be verified by repeating same experiments for at least three seasons.

Introduction

Vegetables are important crops of economic value in Nepal. They are grown in wide range of agro-climatic zones covering 145 thousands hectares of land (CBS 1997). High value crops account for 8 percent of the total cropped area however, contributes for 14 percent of total agricultural GDP. Value of vegetable production is 45 percent greater than that of fruit production (APP, 1995).

Nepal is not self-reliant in vegetable production for its mushrooming population. Major factors for insufficient vegetable production include poor technical knowledge, weak marketing system, ineffective management of farmers' cooperative, post harvest loss, instability of vegetable price and significant pest damage. At the same time, high value crops are often heavily sprayed with chemicals with the consequent danger of pollution (APP, 1995). Unintentional human poisoning by chemical pesticides was as high as one million per year, out of which 20,000 people died in Asia (APO, 1996).

Vegetable demand is increasing year after year due to change in food habit of people with rapid urbanization process. There is about 5% increased in urban population per year and demand of vegetable has been increased with increasing urban population. Dhadhing and Chitwan Districts are major suppliers of fresh vegetable to the country capital. There is wide scope for commercial production of vegetables but serious concern of pesticide use and associated hazards became serious concern.

Organic agriculture deals with identifying the causes of problem rather than treating the symptoms after they appear (IFOAM, 2002). Research and development activities were designed to promote organic vegetable production so that farmers' ability to identify problems, their causes and recognizing relevant solutions can be

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strengthened. This forms base for sustainable agriculture and ultimately the sustainable livelihood of farmers.

Materials and methods

Shukra Nagar and Fulbari VDCs of Chitwan district were selected for research and development activity. Group discussion and strengthening activities were conducted in project area. Altogether four groups of vegetable growers have been formed in project sites of Chitwan. Two groups were formed in Fulbari and two were in Sukranagar. Participatory and collaborative approach was adopted for implementation of project and generation of outputs.

Farmers' Field School approach was followed for organic pest management in winter vegetables in Fulbari VDC, Chitwan. Twenty nine farmers of Organic Agriculture Production Cooperative Limited were involved in field school. The cooperative included members from both of the farmers group we worked for the promotion of organic agriculture. Five treatments were compared in four winter vegetables. Treatments included were use of farmers' practice of using liquid manure, three organic pesticides namely Sanjivani (*Trichoderma viridae*), Daman (*Beauveria bassiana*), Surakshya (*Pseudomonas fluorescens*) and mixture of these three biopesticides in winter vegetables. The vegetables used for comparing effectiveness of organic pesticides were Potato (*Solanum tuberosum*), Cauliflower (*Brassica oleraceae cv. botrytis*), Pea (*Pisum sativum*) and Tomato (*Lycopersicon esculentum*). Effectiveness of the applied treatments was compared for vegetable crops. Each treatment was replicated three times and average marketable yield of each treatment were recorded. The plot size was 2 x 1.5 m^2 for each treatment. Farmers analyzed agro-ecosystem of the research plots and discussed over the problems observed by farmers during field monitoring. Facilitators of the field school assisted group to locate the solution and provided technical support when needed for group.

The project adopted Siduwa modality as farmers co-operative in Sidhua, Dhankuta was the most successful cooperative for production of commercial vegetable in Nepal. They followed group approach in vegetable production and marketing. For promotional pathway, series of stakeholders' workshops were conducted on each project sites. These workshops became helpful in disseminating successful practices relevant for promotion of organic vegetable production in Chitwan. Similarly, district level stakeholders workshops and one inter districts stakeholders workshops were also organized. Participatory Guarantee System for marketing of vegetable was also practiced in Project sites.

Results

Research and development activity revealed that there was significant increase in area under production of organic vegetables. Farmers adopted organic vegetable production practices in their farms after their empowerment through series of consultation meetings, trainings and seminars. Farmers' Field School became effective tool for technology transfer in organic vegetable production. Farmers developed their idea on organic vegetable production through series of empowerment activities like formal and informal discussions, trainings, field visits and tours in vegetable production pockets.

Farmers Field School on organic Vegetable production strengthened farmers toward organic pest management, basic cultural requirements and practices for production of selected vegetables. This approach of activity implementation made farmers able to analyze their agro-ecosystem, interpret them and take relevant action against problems. This became effective tool in sharing experiences of farmers among each other and involved various technical and social components (Table 1) for empowerment of community in organic agriculture and cooperative farming practices.

Tab. 1: Technical and social components of the organic vegetable production strategy adopted in Fulbari, Chitwan, Nepal

Key Technical Components
• Regular field monitoring of growth parameters
• Elimination of infected planting materials by disease
• Rouging and field sanitation
• Preparation of organic pesticides using local materials
• Techniques of pesticide formulation and spraying for organic pest control
• Ecological balance tools for maintaining equilibrium
Key Social Components
• Reaching community consensus on OPM implementation
• Formation of a village level committee for OPM implementation
• Enforcement of community-agreed incentives and sanctions
• Regular monitoring of OPM implementation by community members

Comparison of effectiveness of different organic pesticides in winter vegetables (Table 2) revealed that yield of cauliflower was highest in *Trichoderma* used field followed by *Beauveria*. *Pseudomonas* was most effective followed by mixture of three biopesticides for cultivation of Pea. Tomato and potato yielded highest when mixtures of these three biopesticides were used for disease management.

Tab. 2: Effect of different organic pesticides on yield of winter vegetables

S.N.	**Treatments**	**Crop Yield (Ton ha^{-1})**			
		Cauliflower	***Tomato***	***Pea (Pod)***	***Potato***
1	*Trichoderma viridae*	15.33	49.00	8.67	33.33
2	*Beauveria bassiana*	13.67	44.00	9.33	33.33
3	*Pseudomonas fluorescens*	11.00	46.00	12.67	32.33
4	Liquid manure	10.33	45.00	9.67	40.00
5	Mixture of 1, 2 & 3	12.67	53.67	10.33	43.33

In overall, mixture of various bio-pesticides was effective in obtaining good harvest of crops tested.

Discussion

Adoption of participatory and collaborative approach in dissemination of information, skills and technology to community became effective in implementing research and development activities. Group approach of farming vegetables in wide are helped in development of effective pest management practices, sharing of problems and success experiences of farmers thus minimizing risk of crop failure and marketing.

Comparison of various biopesticides in farmers' field indicated that fungal diseases of Solanaceous crops are better controlled by use of mixture of more than one pesticide than use of single pesticide; however single pesticides were also effective for some other crops. Effectiveness of pesticides was different for legumes, crucifers and solanaceous crops even in same season. Overall effect of mixture of three biopesticides was the best for controlling diseases in winter vegetables.

Conclusions

Promotion of organic vegetable production activities implemented in Fulbari and Sukra Nagar VDCs of Chitwan became effective for empowering community in organic agriculture. Farmers' Field School approach became effective means of technology transfer to the community. Among various treatments compared in farmers' field, the highest yield of cauliflower (12.67 ton ha^{-1}), tomato (53.67 ton ha^{-1}) and potato (43.33 ton ha^{-1}) was obtained when mixture of *Trichoderma, Beauveria* and *Pseudomonas* was applied for pest control. However, pseudomonas became effective in higher pod yield of pea among other treatments.

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Research methodology

Towards cognitive holism in organic research

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Key words: development of organic farming, scientific methods, holistic science

Abstract

In the course of the close interplay between any scientific approach and its object, research has a modifying impact on the latter. The same is true for agriculture as scientific object. This is a particularly evident problem in organic farming, as the worldview of organic farming, arguments in marketing and farming practice seem to be in contrast to contemporary academic science which is, however, of great significance for organic research. Thus, organic research often appears to be carried out on the same theoretical basis which is opposed by organic practice and its ethical and philosophical backgrounds. At various levels, the apparent antagonism between holism and reductionism is part of this problem. This paper discusses whether holistic science is necessarily in contradiction to analytic and reductionist methods, or whether different scientific approaches could be brought together and linked in a cognitive process of building wholeness in thinking and imagination.

