



# ***FiBL DOSSIER***

*Results from a 21 year old field trial*

## ***Organic farming enhances soil fertility and biodiversity***



































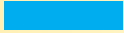





























*in collaboration with*



Zürich-Reckenholz  
Liebefeld-Bern

# DOK-trial: 21 years of results at a glance

	D	O	K	page	
	Bio-dynamic	Bio-organic	Conventional (integrated)		
<b>Input</b>					
Fertilizer				5	 95 – 100 %
Energy				7	 85 – 95 %
Chemical plant protection				5	 70 – 85 %
Mechanical weed control				5	 50 – 70 %
					 < 50 %
<b>Yield</b>				6	
<b>Soil fertility</b>					
Phosphorus (soluble)				9	
Phosphorus (reserve)				9	
Phosphorus (soluble)				9	
Potassium (reserve)				9	
Soil structure					
Earthworms individuals, biomass				11	
Ground beetles activity				11	
Microbial biomass				12	
Microbial activity				13	
Mycorrhiza				14	
<b>Species diversity</b>					
Weed flora				15	
Seed bank				15	
Ground beetles				15	
Earthworms				15	
Microorganisms	higher in the organic systems			15	

*The long-term experimental results from the DOK-trial show that organic management systems allow for a sustainable agricultural production with lower input and lower yields. Simultaneously, soil biological processes and species diversity were improved in organic farming systems.*

## Abbreviations

D1*	Bio-dynamic (0.6) 0.7 livestock units per hectare
D2**	Bio-dynamic (1.2) 1.4 livestock units per hectare
O1*	Bio-organic (0.6) 0.7 livestock units per hectare
O2**	Bio-organic (1.2) 1.4 livestock units per hectare
K1*	Conventional (IP) (0.6) 0.7 livestock units per hectare plus mineral fertilization
K2**	Conventional (IP) (1.2) 1.4 livestock units per hectare plus mineral fertilization
N	Unfertilized
M**	Conventional (IP) farming without manure

CRP	Crop rotation period
IP	Integrated production

\* reduced fertilization

\*\* fertilizer levels correspond to farming practice in Switzerland

## Imprint

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# Is organic farming practicable?

In the early seventies, farmers and agricultural scientists were convinced that agricultural production without external input of production factors like synthetic fertilizers and pesticides would not be feasible. Organic farming as an alternative to conventional developed agricultural practice was not taken seriously. At that time of scepticism, some pioneers initiated a movement to support organic farming research, hoping that the Swiss Federal research stations could be persuaded to direct their focus to this field of research. However, with the exception of some rare efforts of policy makers and universities, there was little response. The main task, i.e. to study the feasibility of organic farming, was not covered by any of the official Swiss Agricultural Research institutions. Hence, an initiative of farmers, politicians and scientists founded the Research Institute of Organic Agriculture (FiBL) in 1973. This private foundation linked administration and practice, and its first task was to elaborate the concept of the DOK field trial.

In 1974, the Swiss Federal Office of Agriculture (BLW) charged the former Federal Research Station for Agricultural Chemistry and Hygiene of Environment (FAC, Bern-Liebefeld) to set up a field trial in collaboration with the FiBL in order to compare the performance of organic farming systems. When FAC-Liebefeld was shut down, the Swiss Federal Research Station for Agroecology and Agriculture (FAL-Reckenholz) took over the responsibility for the DOK trial in close cooperation with FiBL.

The DOK-long term trial - unique in its conception - compares the consequences of bio-organic, bio-dynamic and conventional farming systems in a randomised plot trial that has no other equivalent. Experimental samples are used by many other laboratories to develop new methods in the areas of soil and food quality. Evaluation of the pros and cons of different land management strategies allows for rational system optimization. This would not have been possible without the long-term research carried out within the framework of the DOK-trial.

The DOK-field trial was started in 1978 at Therwil. In the beginning the main goals were agronomic: yield and product quality. The database of agronomic results of more than twenty years has stimulated the discussion about farming systems and has contributed significantly to the general acceptance of organic farming. In Switzerland today, over 5000 farmers successfully farm organically, showing convincingly that organic farming is indeed feasible. In the last decade, therefor research has focused on processes in the soil and on the long-term effects of organic farming practice on the environment.

The investigators are indebted to the Federal Office of Agriculture (BLW), the advisory farmers and the field staff for their constant and unflagging support. The collaborative work with national and international research institutions is gratefully acknowledged.



Photo: Thomas Alföldi (FiBL)

## Field inspection 1991

Scientists, field staff and the advisory farmers meet each year in order to evaluate current management procedures and to decide upon possible changes in farming management.

Exceptionally for the time, farmers from both the farming systems and organic producer's organisations were involved in the planning and executing of the field trial.

# The field trial design

Photo: Archives FiBL

The field experiment is located 300 m above sea level in the Leimental near Basel (CH). The topographically sound field site is on a gentle, north facing, slope in the valley of the «Birsig»stream. In earlier times, the land in this region was used as permanent grassland («Wässermatten») due to the regular flooding and high groundwater table. Today, the soils of the region are used for intensive farming and vegetable production.

*The strategies of fertilization and plant protection are the main differences between the systems, whereas crop rotation and soil tillage were almost identical.*

## Soil and Site

The area where the DOK-trial is located, is documented to have long been in use as arable land (1957–1973 ley rotation, 1973–1975 field legumes and cereals, 1976 oats). In May 1977 the whole area was sown with grass-clover, and in the spring of 1978 the field experiment began with potatoes, spring wheat and spring barley.

The annual mean temperature is 9.5 °C, the mean annual precipitation accounts for 792 litre per square metre.

The soil is a haplic luvisol on alluvial loess of 0.9 to 1.3 meter depth.

## The treatments (systems)

The bio-dynamic and the bio-organic systems are carried out according to the regulations of the respective organic producer's organisations; the conventional system is managed according to the guidelines of integrated farming.

In addition to these three systems, which are commonly amended with manure, another treatment was performed as a conventional system without fertilization in the first crop rotation period, then subsequently fertilized exclusively with mineral fertilizers. An unfertilized control was conducted with the use of bio-dynamic preparations only. These two initially unfertilized treatments were included to evaluate the effects of chemical plant protection and the bio-dynamic preparations.

## Fertilization

The amount of farmyard manure applied in the first two crop rotation periods (CRP) corresponded to 0.6 or 1.2 livestock units per hectare in the low and high input plots, respectively. The amount of manure was increased to 0.7 and 1.4 livestock units per hectare at the beginning of the third crop rotation period.