The problem

In 1906 a German agricultural scientist published an extensive paper on “Agriculture and Science” (Rümker, 1906), in which he suggested that the only chance for agricultural science to develop is to become specialized in different disciplines. In the same paper the author wrote: “in their practical application on the farm, the branches of agricultural science must intimately interact and harmoniously merge to become a well functioning organism”. Thus, at the beginning of agricultural industrialization, Rümker formulates the concept of a farm organism, but at the same time recommends that agricultural science should take on the disciplinary modes of thinking of academic research. Just a few decades later, agriculture became more and more divided into highly specialized parts, and many of the problems with which the organic movement struggles today derive from this specialization. It is a historical fact that Rümker's scientific vision conquered his agricultural vision, and that the reductionist academic mode of thinking altered agricultural reality rather than the other way round (Zimdahl, 1998; Wieland, 1999). Thus, science has a considerable definition power on what is true and necessary. In the framework of organic farming, however also ethical and philosophical concepts exist about truth and necessity apparently contradicting the contemporary mechanistic concepts of “life” and economics agricultural science is built on. Bearing this in mind, it is important to be aware of the mode of thinking that goes along with today’s organic research.

Organic farming is as well ethically, practically, and concerning its market arguments based on these contradicting concepts – at least partly. But what is currently the relationship between organic farming and organic research? Is practical organic farming, which aims to take account of the complexity and entirety of the agrarian context (e.g. IFOAM, 2005), complemented nowadays by a research practice that

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supports its aims, or not? Or could it be that, although certain research activities appear to support organic farming by proposing helpful solutions to practical problems, they intrinsically contradict key organic ideas and aims? In a major paper about the paradigmatic background of organic agriculture, Wynen (1996) argues that organic farming is based on a markedly different paradigm than conventional farming and, equally, that research focusing on organic farming is just as far removed paradigmatically from conventional agri-science. But is the different practical paradigm necessarily reflected by a different scientific paradigm? Drawing on work by Lockeretz (2000), it seems that organic farming as an object has not significantly influenced research methodology; instead, organic scientists generally adhere to the conventional academic research practice used by colleagues concerned with other areas of inquiry. Following Alrøe & Kristensen (2002), this has an impact on the reality of organic farming practice. If the understanding of nature underlying the concepts of organic farming is not covered by accepted scientific descriptions it will again and again be very difficult to explain these concepts convincingly. At this point, a task of science is involved which is not the applicability of results in practice but rather the applicability for education and gaining of understanding and general awareness. Concerning the organic farming concepts this task appears to be essential for organic research. A clear need exists for closing the gap between ethical claims and scientific understandings about the objectives of organic research. To cover this need can not only be the task of ethical philosophers, but it is rather the duty of the researchers themselves, as long as they make the same claims by calling themselves “organic researchers”.

A cognitive holistic approach?

But could it be, that the contradiction within the suggestions of Rümker (1906) is only apparent and that the core problem is not the disciplinary research itself but the lack of bringing things together into the mode of organism? Our suggestion is that to a considerable degree this organism-understanding has to be built within ourselves, that this organism is a (justifiable!) product (image) of the human consciousness. That requires (i) bringing parts together (maybe, more concisely: thinking parts together) and (ii) involving ourselves and our ethical and aesthetical sagacity into the appreciation of the research results. This means however, describing research objects and processes not only in functional but also in qualitative terms. And qualitative terms have the characteristic that they appear close to semantic meanings added by the describing subject to the described object. In the contemporary scientific framework this is a problem. But we have at least to ask whether any human awareness can be free from (even subtle) personal involvement of the subject with the object. The physicist Fischbeck (2003) argues that “life” and “organism”, as phenomena of self-organization, are comprehensible only when we see them as meaningful systems that rely on communication between the interacting parts. And communication is comprehensible only as transmission of semantic content. This argumentation comes very close to the term “organism” used in organic farming. It means that the term “organism” implies discovering (or ascribing) meanings to natural objects and beings. This is possible only on the canvas of individual involvement, thinking, and awareness.

The suggested approach we will explain by the example of the positive effects of organic systems on healthy milk fatty acids: It is a well established fact that grassland based dairy systems, as they often occur on organic farms increase the concentration of beneficial fatty acids like omega-3 fatty acids (n-3 FA) and CLA in milk (e.g. Leiber et al., 2005) and it has already become a marketing claim for organic milk products.

However, an understanding of this fact and of its real significance (or non-significance) is almost lacking. Farmers are bound to the very simple argument "healthy cows from grassland give healthy milk" and consumers have to accept, that n-3 FA prevent them from heart diseases and occur particularly in organic milk. How is it possible to gain a deeper understanding which also enables practitioners and consumers to be aware of the underlying context? From ruminant physiology it is clear, that the main n-3 FA in milk, α-linolenic acid, stems directly from the plant and appears in milk only proportional to those small amounts which are not converted into other FA by ruminal fermentation. It is a plant substance which "survives" the ruminant digestion (cf. Leiber et al., 2005; Leiber, 2006). From human physiology the n-3 FA can be described as active substances which have particular significance in the development of the central nervous system and the retina of the eye. With these aspects, the term "n-3 FA" can be saturated as to mean a plant-derived substance which is saved throughout the cows' metabolism and which is important for the nervous system. "Milk fat quality" thus, appears within a larger framework than only the quantitative presence of certain substances. An aspect of milk quality, in this perspective, could be the mediation of plant qualities via the cows metabolism to human nutrition (cf. Leiber, 2006). As well for the organic farm management as also for marketing arguments this perspective could be fruitful to deepen. It does not go without analytical science but it goes beyond.

To follow phenomena of the appearance of an object under different conditions – in this example the appearance of n-3 FA in the plant, in the ruminant digestion and in the endogenous metabolism of animals and man - may discover the nature of the object in a particularly comprehensive way. However, perhaps the precondition for such an approach lies in acceptance that *understanding* is based on imagination and not only on data. This approach can be thought of as a virtual kind of Goethean experiment. As so well described by Stephenson (2005), J.W. Goethe saw the experiment as a means of understanding an object by making it appear under varying conditions and connecting the different appearances in a cognitive-aesthetic process. Thus, Goethe proposes the idea that it is the variation of appearances that indicates the inner nature of things. This approach does not entail a rejection of analysis; what it does imply, however, is that the results of an experiment need to be put back into a context by the cognitive activity of the scientist, and that the meaning of the object becomes clear not in the single analytical result but in the variation of the appearances. The wide range of agri-scientific activities presents an opportunity to bring the variations together.

To bring it back to our example: after viewing the analytical fact of certain FA concentrations within a larger context, the next step could be to ask, e.g. whether there is any affinity between plant characteristics and the nervous system in mammals and whether the milk necessarily mediates this affinity to the offspring, etc. We found the "affinity" on the biochemical level in form of n-3 FA, appearing in the different places but we can also find it in terms of morphological analogies or similarities. Particularly, if we include the bones, covering the central nervous system (spinal column and skull), it has in several respects striking correspondences with the shape and development dynamics of annual herbs (Leiber, 2006). We have to be very careful with such analogies; however, in the organic scientific community, which asks for the "inner quality" of products it should be not too strange to ask cautiously for an inner correspondence between certain plants and the central nervous system. If we consider, that these annual herbs occur particularly frequent in those kinds of pastures which lead to high n-3 FA in milk, this gives a picture. Such a picture, although it is clearly subjective may help to reach a different level of understanding the "whole". It could help to reach awareness via personal involvement – and that could be an awareness which enables the recipient not only to accept biochemical facts but also to go in to the phenomenon – thinking and imaginating. The compulsory condition, of course, is the permanent possibility to develop or even to falsify any such ascriptions within the scientific and the public dialogue.

Conclusion

If organic research relies on the same scientific mode of thinking that has led to conventional agricultural solutions, it can be expected, in the long run, to catalyze a conventionalization of organic farming practice. Holistic science is repeatedly stated as an alternative, but the relation between holistic and analytical / reductionistic approaches is often considered as oppositional. We have suggested a cognitive approach to holism which can function as a complement to recent research practice rather than as a substitute for it. Our suggestion is to put scientific facts, derived from different methodologies, into common horizons of reflection and into larger and more differentiated cognitive contexts than is usually the case. The suggestions made here are intended to offer a different perspective on holism. They are by no means intended to derogate other, more empirical holistic approaches.

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Research into Practice: Mind the Gap

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Key words: Organic research; dissemination; adoption; advice.

Abstract

The uptake of organic research by commercial producers has been variable due to a number of factors including lack of access to research findings, financial pressures, research priorities, market demands and producer perspectives. Consequently "best organic practice" is not universally applied and apparently intractable problems remain, even though in some cases solutions are available. This paper identifies the role of advisers in supporting organic farmers and the establishment of a system for disseminating the results of research through a number of routes including a web-based archive, advisory leaflets and workshops.