In the organic systems, manure was applied in smaller amounts, but more often than in the conventional system, where the whole amount of manure was split between the two root crops. The mineral nitrogen fertilization was adjusted according to N<sub>min</sub> analysis in early spring in cereals and root crops.

## Main differences of the farming systems

Treatments	bio-dynamic		bio-organic		conventional (IP)		mineral NPK (IP)	unfertilized
	D1	D2 *	O1	O2 *	K1	K2 *	M *	N
Fertilization								
Farm yard manure (FYM)	composted FYM and slurry		rotted FYM and aerated slurry		stacked FYM and slurry		–	–
Livestock units	(0.6) 0.7	(1.2) 1.4	(0.6) 0.7	(1.2) 1.4	(0.6) 0.7	(1.2) 1.4	–	–
Mineral fertilizer	–		rockdust, K Magnesia		NPK fertilizer as supplement		exclusively mineral NPK	–
Plant protection								
Weed control	mechanical				mechanical and chemical			mechanical
Disease control	indirect methods				chemical (thresholds)			indirect methods
Insect control	plant extracts, bio-control				chemical (thresholds)			plant extracts, bio-control
Special treatments	biodynamic preparations		CuSO <sub>4</sub> in potatoes until 1991		plant growth regulators			biodynamic preparations





### The crop rotation

1. CRP 1978–1984	Variety	2. CRP 1985–1991	Variety	3. CRP 1992–1998	Variety	4. CRP 1999–2005	Variety
1. Potatoes	Ostara	1. Potatoes	Désirée	1. Potatoes	Désirée	1. Potatoes	Désirée
Green manure		Green manure					
2. Winter wheat 1	Probus	2. Winter wheat 1	Sardona	2. Winter wheat 1	Ramosa/Tamaro	2. Winter wheat 1	Tamaro
Fodder intercrop		Fodder intercrop		Fodder intercrop		Green manure	
3. White cabbage	Wädenswiler Original	3. Beetroots	Mobile	3. Beetroots	Mobile	3. Soybeans	Maple Arrow
						Green manure	
4. Winter wheat 2	Probus	4. Winter wheat 2	Sardona	4. Winter wheat 2	Ramosa/Tamaro	4. Maize (silage)	Magister
5. Winter barley	Gold	5. Winter barley	Gerbél/Triton			5. Winter wheat 2	Tamaro
				5. Grass-clover 1	Standard-compos. 430		
6. Grass-clover 1	Standard-compos. 330	6. Grass-clover 1	Standard-compos. 330	6. Grass-clover 2	Standard-compos. 430	6. Grass-clover 1	Standard-compos. 330
7. Grass-clover 2	Standard-compos. 330	7. Grass-clover 2	Standard-compos. 330	7. Grass-clover 3	Standard-compos. 430	7. Grass-clover 2	Standard-compos. 330

### The crop rotation

The crop rotation was the same in all systems. Duration and versatility of the crop rotation was a compromise between those used in the various farming systems, which would normally differ markedly at the farm level.

The crop rotation was adjusted to the needs of practice and science at the beginning of each crop rotation period, in consultation with the farmers and scientists. The choice of varieties was also a compromise between conventional and organic agriculture.

### Input of nutrients and pesticides

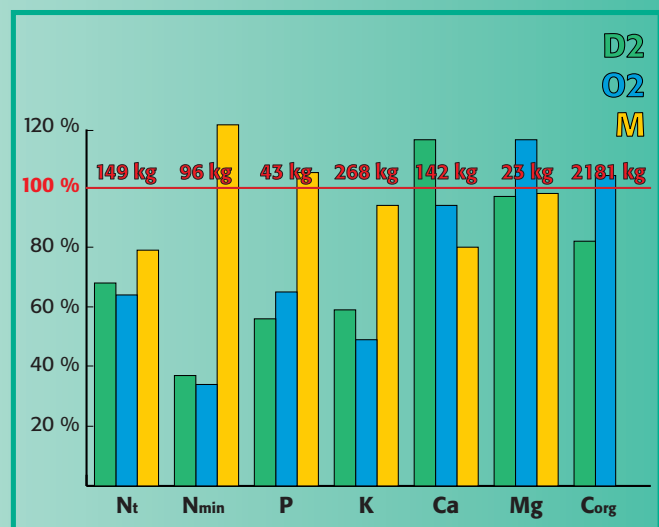
On average, over the three crop rotation periods, the organic systems received markedly lower amounts of the macro-elements N, P, and K. According to the experimental design the amount of organic matter applied was similar. In the bio-dynamic system, the input of potassium almost doubled in the third crop rotation period due to delivery of manure from a different farmer.

The arable crops were treated with pesticides 3.6 times per year on average, whilst the organic plots were sprayed once every second year. The bio-dynamic plots were sprayed several times per year with preparations 500 and 501.

Up to 9 pesticide amendments were necessary in conventional potatoes due to the high incidence of pests and diseases. Direct control of late blight (*Phytophthora infestans*) was performed in the bio-organic system with copper sprays, and in both organic systems *Bacillus thuringiensis* preparations were used to fight the potato beetle.

**Fertilization and plant protection were performed according to the regulations of the farming systems under investigation.**

Average input of nutrients in kg per hectare and year, K2 = 100 %



The amount of nitrogen applied as nitrate or ammonia made up the biggest difference between the systems. Total N, P and K was 40–50 percent lower in the organic systems.

# Do organic systems produce sufficient yield?

*Organically grown crops do not reach the crop yield level of conventional systems that are minerally fertilized and protected by synthetic chemicals. An average crop yield reduction of 20 percent has to be accepted.*

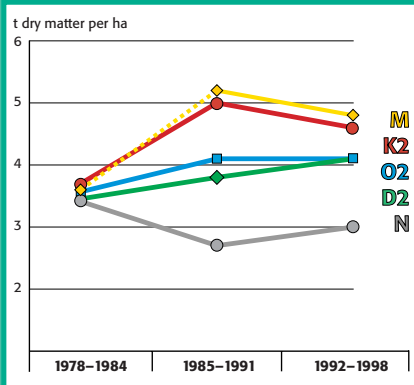
Considering that the input of fertilizers was almost 50 percent lower in the organic systems, the average yield reduction of 20 percent appears to be reasonable. Moreover, organic systems avoid the use of synthetic fertilizers and pesticides that are produced with fossil energy and at high environmental costs. Crop yield in the organic plots was in fact higher than expected. Nutrients in the soil appear to be utilised to a higher extent as supported by root symbioses with rhizobia and mycorrhizae.