Introduction

Research is a critically important component of the development of agriculture. It provides new insights into all aspects of food production and related impacts on society and the environment as well as guidance to policy makers and support to farmers through the resolution of technical problems and demonstration of new and more effective techniques. During the last 25 years there has been a substantial investment in organic agricultural research in the UK. This paper considers the role and effectiveness of that organic research and investigates mechanisms for furthering the dissemination and uptake of research by farmers.

Materials and methods

The paper is based on the personal experiences of the author, who spent 15 years as Head of the Organic Advisory Service in the UK, working closely with researchers at The Organic Research Centre (ORC) at Elm Farm, and more recently Director of the Institute of Organic Training and Advice (IOTA) — throughout all that time providing technical advice to organic farmers. It draws on some of the experiences of other countries, provides a summary of the impact of research and an analysis of different mechanisms for disseminating the results of research.

Results

During the 1985 Cirencester Organic Conference there was an audacious proposition that one of the Ministry Experimental Husbandry Farms (EHF) should be converted to organic. Some 15 year later there were four of the EHFs with organic units, no less than nine research institutions with organic sites, to say nothing of the five dedicated organic research sites linked to ORC and Garden Organic (GO). Until recently, annual spending on organic research was around £ 4.1 million a year, half of which was

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funded by the Department for the Environment, Food and Rural Affairs (Defra). (Organic Research Centre, 2003)

During this time, organic research has undoubtedly contributed to a better understanding of the farming system, of nutrient flows and the potential for more effective management to minimise pollution and improve productivity. It has provided some hard science on the positive impact of organic farming on the environment and biodiversity and much needed information for determining policy and support, but this has not been of much help to farmers. A great deal of work has been done on farming techniques: varieties, feeding trials, green manures, blight control, parasite control, weed control, mastitis management and so on. However there remain many intractable problems for farmers, for example, yields which in some instances are only 60% of conventional and many unanswered questions (Wynen, 1996).

Not only has the uptake of organic farming been slow but organic practices do not, with some notable exceptions, reflect the results of the considerable research effort of the last 20 years: crop and forage yields have not risen significantly, the fundamentals of closed farming systems are not routinely put into practice, animal breeding is still focused on production rather than health, use of antibiotics in dairy cows seems to have increased and there still remain negative environmental impacts from organic farming which could be eliminated with better management.

Organic agriculture has not been revolutionised in the way that might have been expected from the revolution seen in conventional farming. Perhaps this is because £4 million per year is actually a very small sum in research terms, perhaps it is because it is very difficult to research farming "systems" and concepts of "health and vitality". Or perhaps it is something to do with the psychology of farmers—those attracted to organic farming are not by their nature at the cutting edge of science?

It may also be because of the research itself. Has it failed to focus on the primary concerns of farmers? Is the research only confirming what commercial farmers have already discovered for themselves? Is it that we have false expectations of research? For example the value of research may be that a new concept or technique, such as stockless systems, is more widely understood and accepted, rather than resolving a technical problem. Organic research certainly needs to recognise that organic agriculture requires a different type of research (Woodward, 2002), tackling different and often holistic issues and it needs to be undertaken in a more integrated manner than is standard practice in conventional research.

Underlying all this is the fact that there is so often a gap between the publication of research and the findings getting adopted by commercial farmers. Sometimes the block is the sheer financial pressure on farming, sometimes market intransigence (demanding stringent cosmetic and processing qualities) and in some cases failure of the organic certification process, but it is frequently also about communication.

There have been valiant efforts at farmer engagement (ADAS, 2002). Some researcher-led projects have involved farmers throughout the process: prioritising issues, developing protocols, discussion of the results and even paying for their involvement, for example, the on-farm ORC cereal variety trials and the much-valued GO participative knowledge exchange in weed control (Turner, 2006). Such approaches have certainly succeeded in engaging farmers in the research and their positive feedback suggests that the work is valued, but how effectively the results are applied is not known.

A more "bottom-up" approach has even more to recommend it. Experience of research initiated and in part undertaken by farmers in the Netherlands (Baars, 2002), Germany and Switzerland is that there is a degree of ownership and engagement in the work which results in application of the findings on farm. Interest in research amongst farmers in the UK is mixed, therefore ensuring their involvement at the initiation stage requires a high degree of stimulation by an adviser working with a research organisation or in some instances by a marketing co-operative, as demonstrated by the Organic Milk Suppliers Co-op.

As advisers, we must take some responsibility here. We play a crucial role in engaging with research and ensuring that it is put into practice. One to one, on-farm advice from experienced organic advisers still provides the most effective means of communicating new ideas or techniques. Advisers typically do not have much time available for attending research conferences or trawling through research papers and the need to earn a living limits their professional development time. So how do they keep up to date? They do it by reading magazines, websites and reference books and perhaps attending 3 or 4 training courses per year. While some advisers are dedicated to organic farming there are many in the UK who advise both organic and conventional farming, so they have an even greater challenge to keep up to date.

In order to facilitate access to research, IOTA has established the UK arm of Organic EPrints—www.orgprints.org—a user-friendly and fully searchable web-based archive, which provides free access to over 10,000 papers from the majority of organic research programmes of Europe. IOTA has uploaded more than 200 papers during the last year, including all the Defra funded work since 2000.

To support advisers in the time-consuming task of pulling together the results of research from a number of sources, IOTA has also commissioned Research Reviews. Undertaken by experienced advisers, reviews of 21 topics are available on the IOTA website www.organicadvice.org.uk. These reviews are common-sense analyses of the research on critically important topics, such as dairy cow nutrition, the benefits of composting, protein crops, stockless arable farming, nitrogen management, energy management and minimal cultivations. The work has really put research results into a practical context of use in advising farmers.

Discussion and Conclusions

With the major shift in UK government research funding away from a dedicated organic programme to the Defra "sustainable agriculture research programme" there are serious issues for ongoing organic research priorities and funding. Private funding of research remains small but it is just as important as in 1985, and good dissemination will be ever more critical.

The establishment of a common archive of research results has been a useful contribution and collation of research results on the basis of subject has further helped overcome the limited time which organic advisers have in keeping up to date with research information. Subject-focused workshops have provided an opportunity for engagement between advisers and researchers and have been a valuable learning process for both parties.

Experience of the ability of research to influence organic farming practice has been mixed. What is clear is that no one means of dissemination will suit all situations. The nature of organic agriculture requires research of both a different type and methodology and a different approach to communication—one where farmers, advisers and researchers are engaged throughout the process. The form of that communication needs to be tailored to the particular needs of the recipients, whether they be farmers or advisers and to the type of information being communicated.

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Meta-evaluation of action plans – The case of the German Federal Organic Farming Scheme

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Key words: Organic farming policy, Policy evaluation, Organic action plans

Abstract

Meta-evaluation can be seen as a quality control measure of policies or programs. For that purpose, a formal methodology is used when assessing the quality of an evaluation work. The presented meta-evaluation is based on an adapted version of the evaluation standards used by DEGEVAL (German evaluation society). The well-balanced design of the DEGEVAL standards makes them widely applicable and useful also for conducting meta-evaluations. This paper presents the results of a meta-evaluation undertaken on the evaluation of the German Federal Organic Farming Scheme. Concerning most sections the quality of the underlying study is excellent.

Introduction

Evaluations have become an expected part of the policy cycle and are a well established technique to solve the problems that arise when implementing programs. However, it is crucial to question the way in which these evaluations are conducted. With this in mind, it could be helpful to take a look at the meta-level and to that effect, conduct a meta-evaluation. According to DEGEVAL (2003) the use of *general standards* can "help to raise transparency of evaluation as a professional code of practice vis-à-vis the general public". This paper presents the results of a meta-evaluation undertaken on the evaluation of the German Federal Organic Farming Scheme (FOFS).

Meta-evaluation in the political field of organic farming policy has not been applied up until now and this study can therefore be considered to tread on entirely new ground, scientifically speaking. The aim of conducting this meta-evaluation is to assess whether the evaluation of the FOFS is done in accordance to broadly accepted professional standards (in this case according to the adapted DEGEVAL-Standards, referred to here as *general standards*) and whether the findings follow a logical order. According to Widmer (1996), the outcome of a meta-evaluation can provide insights into the design and methodological configuration of evaluation studies ("How is the evaluation study constructed?"), as well as into the classification or the indexing of the standards ("Do the study evaluated meet the criteria?"). The main aim of this study was to investigate the specific methods used in the evaluation study, in order to improve upon future evaluation studies in the field of organic action plans.