Potato tuber yield reduction was most severe compared to the conventional system and may be explained by a high plant demand for nutrients in a relatively short vegetation period, in addition to the high susceptibility of this crop to pests and diseases.

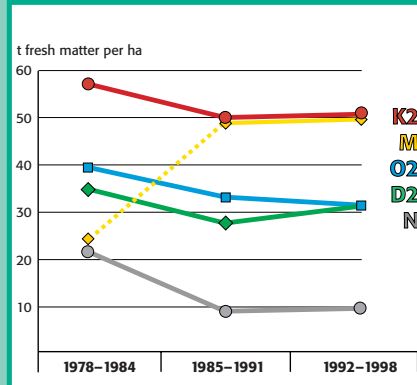
Due to the appropriate choice of crop rotation and mechanical control, weeds never competed significantly with the crop plant. The possibility for direct plant disease and pest control, as well as application of soluble fertilizers, resulted in the conventional systems in a slightly enhanced crop yield stability.

The following years will show if the organic systems will be able to compensate for the lower soil nutrient loads by an enhanced soil fertility.

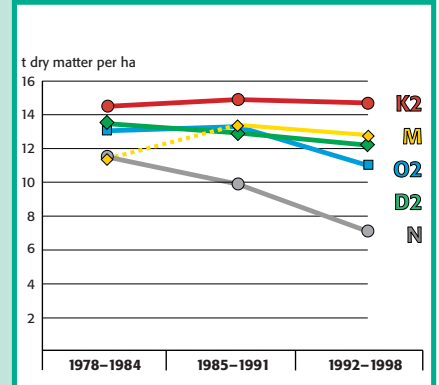
**Winter wheat, grain yield**



**Potato tuber yield**



**Grass-clover yield in the first two ley years**



Winter wheat yield was 11–14 percent lower under organic conditions than in the conventional systems. In the first crop rotation period the yield appeared to be comparable. Thereafter, improved management and better varieties led to higher crop yield in all systems.

Potato yield in the organic systems was 34–42 percent lower than with conventional treatments. This was observed already in the first years after conversion. In addition to lower tuber yield, a greater proportion of small tuber classes reduced the marketable yield, as did the increased damage due to wireworms.

The differences in the yield of the first two years of the grass clover ley were comparably low, with 11–13 percent less. During the third crop rotation period the yield difference increased, possibly due to the changed grass-clover mixture and the slightly lowered manure rates. The slight difference between the two organic systems in the third crop rotation period may be caused by the increased potassium fertilization in the bio-dynamic system.



# Are nutrient input and output in organic farming balanced?

Organic farming systems largely avoid the external input of mineral fertilizers. On the other hand nutrients are withdrawn from the soil by the crop. Accordingly, the nutrient-balance in the organic systems becomes negative for the main elements nitrogen, phosphorus and potassium.

The **nitrogen** balance was negative for all systems. This means N-fertilization was less than the withdrawal by the crop. Nitrogen mineralisation, N-fixation by legume crops and nitrogen precipitated with rain, however, were not considered in this calculation.

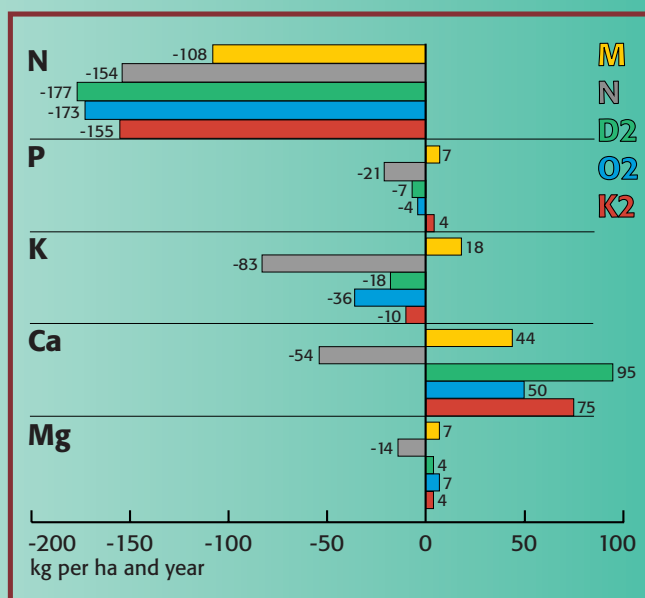
**Phosphorus** in the conventional systems showed a surplus, whereas in the organic systems the P-balance was negative.

Only the minerally-fertilized plots showed a surplus in **potassium**. The bio-organic system showed the greatest deficiency.

**Calcium** was sufficiently fertilized in all the systems with the highest surplus in the bio-dynamic system.

*Organically managed plots exhibit higher deficits in nutrients than conventional plots. Stocks of the most important plant nutrients should be analysed regularly.*

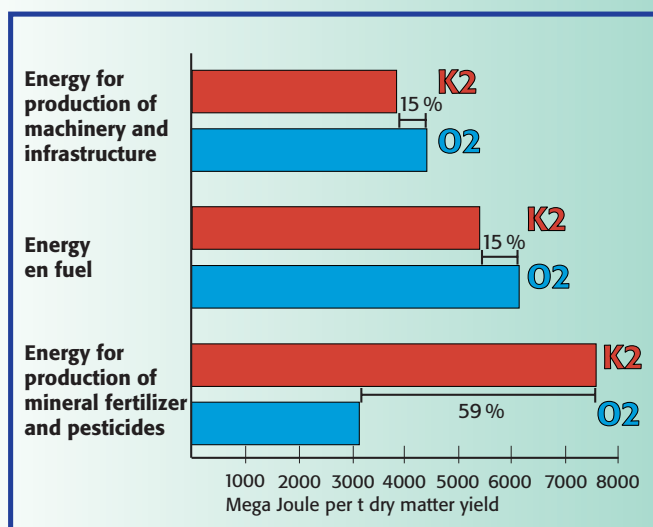
Balance of nutrients (1978–1998)



# Is organic farming energetically sound?

*Organically grown crops use less fossil energy than conventional crops.*

Direct and indirect energy components in the crop



Organic farming needs only slightly more energy for infrastructure and machinery as well as for fuel, whilst markedly lower energy input for the production of fertilizers and pesticides.

The efficiency of resource utilization is an important feature of sustainable production systems. All factors contributing to the production of a yield unit are assigned energy units. In order to compare energy efficiency, direct energy components e.g. tractor fuel, have to be considered as well as indirect components like the energy needed to produce fertilizers and pesticides.