Materials and methods

The meta-evaluation presented was conducted between October 2006 and February 2007, and was based on the official evaluation report (Becker et al. 2004). The *general standards* used are the "Standards for Evaluation" of the "Gesellschaft für

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Evaluation" (DeGEval; German evaluation society, 2003), with some adaptations (Stufflebeam 1999 and Stufflebeam 2001)[1]. The DEGEVAL standards are based, in principle, on the standards of the U.S. Joint Committee on Standards for Educational Evaluation. The well-balanced design of these standards makes them applicable in a wide range of situations and useful in conducting meta-evaluations. The *general standard* set is divided into four main categories: *Utility Standards* are intended to ensure that the evaluation is guided by both the stated objectives of the evaluation and the information needs of its intended users. *Feasibility Standards* are intended to ensure that the evaluation is planned and conducted in a realistic, thoughtful, diplomatic, and cost-effective manner. *Propriety Standards* are intended to ensure that in the course of the evaluation all stakeholders are treated with respect and fairness. *Accuracy Standards* are intended to ensure that the evaluation produces and discloses valid and useful information and findings pertaining to the evaluation questions (cp. DEGEVAL 2001). The underlying study was then analysed by the author of this paper with respect to the adapted set of standards.

As this meta-evaluation is planned as a desk study, not all *general standards* and sub-standards listed could be classified. Some of the valuations were not possible due to limited data. Regrettably, several interesting points e.g. concerning reliability and financing could not be evaluated in detail. In any case, the meta-evaluation helped to shed some light on the evaluation method used and accordingly improve the evaluation methodology in the field of organic farming support schemes. One important criterion is the analysis of stakeholder integration in the planning, implementation and assessment of an evaluation.

Every standard listed in Tab. 1 is itemized into some (3 to 22) sub-indicators. To provide an example, for the case of the standard *Stakeholder Identification* these ten sub-indicators are: (1) Clearly identify the evaluation client, (2) Engage leadership figures to identify other stakeholders, (3) Consult potential stakeholders to identify their information needs, (4) Use stakeholders to identify other stakeholders, (5) With the client, rank stakeholders for relative importance, (6) Arrange to involve stakeholders throughout the evaluation, (7) Keep the evaluation open to serve newly identified stakeholders, (8) Address stakeholders' evaluation needs, (9) Serve an appropriate range of individual stakeholders, and (10) Serve an appropriate range of stakeholder organizations. If all 10 sub indicators are quoted positive, the *general standard* would been quoted with 10 ☐.

Results

The meta-evaluation shows that the evaluators[2] have followed most of the applied standards. Concerning the section of *Utility, Feasibility* and *Propriety* standards, the quality of the study is excellent.

Looking at some of the shortcomings, one can point to the fact that not all points regarding *valid and reliable information* and a*nalysis of qualitative and quantitative information* were observed when preparing and conducting the evaluation study.

[1] The detailed list of standards can be requested from the author

[2] C. Becker, S. Ekert, J. Sommer and A. Zorn, see also list of references

Tab. 1: Meta-evaluation of the FOFS according to the prescribed set of standards

	≲	☐	≈
U1 Stakeholder Identification (max. 10 Pts.)	1	8	1
U2 Clarification of the Purposes of the Evaluation (max. 3 Pts.)	1	2	
U3 Evaluator Credibility and Competence (max. 10 Pts.)		8	2
U4 Information Scope and Selection (max. 10 Pts.)		10	
U5 Transparency of Values (max. 13 Pts.)	3	10	
U6 Report Comprehensiveness and Clarity (max. 14 Pts.)	1	13	
U7 Evaluation Timeliness (max. 10 Pts.)		6	4
U8 Evaluation Utilisation and Use (max. 13 Pts.)	1	10	2
F1 Appropriate Procedures (max. 11 Pts.)	1	6	4
F2 Diplomatic Conduct (max. 3 Pts.)		3	
F3 Evaluation Efficiency (max. 13 Pts.)	1	10	2
P1 Formal Agreement (max. 11 Pts.)	1	10	
P2 Protection of Individual Rights (max. 12 Pts.)		11	1
P3 Complete and Fair Investigation (max. 10 Pts.)		10	
P4 Unbiased Conduct and Reporting (max. 2 Pts.)	1	1	
P5 Disclosure of Findings (max. 11 Pts.)	2	7	2
A1 Description of the Evaluand (max. 11 Pts.)	1	8	2
A2 Context Analysis (max. 11 Pts.)	2	9	
A3 Described Purposes and Procedures (max. 12 Pts.)	1	8	3
A4 Disclosure of Information Sources (max. 11 Pts.)	1	10	
A5 Valid and Reliable Information (max. 22 Pts.)	6	12	4
A6 Systematic Data Review (max. 1 Pt.)			1
A7 Analysis of Qualitative and Quantitative Information (max. 20 Pts.)	10	9	1
A8 Justified Conclusions (max. 11 Pts.)	1	10	
A9 Meta-Evaluation (max. 11 Pts.)	10		1
Total	45	191	30
%	16,9	71,8	11,3
Appraisable (in %)	88,7		

Codes: ≲ = No (evaluation study is missing the standard), ☐ = Yes (evaluation study fits the standard), ≈ = No answer (No data available to evaluate that standard)

Discussion and Conclusion

The *general standards* (like the ones established by DEGEVAL) are in fact not precise enough to measure a specific program or project. These need to be supported and concretized by specific, *tailored standards,* such as those used in the FOFS evaluation. Nevertheless, these *general standards* could be seen as a tool for evaluators when preparing an evaluation. The consideration of such standards could help to ameliorate evaluation studies and safeguard utilization of the results by means of a more *user friendly* (or in the words of an evaluator - *stakeholder oriented*) format.

The standards used for this meta-study can be considered as very suitable for this sort of evaluation and can therefore be recommended for other evaluation studies in the field of organic action plans (e.g. the *European Action Plan of Organic Food and Farming*). In order to achieve transparency and guarantee a complete assessment of all standards and sub-standards, it is important to choose an evaluation scheme that includes these considerations. Furthermore, for a complete assessment of a study it is necessary to make sure that all documents and reports prepared during the evaluation (financing, treaties etc.) are accessible and analysed by the meta-evaluators.

As a final recommendation for designing future evaluations, it can be stated that a specific and deliberate set of evaluation standards ("*tailored standards"*) has to be adapted and calibrated in accordance to the examined topic (such as organic action plans). However, it is helpful for evaluators and can furthermore greatly facilitate a worthwhile evaluation study if a set of established and accepted standards (e.g. DEGEVALs *general standards*) are consulted when preparing the evaluation. Such improvements would increase the likelihood that evaluation results will be utilised, encourage greater acceptance of the outcomes and thus justify evaluation itself.

Acknowledgment

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The sustainable livelihoods approach: A frame for furthering our understanding of organic farming systems

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Key words: Sustainable livelihoods, organic agriculture, agricultural research

Abstract

The rapid development of organic agriculture on a global scale has led to an increased inclusion of producers in developing and transitional countries in the organic food chain. In order to enhance the theoretical frame for the analysis and understanding of the impact that inclusion in the organic food chain has on producers and their families, an analysis was conducted of the use of the Sustainable Livelihoods Approach (SLA). The SLA provides a holistic and integrative approach which researchers can use as the overriding frame for their research. The application of the approach is recommended as it enables us to maintain important elements of the sustainability vision, yet emphasises that a number of assets influence farmers' livelihoods and it maintains the focus on salience, legitimacy, and credibility in the research.

Introduction

Organic production and consumption has developed markedly on a global scale within the past decade, rapidly increasing the demand for organic products, in particular in the Western world (Yussefi, 2006). Greater demand for organically produced foods has, amongst other impacts, seen an increased reliance upon organic products produced in developing and transitional countries (henceforth termed developing countries). The globalisation of organic agriculture poses a variety of challenges for the direction of its future development, for example the increased global trade of organic products means that organic farming may face many of the same globalization challenges and threats to sustainable development as conventional agriculture (Byrne et al. 2006).

The rapid growth of organic farming in developing countries has brought about increased interest in the potential of organic agriculture to improve the livelihoods of small-scale farmers. This is, in particular, reflected in the increased integration of organic agriculture into the rural development agenda (see for example http://www.fao.org/organicag/). However, organic agriculture initiated under the guise of promoting development and alleviating poverty raises a variety of pertinent questions, for example, whether organic agriculture does, in fact, lead to improved livelihoods, whilst still securing the benefits inherent to organic agriculture.

The investigation of such complex situations requires a multi-scaled integrated approach which can enable the researcher to deal with complexity. One such approach is the sustainable livelihoods approach (SLA). The aim of this paper is to discuss the application of the SLA in investigating the impacts of organic farming on farmers' livelihoods.

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Materials and methods

This paper is based upon relevant literature within development thinking, organic farming and a review of the applicability of conceptual frameworks for livelihood analysis of organic farmers.

Results and Discussion

The Sustainable Livelihood Approach (SLA) was initially architected in a working paper by Chambers and Conway (1992), after which it was developed and applied in the implementation of development projects by international development agencies throughout the 1990's. The sustainable livelihoods framework, presented below, summarises the SLA. Messer & Valarini (2003) describe the aim of the framework concisely as *'a tool for understanding how household livelihood systems interact with the outside environment – both the natural environment and the policy and institutional context*'. Thus, the framework depicts a way in which livelihoods can be understood and analysed. A framework such as this should be considered as an analytical structure for guiding our thinking – understanding the complexity of rural people's lives and understanding the importance of upper level transforming processes and how they interplay with livelihood assets (the five capitals).

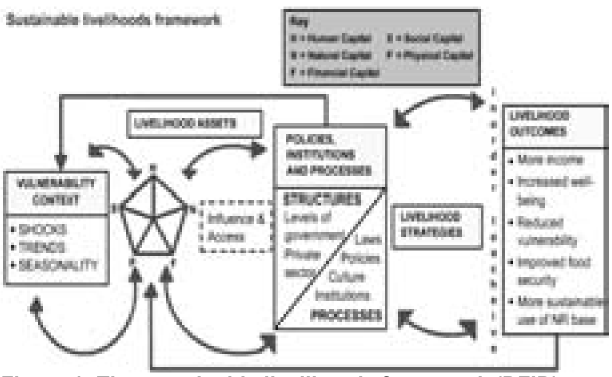

Figure 1: The sustainable livelihoods framework (DFID)

The strength of the sustainable livelihoods framework is that the conceptualization of people's lives assumes a more holistic approach than previously applied in development research, where indicators of project impacts typically accounted for indicators such as food consumption and income. Applying the SLA in an investigation of the impacts of organic farming on peoples' livelihoods forces us to take stock of the five livelihood assets and enables us to relate the status of these indicators with the influence of transforming structures and processes (for example institutions). For example, how do institutional or organizational structures and processes influence the status and access to livelihood assets? Analysis of the context within which people operate enriches our understanding of livelihood strategies.

As briefly discussed in the introduction, the application of organic agriculture as a tool for development may result in trade-offs. For example, improving local farmers' financial capital by linking them to an international market may have detrimental effects upon other livelihood assets, such as natural capital. Is this a desirable trade-off? Consider, for example, this situation vice-verse – restricting farmers' market access to preserve natural capital. This example highlights an important point to take into consideration when conducting research at this level of complexity. The SLA will enable us to provide a thorough analysis of what types of impacts organic farming can bring about within a certain context and how these impacts are interrelated.

In our current research, undertaking farm level studies of the agroecology of organic farming systems and the socio-economic impacts of organic farming in developing countries, we consider the SLA as a highly suitable guiding frame, essentially, using the SLA as a reviewing or impact assessment tool. Here a few examples of the impacts that will be considered using the SLA:

- How the growth of organic farming in an area has affected the livelihoods of different stakeholders. What types of impacts have there been upon the livelihood assets (including the difficult to quantify assets such as social capital) and what are the trade-offs.
- The adoption of organic farming in a village/region – how does this fit with people's livelihoods and who and importantly who are not the beneficiaries and participants.
- The framework enables us to link impacts at various scales and help in understanding causal relationships, for example linkages between household impacts of organic agriculture and policies, institutions and processes.

Rural livelihoods in developing countries are becoming increasingly separated from the actual farming activities (Rigg, 2006). This has important connotations for how we choose to conceptualize, and thus research rural people's livelihoods and emphasises the need to consider new guiding paradigms and new research questions in these contexts. Cash and Buizer (2005) argue that for research to translate into (and thus reflect) real-life situations, then there are three essential components which are necessary to meet: salience, credibility and legitimacy.

Salience relates to the perceived relevance of the information: does the system provide information that the users think that they can use, in a useful form and at an appropriate time? Credibility addresses the perceived technical quality of information: does the system provide information that is perceived to be valid, accurate, tested, or at least as likely to be true as alternative views? Legitimacy concerns the perception that the system has the interest of the users in mind or, at a minimum, is not simply a vehicle for pushing the agendas and interests of other actors. What is it about the SLA that can enhance salience, credibility and legitimacy of research conducted for agricultural development? The application of the SLA approach to scientific research can assist us in asking the right questions. An analysis of a problem situation using the SLA approach helps according to Farrington (2001) in (1) Identifying groups of people according to their main livelihood sources, (2) Identifying the main sources of vulnerability associated with these livelihoods, (3) Identifying the main assets supporting these livelihoods – in particular the inclusion of economic and social assets, (4) Identifying the qualitative aspects of these assets (5) Identifying multiple rural livelihoods – the heterogeneity of poor peoples' livelihoods and their ways of addressing poverty, and (6) The identification of policy areas which can influence and also specifically target certain groups.

The sustainable livelihoods framework provides researchers with a holistic and integrated view and understanding of the components and processes of peoples' livelihoods. This raises the question of the operational prowess of the framework. The usefulness, and thus the manner of application of the framework, is essentially set by the user (Carney, 2002). Therefore, the SLA should be used as a guiding framework for one's research – it is a conglomeration of many theories from various disciplines – the framework enables us to unify thinking that lays the foundation for these theories.

Conclusions

The aim of this paper was to analyse the sustainable livelihoods approach as a research tool within organic farming. The SLA draws together a number of disciplines, providing a holistic approach which researchers can use as the overriding frame for their research. The application of the approach is recommended as it enables us to maintain important elements of the sustainability vision, yet emphasising that a number of assets influence farmers' livelihoods and maintaining focus on salience, legitimacy, and credibility in the research.

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Challenges in Transitioning to Organic Farming in West Bengal, India

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Key words: developing countries, extension, Farmer Field Schools, Green Revolution, organic conversion

Abstract

This paper uses a case study of small-scale rice and vegetable producers in West Bengal, India to argue that some of the same infrastructural and technical roots to problems that plague small farmers attempting to use chemically-intensive farming methods also hinder their ability to fully convert to global-style organic farming. In particular, problems in accessing knowledge and technical inputs are likely to translate into difficulties in adopting and maintaining organic production practices. This case study raises the question of whether the global organic model, which is highly dependent on specialized, knowledge-intensive techniques and expensive inputs, offers a true alternative for the developing country context. A locally developed model based on low-cost, local resources and disseminated through local information networks with substantial farmer participation may offer a more viable alternative.

Introduction

At first glance, organic farming appears to offer a simple anecdote to the problems generated by the Green Revolution model of agriculture, such as decline of soil organic matter and nutrient-holding capacity, over-exploitation of groundwater, pesticide resistance, and toxicity to farmers and communities from pesticide exposure. However, adoption of certified organic farming, as commonly understood in the global context, presents a host of challenges to small-scale Third World farmers. Many of these constraints are similar to those hindering the improvement of chemically-intensive farming systems: inadequate extension capacity, lack of technical training materials, and shortage of capital to purchase costly inputs. The result is that the spread of organic farming in many developing countries has been slow. In India, for example, the International Federation of Organic Agriculture Movements estimates that an area of about 150,790 ha is under organic farming, representing only about 0.1% of the total cultivated land (Willer and Yussefi 2007). Moreover, more than half of India's organic production consists of export crops such as tea, coffee, and spices.

To illustrate the challenges of a transition to organic farming in India and other developing countries, we draw from a case study in West Bengal, India where an effort is being made to spread sustainable alternatives to chemical-intensive farming.

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Materials and methods

Fieldwork was performed in 2006 while based at Swanirvar, a rural development NGO in the district of North 24 Parganas in southern West Bengal. Numerous individual and group interviews were conducted with Swanirvar staff and leaders of farmer groups receiving support in sustainable agriculture techniques from Swanirvar. Also consulted were local, state, and central government officials in charge of agricultural extension, researchers at agricultural universities, and staff of other rural development NGOs. Participant observation was conducted at Farmer Field School-type extension meetings organized by NGOs or the government.