Since crop yields were considerably higher in the conventional systems, the difference in energy needed to produce a crop unit was only 19 percent lower in the organic systems. Per area unit this difference accounted for 30–50 percent. Most of the difference was due to external production factors.

# Is organic farming healthy for the soil?

*Fertilization in organic systems has a positive effect on the content of organic matter and helps to avoid soil acidification.*

Soil organic matter and the pH markedly affect soil structure, biological activity and plant growth. Soil organic matter decreased in all the systems of the DOK-trial. In soils that were not fertilized with manure the decrease in soil organic matter was higher than in manured soils. Losses in soil organic matter among the manured systems were similar, whilst the organic matter content in the bio-dynamic plots at the end of the third crop rotation period was 15 percent higher than in the conventional and 30 percent higher than in the unmanured plots.

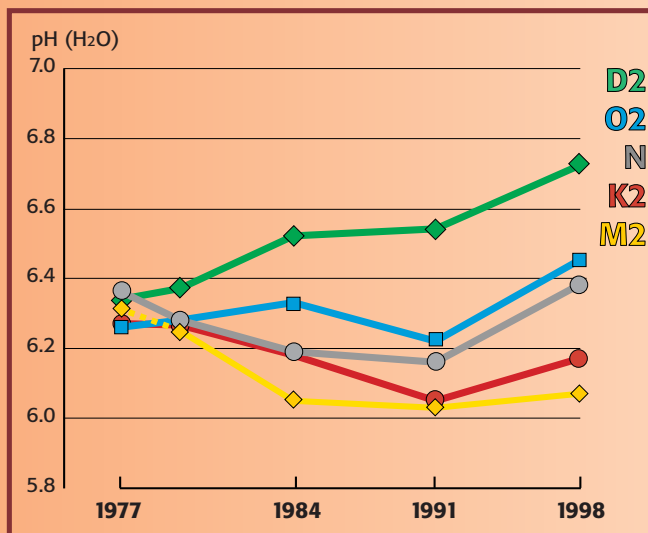
Utilization of composted manure, as in the bio-dynamic system, had positive effects on soil pH and organic matter, as affirmed by chemical fractionation that showed a greater proportion of stable organic matter compounds. Chemical fractionation revealed that the amounts of fulvic and humic acid amounts did not differ between the various management systems. The humin fraction that is considered stable was significantly higher in the bio-dynamic system.



Photo: Archives FiBL

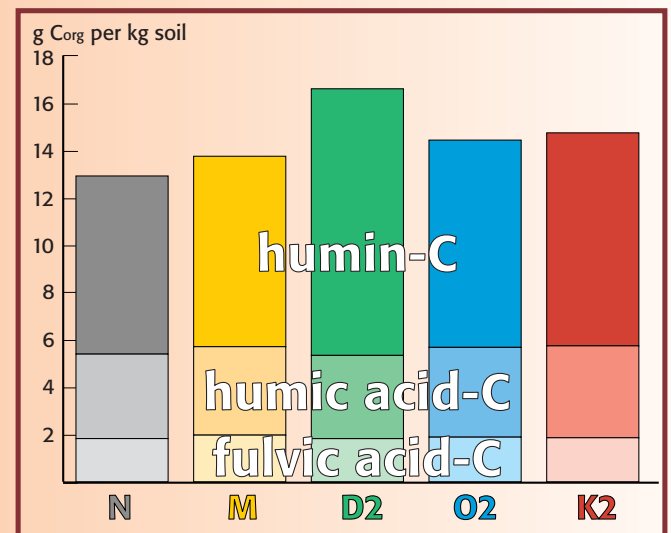
Amending soils with composted manure led to an increase in soil pH and stable humus fractions.

## Soil acidity



Compared to the initial values, the pH in the bio-dynamic plots increased considerably, remained on the same level in the bio-organic and unfertilized plots, and decreased in both conventional systems. The pH decrease was possibly due to the acidifying effect of the applied mineral fertilizers. In 1999 the conventional plots were limed with CaO and in order to prevent further acidification they are now fertilized with alkaline fertilizers.

## Carbon distribution among humic matter fractions



Total soil organic matter content reacts slowly to management changes. Soil fractionation yields soil organic matter pools with defined functional attributes. The higher soil organic matter content in the bio-dynamic treatments rests on a higher proportion of stable organic compounds, represented by the humin fraction.



# Does organic farming mine our soils?

*The negative nutrient balance for phosphorus and potassium leads to a decrease in the easily available fraction of these elements. The nutrient reserves in soil, however, decreased less dramatically.*

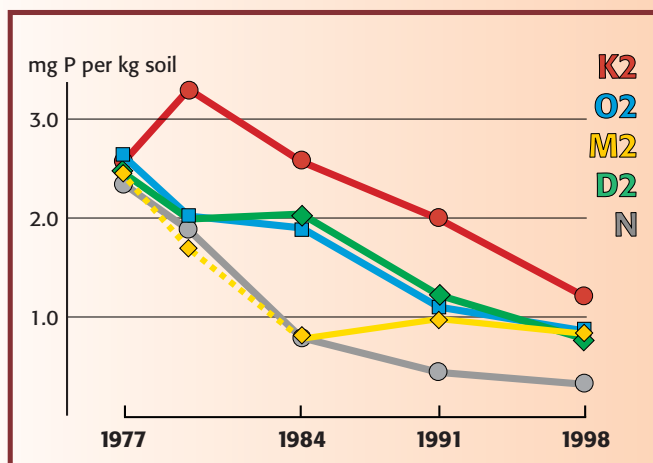
Even though soluble phosphorus was low in the organic systems, phosphorus deficiency has not yet been observed. This can be explained by the increased transfer of elements between the solid phase and the soil solution and by the higher microbial activity (An investigation carried out by the Institute of Plant Sciences, ETH-Zürich).



Photo: Archives FAL

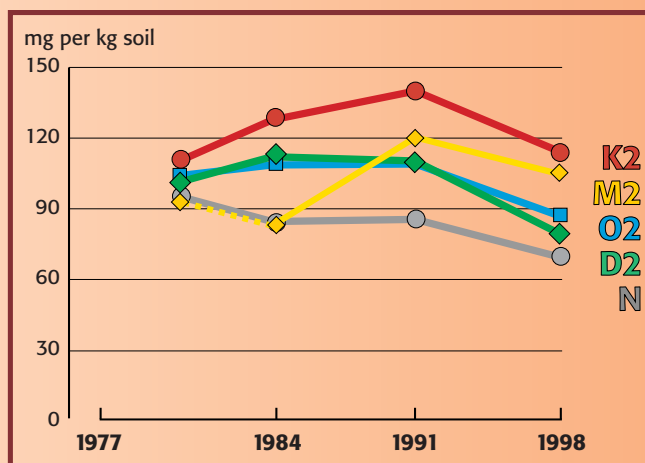
Potassium became rate-limiting relatively early after conversion to organic management when potatoes were cultivated. Fertilization with potassium is indicated where allowed according to the rules of organic farming.

## Water-soluble Phosphorus



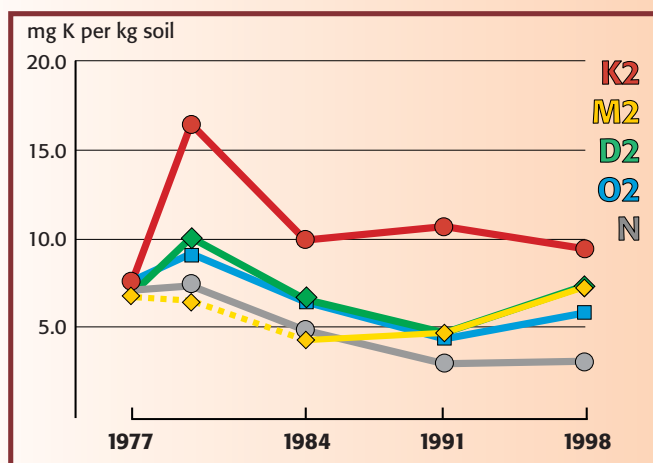
Water soluble phosphorus decreased markedly in all systems. In the beginning of the field trial the conventional system was strongly fertilized to enhance the phosphorus and potassium concentration. Towards the end of the third crop rotation, however, soluble phosphorus values decreased to those of the organic systems.

## Phosphorus soluble in citric acid (2%)



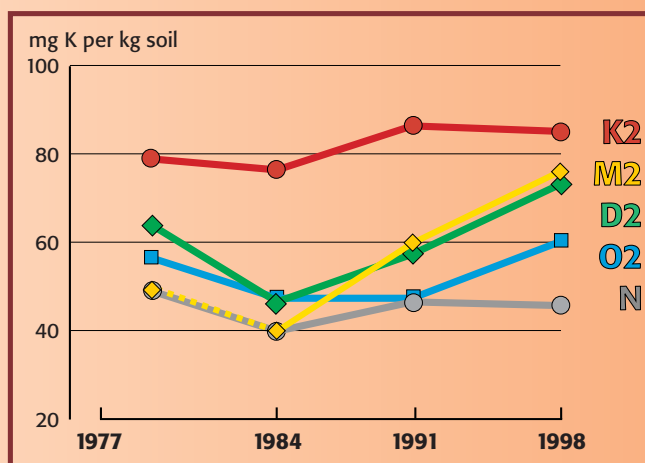
The phosphorus soluble in 2% citric acid is less immediately available, and represents reserve nutrients. Starting from similar phosphorus-loads at the beginning of the trial, no large changes were apparent, but total phosphorus-load was higher in the conventional system.

## Water-soluble Potassium



The water soluble potassium in the organic soils has remained at the same level. The increase after stock fertilization in the conventional system in the beginning of the field trial is obvious.

## Potassium soluble in lactic acid



Potassium soluble in lactic acid, the reserve fraction, even increased in the organic systems and remained at a constant level in the conventional system.

# Does organic farming improve soil structure?

*Organic soil management improves soil structure by increasing soil activity, thus reducing the risk of erosion.*

The build up of soil fertility is an important goal of sustainable land use. The Swiss «Ordinance relating to Impacts on the Soil» (OIS) defines a soil as fertile, if it provides a species-rich, biologically active, biotic community typical for the site, and if it has a typical soil structure and allows for undisturbed decomposition.

Organic matter has a positive effect on the development and stability of soil structure. Silty and loamy soils profit from organic matter by an enhanced aggregate structure. Organic matter is adsorbed to the charged surfaces of clay minerals. The negative charge decreases with increasing particle size. Silt is very susceptible to erosion since it is not charged, but organic matter layers on the silt surface may favour aggregates with silt too.

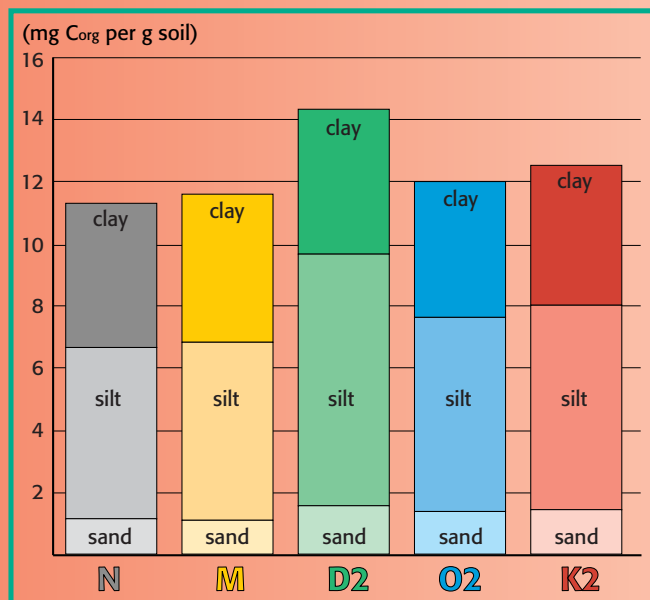
The results of the DOK-trial show that not only prudent use of heavy machinery that may lead to soil compaction is required to maintain soil structure. Fertilization and plant protection strategies must also be designed in such a way that soil biological processes leading to a better soil structure are supported.



Photos: Thomas Alföldi (FiBL)

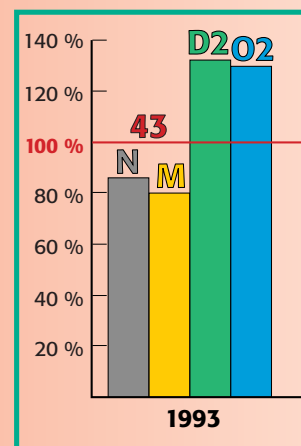
In early spring, distinct differences in disaggregation of soil particles and structure are visible at the soil surface. Most obvious is the difference between the bio-dynamic (left) and the conventional (mineral) (right) field trial plots.