Results

The study site is characterized by a population density of 2,181 persons/sq km (Govt W. Bengal 2002) and approximately 75% of landowning households own less than 1 hectare of land (Dasgupta 2005). Over 60% of the cultivated land is under irrigation, and most of this land produces more than one crop per year. The advent of a dry season rice crop was fostered by the government in the 1970's and 1980's through programs which distributed kits with seeds of high-yielding varieties as well as chemical fertilizers and pesticides. These new technologies initially produced a spike in rice yields which continued for 10-15 years; however, farmers in the study reported 20-50% declines in yields in recent years. Field visits revealed that zinc and iron micronutrient deficiencies are common because of farmers' heavy dependence on commercial fertilizers such as urea phosphate. In addition, farmers require increased applications of pesticides for the same level of pest control, especially in vegetable cultivation. Some farms are even reducing their area under eggplant, one of the highest-value cash crops, due to mounting costs of production inputs and increasing difficulty controlling pests.

The onset of the pesticide treadmill has been hastened by a lack of information about active ingredients and their modes of action. In the absence of adequate government extension capacity, local pesticide retailers are the most common sources for advice on pest management (Jana 2004). Interviews with shopkeepers suggest little understanding about the importance of rotating pesticides based on different active ingredients. Furthermore, the newer generation pesticides that are more selective and have different modes of action are either unavailable or unaffordable. A village-level study showed that the majority of pesticides used on vegetables are still pyrethroids and older-generation organophosphates (Kole and Basu 2005), many of which have been banned or are declining in use in developed countries.

Given this inability of public extension and private sector industry to educate farmers with appropriate information about products that have been used for decades, the information vacuum for farmers trying to convert to organic agriculture is even greater. For example, having depended on broad-spectrum pesticides for more than two decades, farmer understanding of pest identification and invertebrate ecology is rudimentary, especially with respect to predatory insects. None of the NGOs engaged in IPM extension had good quality pest and predator identification guides for distribution to farmers. Government agriculture officials promoting IPM through Farmer Field School-type trainings also admitted to a lack of appropriate educational materials, and noted that the only books containing good photographs for pest identification are published in English.

Moreover, NGOs themselves have difficulty finding locally relevant information on organic methods. One organization, led by an individual with an advanced university degree, relied on contacts with scientists and institutes in New Delhi, over 1300 km distant, to obtain information on organic and biodynamic farming. NGOs without the means or English-educated staff to access scientific articles relied on the experience of their own staff members, who are typically also farmers, and the expertise of other NGOs.

In addition, just as they are unable to access newer generation synthetic chemical pesticides, local farmers have little access to high-tech organic farming inputs commonly used in developed countries, even when they have knowledge of these inputs. For example, a Farmer Field School training session organized by the Kolkata-based, government-run IPM Centre provided farmer trainees with detailed information about the use of pheromone traps and their function to monitor insect pest populations. However, these "natural" pesticides are often as costly or costlier than synthetic chemical pesticides. The cost of one pheromone trap, for example, is Rs 40-50, which is close to a rural labourer's daily income. The price of a litre of a product containing *Bacillus thuringiensis* (Bt), a natural pesticide commonly used by organic farmers in developed countries, cost up to Rs 1,000 (Singh 2002). Moreover, most such products are not sold in local villages. Biopesticides such as Bt break down quickly, especially in high temperatures, making rural distribution problematic. In addition, quality control is lacking in India's biopesticide and biofertilizer industries, often resulting in ineffective products (Narayanan 2005, Singh 2002). One local pesticide shopkeeper who stocked neem-based products was reluctant to aggressively promote them for that reason. Finally, the fees set by accredited organic inspection and certification agencies are prohibitively high for most farmers in West Bengal. Under current government policy, it takes at least two years for a farm to be certified as organic. The cost of inspection and certification for small holder groups is around Rs 5,000/day, not counting travel expenses and other fees. These charges, together with the initial transaction costs of organizing into groups of 25 to 50, place a high burden on small and marginal farmers.

Discussion and Conclusions

The few local farmers who are successfully producing organic commercial crops are innovative individuals who do not use any of the above inputs. Instead, they capitalize on their small size and grow polycultures, use cow dung and urine, and continually experiment with home-crafted products like fermented neem leaf compost. Local NGOs are finding more success by building on the examples of these innovators and following a step-by-step approach that focuses first on eliminating pesticide use and improving soil health with underutilized resources, such as cow urine, crop residues, and tree leaves, before promoting completely synthetic-free production. With the loss of many traditional varieties and indigenous knowledge of earlier farming methods, the NGOs hope to foster a gradual transition to organic farming, built on locally developed and tested techniques. This approach has already proven fruitful in reducing input costs and pesticide use, while also reversing the decline in yields, thereby increasing profitability and safety, especially in the input-intensive dry season rice crop. These results are consistent with other research findings that show that transitions to organic, agro-ecological methods can increase productivity and improve livelihood in developing countries (Pretty et al. 2003).

To overcome extension constraints, the NGOs are also organizing farmers into groups, meeting with them over a whole growing season or longer, encouraging them to learn from each other, and helping them to become volunteer trainers for other farmers. Their approach is loosely based on the Farmer Field School model, widely considered a more successful methodology for introducing complex crop management approaches like IPM (Mattson 2000). By following this approach, Swanirvar staff have helped many local farmers adopt simple seed selection techniques to improve stand development, add micronutrients to the soil, improve plant spacing to reduce disease problems, and use more natural and locally-available materials for pest control. Only by understanding the factors underlying farmers' problems with high-input, chemical-intensive agriculture will we be able to avoid the same types of problems in promoting organic methods in developing countries. Organic farming is not a monolithic model that can be transferred, as is, from one part of the world to another (cf. Parrot et al. 2006). Nor can success be achieved by "reverting" to older farming methods based on pre-existing indigenous knowledge. In many areas of the developing world, especially in Asia, the Green Revolution so drastically altered the agricultural landscape that the only way to move forward with organic farming is to work with local farmers to craft a new knowledge base that starts with key agro-ecological principles and incorporates elements of traditional knowledge and new technology in a process of continuous adaptation and innovation.

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How transgenic crops impact on biodiversity

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Key words: biodiversity, developing countries, genetic engineering, transgenic crops

Abstract

Genetic engineering is heralded as key technology to intensify agriculture and the acreage under transgenic crops is increasing. Agricultural diversity, on the other hand, can be considered a global resource base for food and bio-energy that may be vital in responding to unknown future needs. The article discusses the impact of genetic engineering on agricultural biodiversity, concludes that GE crops have amplified the negative impact of farming on biodiversity and proposes alternatives.

Introduction

Genetically engineered (GE) or transgenic crops are increasingly promoted to intensify agriculture. Agricultural diversity, on the other hand, can be considered a global resource base for food and bio-energy, a resource that may be vital in responding to unknown future needs, such as adaptation to climate change. Although both are important issues in agriculture, little attention has been given to their interrelationship. The main question is: How does GE technology impact on biodiversity? Is it beneficial, neutral or detrimental? This will be discussed in the following article.

Material and methods

This article reviews scientific evidence on biological and economic changes from the use of transgenic crops, and investigates their impact on biodiversity. The short article cannot be comprehensive, but it highlights the most important features by presenting a few examples. As the majority of plant genetic resources are located in tropical and sub-tropical regions and are largely preserved by small farmers, the article focuses on smallholder agriculture in developing countries.

Results

Transgenic crops in developing countries. The estimated global distribution of transgenic crops is assessed by ISAAA, a biotechnology-promoting network. The estimations for 2006 are approximately 102 million ha (James 2006). As no other sources are available, the figures cannot be verified, and some consider them to be inflated (Ashton 2003, Robinson 2004, Zarzer 2006, López Villar et al. 2007). The transgenic crops are distributed as follows: Four crops account for 95% of all transgenic varieties planted: soybean, maize, cotton and canola. Most are grown for industrial purposes or as animal feed. Approximately 40% of the total acreage is in developing countries, and this 40% is concentrated in only 6 countries: Argentina, Brazil, China, India, Paraguay and South Africa. A third feature also deserves consideration. Until now, only two genetically-induced traits have gained commercial

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importance: herbicide tolerance (HT) and pest resistance through insertion of a gene from *Bacillus thuringiensis* (Bt).

Transgenes – genetic enrichment or contamination? After a transgenic plant is released from the greenhouse to the field, it cross-pollinates with other varieties and sometimes even with wild relatives. Pollen can spread much further than expected. For instance, Watrud et al. (2004) measured distances of up to 21 km for pollen of transgenic grass *(Agrostis stolonifera)*. Greater distances were assumed but not quantified. This pollination, following "introgression", is irreversible, difficult to limit regionally and makes coexistence of transgenic crops with non-transgenic crops very difficult. The case of transgenic maize in Mexico is a prominent example. Mexico probably has the richest maize gene pool in the world. With the commercial use of transgenic maize varieties in North America, transgenic maize entered the country in various ways, mainly through food imports. In 2001 evidence was produced that GM varieties had introgressed into the genome of landraces of maize in southern Mexico (Quist and Chapela, 2001), a finding that was later confirmed by other research teams (CEC 2004). Until today it remains controversial, whether the introgression of transgenes threaten or enrich genetic diversity. According to CIMMYT (2002) and referring to the Mexican problem, landraces of maize may change as they frequently do through cross-pollination with other (new) varieties. By doing this, they do not disappear and in fact, with the transgenes, they can become even more diverse. On the other hand, all CGIAR Centres are advised by FAO (2007) to do everything possible to avoid unintentional transgenic introgression into their *ex-situ* gene bank collections. Molecular biologists are bringing in new aspects. Genetic regulation is obviously more complex and dynamic than commonly assumed. It goes beyond single genes, beyond DNA and is implemented by a network (Polanyi 1968, Gould 1993, Strohman 1997). Accordingly, a growing number of scientists demand a paradigm shift from genetics to epigenetics. Secondly, its traits appear to be dynamic as they change over time and according to their environment. (ENCODE 2007, Sample 2007). Therefore, the transfer and incorporation of DNA from other species can cause disturbances in cell regulation; unexpected changes of GE organisms are not uncommon. For example, Gertz et al. (1999) found that transgenic soybeans have up to 20% higher lignin content, and they assume that the new gene influences lignin metabolism. The change in lignin content has a negative influence on heat tolerance, which in turn results in lower yields of transgenic soybean under heat stress. Many more unintended effects have been reported (Liebman and Brummer 2000, Haslberger 2003) and may occur with a substantial time lag (Wilson et al. 2006). If this holds true, transgenic crops contain unknown risks and the unintentional introgression of transgenes must be considered a genetic contamination not an enrichment for plant genetic resources.

Does herbicide tolerance have an effect on biodiversity? In the mid-1990s transgenic soybean varieties were introduced in Argentina. Roundup-Ready (RR) soybeans are resistant to the herbicide glyphosate and allow fully mechanized production. With herbicidal weed control, no-till techniques were applied more often, cropping became easier, production risks were reduced and moderate yield increases achieved. But the main reason for adoption was that less agricultural skill is required. "Farming without farmers" became possible and large acreages could be managed by only one person. In a country with an already high share of industrial soybean production, the RR technology accelerated the ongoing drastic changes to land use and farming systems in Argentina. Within the past ten years, the acreage under soybean has increased from 6 to14 million hectares, and the share of transgenic soybean from zero to 99%. And, the Argentine government aims to triple present production by 2010 (Lopez 2003). As a result, the diversity of landscape and farming systems has been reduced significantly. "The rapid shift of land to soybean production eroded two traditional sources of strength in the Argentinean agricultural sector – the coupling of livestock and crop production on the same farm, and second, adherence to diversified rotations needed in order to break pest and disease cycles and sustain soil productivity. […] Farmers are increasingly growing a single crop, soybeans" (Benbrook 2005). According to national statistics, food production in Argentina has fallen significantly. For rice and potatoes a reduction of 40% and 38% respectively has been recorded (Dominguez and Sabatino 2003), even higher losses have been observed with vegetables, and a similar trend has been observed with animal products such as milk, eggs and meat (Jacobson 2005). With regard to biodiversity, it can be confirmed that smallholders and their mixed farming systems are gradually disappearing, and they are being replaced by large mono-cropped fields.

Does Bt-technology reduce the negative impact of cropping on biodiversity? The incorporation of bacterial DNA from *Bacillus thuringiensis* (Bt) into agricultural crops promised to reduce pesticide application and alleviate damage to the fauna of agro-ecosystems. Many studies from the early years of using Bt-crops – cotton in particular – stated that pesticide-use was substantially reduced, costs of production decreased and net incomes were improved (e.g. Qaim and Zilberman 2003, Traxler et al. 2003). A reduced negative impact on insect biodiversity (compared to conventional production) was observed in farm scale field trials by Cattaneo et al. (2006).

Meanwhile the picture has changed. For instance, in a study of 481 farms in 5 provinces of China, researchers from Cornell University (Wang et al. 2006) found that such benefits of Bt-cotton had completely disappeared. "A majority of Bt-cotton farmers cited the fact that they must spray 15-20 times more than previously to kill secondary pests, Mirids, which did not require any pesticide in the early years." Further, farmers spent the same amount on pesticides as non-Bt growers and about 2-3 times more for seeds. A similar finding has been reported from the Makhatini Flats, the leading Bt-cotton area in South Africa (Hofs et al. 2006), and the authors state that Bt-cotton has not generated sufficient income to achieve a significant and sustainable socio-economic improvement. Finally, a much more comprehensive evaluation of 47 peer reviewed articles on the economic impact of Bt-cotton on farms in developing countries concludes: "…the overall balance sheet, though promising, is mixed. Economic returns are highly variable over years, farm type and geographical location" (Smale et al. 2006).

In summary, it can be concluded that the Bt-gene does not reduce pesticide use in the long term. At best, the impact of Bt in cotton on biodiversity is neutral compared to conventional cropping systems.

Changes in seed supply and access to breeding material. Within the past 25 years an unparalleled concentration of the seed sector has taken place and a worrying shift from the public to the private domain can be observed (GRAIN 2007). "Based on 2006 revenues, the top 10 seed corporations account for 55% of the commercial seed market" (ETC-Group 2007). As far as transgenic crops are concerned, only one company (Monsanto) provides seed, directly or indirectly, for approximately 90% of the total area under transgenic crops. This quasi monopoly creates dependency among farmers. At the same time it leads to genetic uniformity of cropping systems. Needless to say, the monopolization of the seed sector is not caused by biotechnology, but the latter has accelerated und reinforced this process. One main reason for this is that the breeding costs for GE crops are extremely high; the necessary investment can only be borne by larger companies, which are increasingly required to take advantage of economies of scale. A standardized variety or a whole cropping technology has to be distributed as widely as possible. A second aspect is no less worrying: the increasing control of genetic resources by a few companies through patents on genes. In the past, genetic material for breeding purposes has been in the public domain. Today, it is becoming increasingly inaccessible without the permission of patent holders. By granting or withholding their permission, they have a strong influence on breeding programmes and strategies. Monopolized seed supply and growing corporate control over genetic resources probably have the greatest impact on biodiversity.

Discussion and conclusions

Transgenic crops have accelerated the industrialization of agriculture and have thus amplified the negative impact of farming on biodiversity. In addition, biodiversity is now exposed to a new threat: the contamination of genetic resources by transgenes – a risk, which is so far unpredictable. The question in this respect is whether such biodiversity "sacrifices" are really necessary to address future needs. So far most of the promises of GE protagonists – to reduce global hunger, for instance – have not been fulfilled. Most of the progress in plant breeding has been achieved by conventional methods (Meyer 2007). Another question is whether existing transgenic crops have the ability to perform better than non-GE crops. Scientific comparisons often show a bias when selecting an appropriate reference system. The sector of cotton production may illustrate this. Pesticide savings and yield increases through Bt-cotton are measured in comparison with conventional cropping systems. This reference system will automatically give Bt-cotton an advantage. The task should be to compare GE cropping systems with other innovative breeding and production technologies that have emerged within the past 20 years, parallel to the GE cropping technology. Two such innovations can be considered success stories in cotton production. One is Integrated Pest Management (IPM) (Russel and Kranthi 2006 a+b), and the other is Organic Agriculture (Eyhorn et al. 2007, Williamson et al. 2005, Blaise 2006, Lanting et al. 2005). Both IPM and Organic Agriculture are economically competitive and environmentally friendlier; they work with reduced or no synthetic pesticide input, and they enhance biodiversity (FAO 2002). Marker assisted selection (MAS) is the third innovation that merits attention. Gene-markers are used to identify desired traits more easily, a method that is already possible at the seedling stage of a plant. MAS speeds up the selection process enormously, and allows wild relatives to be included more easily. It has upgraded classical breeding and is intensively used by almost every major seed breeding company. The performance and competitiveness of GE technology must always be appraised in comparison with the best technologies at hand and, in addition, be based on thorough risk assessment of GE organisms. In general we must bear in mind that biodiversity is an indispensable resource to meet future challenges (e.g. climate change); agricultural intensification must not proceed at its expense but must harmonize with it. Ecological innovations as described above offer a reasonable chance of achieving this.

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The complete list of references can be found in: Eprints N°: 12645

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Experimental systems to monitor the impact of transgenic corn on keystone soil microorganisms

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Key words: GMO, environmental impact, arbuscular mycorrhizal fungi, co-existence, non-target organisms.