## Carbon distribution among particle size fractions



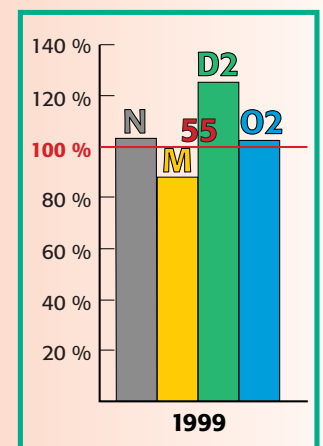
The particle size fractionation shows that differences in total organic carbon are mainly due to the higher carbon content of the silt fraction. Silt particles are subject to erosion and therefore a better aggregation by organic matter may reduce deterioration of soil structure.

## Percolation stability in ml per minute, K2 = 100 %



The percolation technique reflects the stability of soils to erosion, which was 30 percent higher in the organic systems as compared to the conventional with manure, or even 60 percent higher if compared to the unmanured systems. Using a wet sieving technique with field moist soils, the difference was less distinct, but still accounted for 10–20 percent. When dried samples were used (standard procedure) no differences were detectable, affirming the role of biological structures in soil aggregate stability.

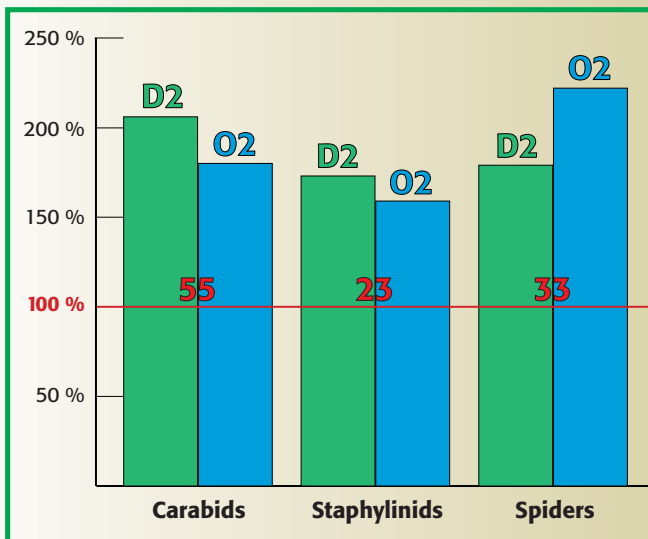
## Soil aggregate stability in % aggregates > 250µm, K2 = 100 %





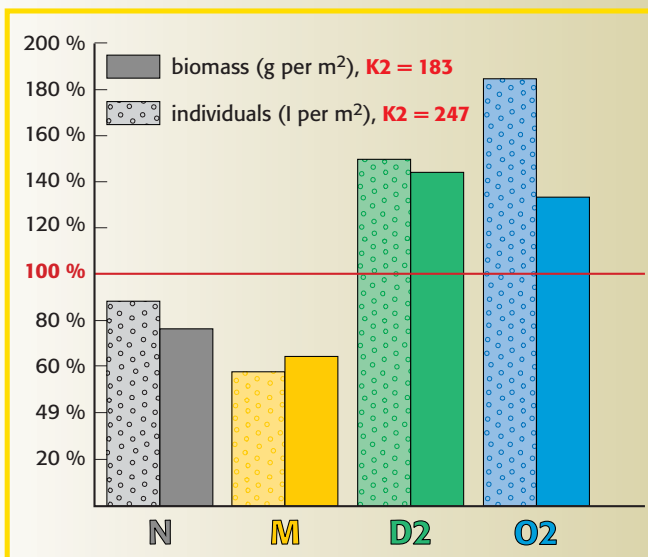
# Is organic farming beneficial to soils?

**Density of carabids, staphilinids and spiders  
(average of 1988, 1990 and 1991), K2 = 100 %**



In the organic systems the density of arthropods living on the soil surface was almost twice that of the conventional soils. This difference is explained by prey deficiency due to pesticide influence as well as by a richer weed flora in the standing crop that was less dense than in the conventional plots.

**Biomass and density of earthworms  
(average of 1990, 1991 and 1992), K2 = 100 %**



Photos: Siegfried Keller (FAL)

## Arthropods

Epigaeic arthropods that live above ground, like carabids, staphilinids and spiders, are considered sensitive indicators for the evaluation of site quality. Some species are recognized as important predators, who feed on other insects and especially on the highly abundant pest populations.

*Organic management promotes the development of earthworms and above ground arthropods, thus improving the growth conditions of the crop. More abundant predators help to control harmful organisms (pests).*



## Earthworms

Earthworms are well known for their sensitivity to pesticides. The interpretation of system effect, therefore, relies heavily on the direct and indirect effect of pesticides in the conventional systems. Moreover, earthworms react positively to organic fertilization, a factor which must also be taken into account.

The biomass of earthworms in the organic systems was 30–40 percent higher than in the conventional systems, their density even 50–80 percent higher. Compared to the mineral fertilizer system this difference was even more pronounced.

# Carbon fluxes in the soil ecosystem

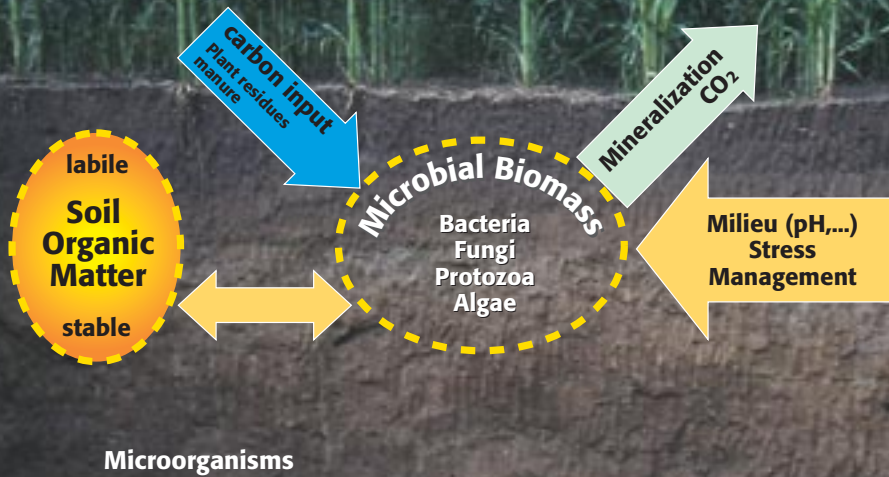
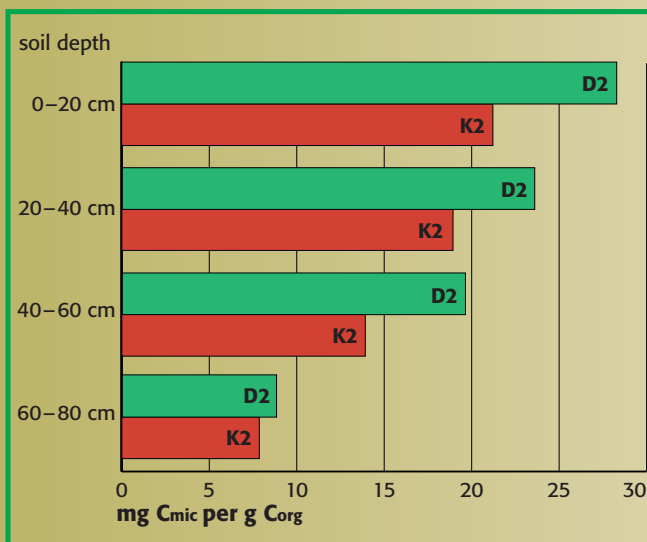


Photo: Gabriela Brändle (FiBL)

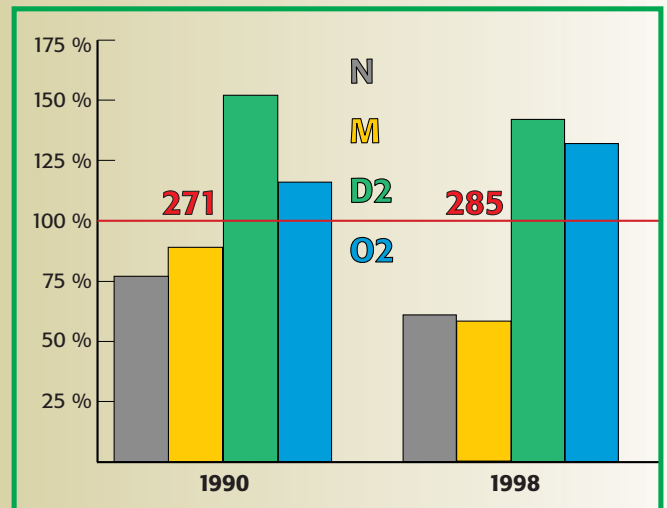
Soil is the habitat for plants, animals and microorganisms. As plants build up organic matter, soil animals feed on them and their debris, whilst microbes decompose the complex organic compounds to their mineral components and CO<sub>2</sub>. The living soil is a central part of soil fertility, because the activity of soil organisms renders available the elements in plant residues and organic debris entering the soil. Part of this material however remains in the soil and contributes to its stabilisation by humus build up.

## Ratio of microbial biomass carbon to total organic carbon (C<sub>mic</sub>-to-C<sub>org</sub> ratio)



The microbial biomass as a proportion of the total soil organic matter pool indicates soil organic matter quality with respect to its role in supporting soil microorganisms. The ratio of microbial carbon (C<sub>mic</sub>) to total soil organic carbon (C<sub>org</sub>) was higher in the organic system as compared to the conventional. The difference was significant down to a depth of 60 cm. At 80 cm, no difference was observed.

## Microbial biomass in mg C<sub>mic</sub> per kg soil, K2 = 100 %



The total mass of microorganisms in the organic systems of the DOK-trial was 20-40 percent higher than in the conventional system with manure and 60-85 percent higher than in the conventional system without manure. This result was already stated in 1990.

Microbial biomass and enzyme activities were closely related to soil acidity and soil organic matter content.



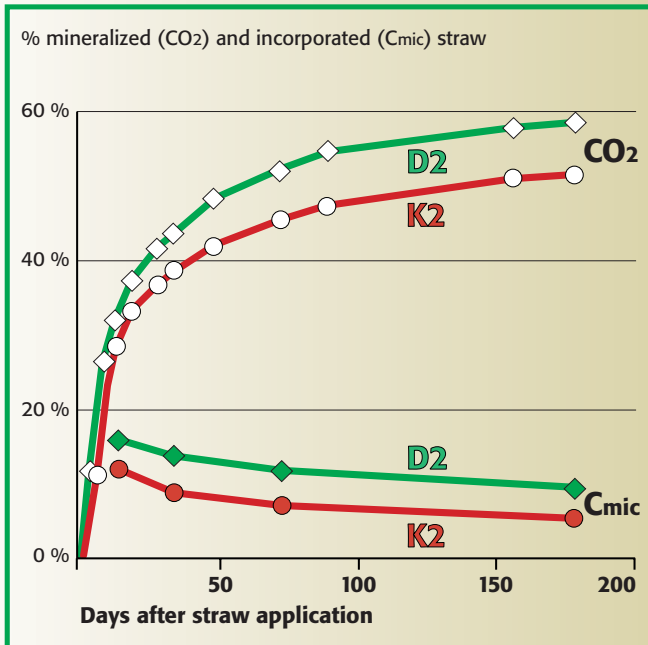
Photo: Hansueli Dierauer (FiBL)

Mineralization of plant residues is the most important activity carried out by soil organisms, on par with the activity of plants to assimilate CO<sub>2</sub> from the air. In the case of wheat, crop plant residues may add up to 10 t of straw per ha. At an average carbon content of 40 percent, and given the assumption that roots make up the same amount as the straw, 8000 kg of carbon enter the soil via the residue. Microbes mineralize it to CO<sub>2</sub> and use it for biomass build up.