Abstract

Risks and benefits of transgenic crop plants should be evaluated not only by assessing pollen flow, but also by considering soil persistence of transgenic products, such as Bt toxins, which can accumulate in the soil and remain active for a long time. Moreover, transgenic plants are often ploughed under as crop residues, representing a potential hazard for non-target arbuscular mycorrhizal (AM) fungi, a group of beneficial plant symbionts fundamental for soil fertility. In this study we monitored the effects of transgenic corn plants (Bt 11 and Bt 176) and their residues on AM fungal growth and root colonization ability. Both transgenic plants decreased mycorrhizal colonization and Bt 11 plant residues negatively affected mycorrhizal establishment by indigenous endophytes, four months after their incorporation into soil.

Introduction

After the approval of the European Community Directive 2001/18 a debate started in Europe about the co-existence, in space and time, of genetically modified organisms (GMO) and organic or conventional agriculture. So far poor knowledge exists on the interactions among the different components of agroecosystems and on the potential hazards posed by unintended modifications occurring during genetic manipulation. The increasing amount of reports on the ecological risks of GM plants stresses the need for experimental works aimed at evaluating the environmental impact of GM crops not only assessing pollen flow, but also considering soil persistence of transgenic products (Stotzky 2004). Major environmental risks associated with GM crops include their potential impact on non-target soil microorganisms, such as arbuscular mycorrhizal (AM) fungi, fundamental for sustainable and organic agriculture, given their important role in soil fertility, plant nutrition and ecosystems functioning. AM fungi are strongly affected by agricultural practices, including treatments with chemical fertilisers and pesticides, and by changes in soil characteristics, thus representing potential key non-target microorganisms to be monitored in studies on environmental impact of GM plants. In this work we describe an experimental system to investigate the potential effects of two *Bt* corn lines and their plant residues on AM fungi.

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Materials and methods

Transgenic *Bt* corn lines (transformation events *Bt* 11 - isogenic to NK4640 - and *Bt* 176) genetically modified to express the *cry1Ab* gene from *Bacillus thuringiensis* and the non transgenic maize NK4640 (wt) were used to study their impact on the AM fungal species *Glomus mosseae*. The experimental system (microcosm) used to study mycorrhizal establishment was described by Turrini et al (2004). Ten replicates were set up for each trial. After 5 weeks growth in the microcosm, the plants were transferred into pots filled with soil from conventional agriculture. Corn plants were cultivated and maintained in a greenhouse for 10 weeks. After 5, 8 and 10 weeks' growth, plant root systems were sampled and the percentage of mycorrhizal colonization was assessed. In a second experiment, corn plants were grown in pots for 12 weeks and then ploughed under: leaves and stems of *Bt* 176, *Bt* 11 and Wt plants were cut into 2-3 cm pieces and mixed with the soil originating from the same pot where they were grown. Levels of colonizations by indigenous AM propagules were assessed on *Medicago sativa* plants grown in residues-amended soil. In order to test the effects of *Bt* plant residues on hyphal growth of *G. mosseae*, 15 sporocarps were placed on membranes in a sandwich system (Giovannetti et al., 2006). Sandwiches were placed onto Petri dishes and covered with soil containing residues. After 21 days membranes were opened and stained with 0.05% Trypan blue. Data on root colonisation were arcsin(sqrrt(x)) transformed and submitted to two-way ANOVA and to Test for the Equality of regression slopes.

Results

The impact of *Bt* plants on AM fungal symbionts was monitored both on the collection isolate and on indigenous endophytes from corn experimental soil. Colonisation in *Bt* corn plants (both *Bt* 11 and *Bt* 176) by the symbiont *G. mosseae* was significantly lower than in wt plants, by slopes equality test ($F=8.59$, $P<0.001$) (Fig. 1).

The impact of transgenic plant residues on AM fungi was assessed by monitoring both pre-symbiotic mycelial growth of *G. mosseae* in the experimental soil and *Medicago sativa* root colonization by AM fungal propagules living in the experimental soil. Mycelial length of *G. mosseae* grown in soil samples containing *Bt* and non-*Bt* corn residues was monitored up to four months and did not show significant differences among lines. Two ways ANOVA showed that indigenous AM fungi were significantly affected in their ability to colonize *M. sativa* roots grown in soils containing different plant residues at different times after ploughing under ($F=45.97$, $P<0.001$). Moreover, regression slopes of root colonisation percentages of *M. sativa* grown in soil containing corn residues were different by the slopes equality test ($F=27.13$, $P<0.001$). Data obtained suggested that indigenous AM fungal colonization ability was affected, by GM corn cultivation, and that it was particularly reduced in *Bt* 11-amended soil (Fig. 2).

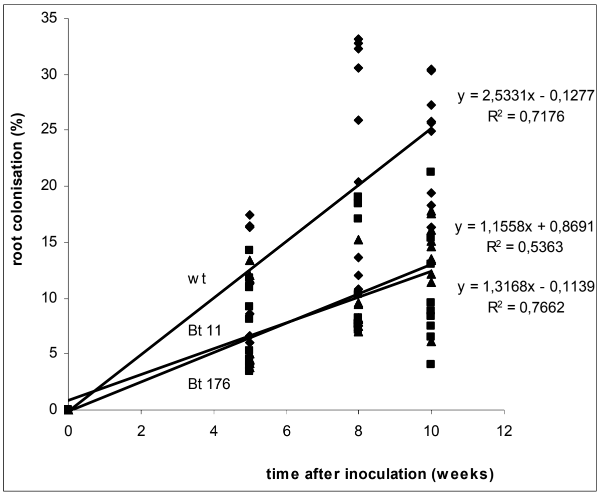

Figure 1: Distribution of data and regression lines of root colonisation by the AM fungus *Glomus mosseae* on *Bt* and wild type corn plants, from inoculation to 10 weeks of culture.

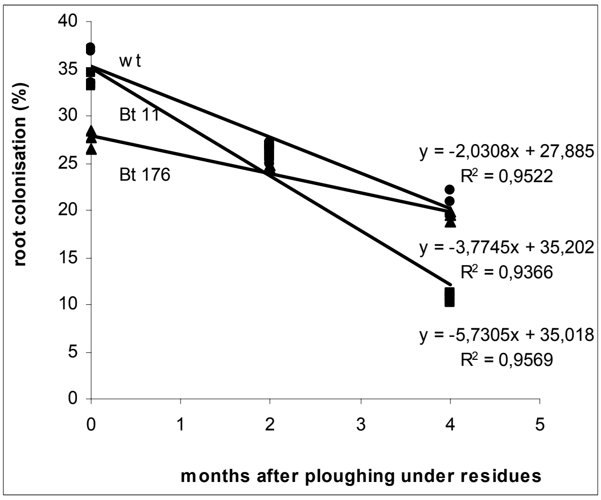

Figure 2: Distribution and regression lines of root colonisation data by indigenous arbuscular mycorrhizal fungi on *M. sativa* during culture in soil samples containing *Bt* and wild type corn plant residues ploughed under.

Discussion

Our experimental systems allowed us to monitor the impact of two *Bt* corn plants and their residues on AM fungi. Both transgenic plants decreased mycorrhizal colonization by *G. mosseae* and *Bt* 11 plant residues negatively affected mycorrhizal establishment by indigenous endophytes after their incorporation into soil. Mycelial growth in the presence of transgenic residues was not affected. Transgenic root exudates and residues incorporated into soil may produce long term effects on soil microbes (Castaldini et al., 2005). Studies on *Bt* toxin persistence have shown that this protein maintains its activity after absorption to clays or binding to humic acids (Saxena and Stotzky 2001) and retains its activity for 234 days (Saxena et al. 1999; Stotzky 2004). Other authors have demonstrated slower litter decomposition for *Bt* compared with non *Bt* lines (Flores et al. 2005). It remains to be established whether mycorrhizal colonization is reduced directly by the *Bt* toxin present in corn litter or indirectly by soil microbial population alterations or by other factors. Moreover, it is possible that prolonged permanence of litter in the soil could significantly affect inoculum potential of mycorrhizal fungi.

Conclusions

Further long-term studies in the field are necessary to evaluate the impact of GM plants on microbial communities fundamental for soil fertility and quality. In particular, the risk posed by GM plant residues to non-target beneficial soil microbes should be thoroughly investigated, since any reduction in their biodiversity might produce long-term effects, in space and time, on crops sequentially cultivated in the same soil in the years to come.

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