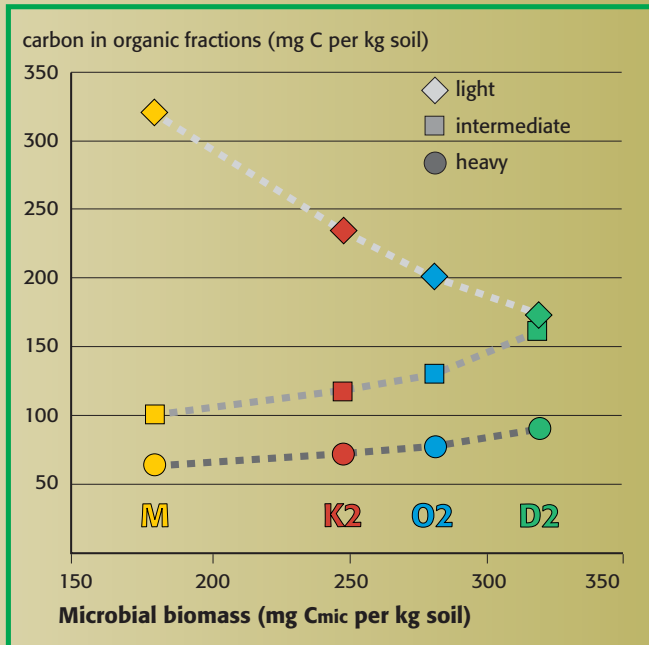
**Earthworms work hand in hand with fungi, bacteria and numerous other microorganisms in soil. In organically managed soils, the activity of these organisms is higher. Thus, nutrients are recycled faster and soil structure is improved.**

### Microbial processes in straw decomposition



A greater fraction of the straw applied to soil of the bio-dynamic system was mineralised (CO<sub>2</sub>) compared to the conventional soil. Additionally more straw-derived carbon was incorporated into the microbial biomass (C<sub>mic</sub>). There was also finally much less untouched straw material in bio-dynamic than in conventional soils. This result shows that microorganisms in organic soils are not only mineralizing more actively, but also that they contribute to the build up of stable soil organic matter.

### The role of microbial biomass in organic matter decomposition

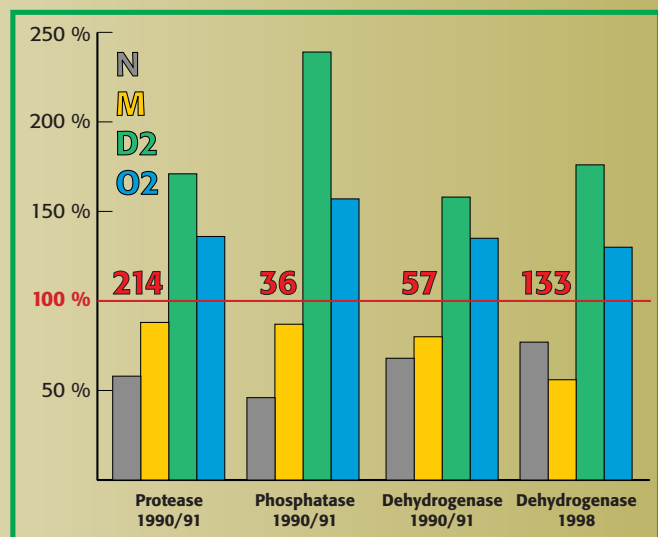


The amount of microbial biomass and decomposition is connected: When relating light fraction organic material (which still has visible plant structures) to soil microbial biomass, the functional role of microbes and their substrates (the residues) becomes evident. At high microbial biomass levels, little light fraction material remains undecomposed and vice versa.

Microbes have activities with important functions in the soil system; soil enzymes indicate these functions. The total activity of microorganisms can be estimated by measuring the activity of a living cell-associated enzyme such as dehydrogenase. This enzyme plays a major role in the respiratory pathway. Proteases in soil, where most organic N is protein, cleave protein compounds. Phosphatases cleave organic phosphorus compounds and thus provide a link between the plant and the stock of organic phosphorus in the soil.

In soils of the organic systems soil enzyme activities were markedly higher than in the conventional soils. Dehydrogenase activity differentiated the systems in a similar manner in both 1990 and 1998.

### Enzymes are indicators of microbial functions



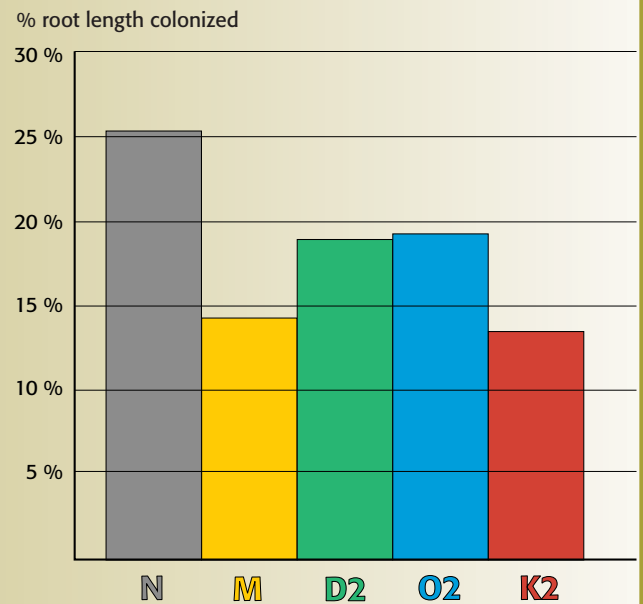
dehydrogenase activity in µg TPF per g soil and hour  
protease activity in µg tyrosine per g soil and hour  
alkaline phosphatase activity in µg phenol per g soil and hour

## Organic crops profit from root symbioses and are better able to exploit the soil

A major part of the soil microbial biomass is composed of fungi. Important representatives of the soil fungi are the mycorrhizae that build up a symbiosis between fungus and plant. Both the plant and the fungus profit from this symbiosis: the plant gets nutrients acquired by the fungus and the fungus receives assimilates from the plant in exchange. Mycorrhizae enlarge the plants rooting zone and can enter small pores in the soil, mobilise nutrients and carry them to the plant. Recently it was shown that mycorrhizae are able to colonize different plants at the same time and may therefore serve as a bridge between them. Moreover nitrogen bound in decaying roots may be saved from leaching. Last, but not least, mycorrhizae play a role in soil aggregate stability.

Spores of mycorrhizae; these spores can survive for longer periods in the soil and germinate when a host is growing. Photo: Department of Botany, University of Basle.

### Colonization of the roots by mycorrhizae (1989–1993)

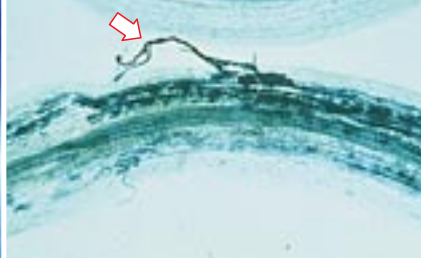


On average, mycorrhizal colonization of roots was highest in the crops of the unfertilized system, followed by the organic systems. The conventional crops had colonization levels that were 30 percent lower.

Among the crops and systems of the DOK-trial the most intense mycorrhizal root colonization was found in grass-clover, followed by the vetch rye intercrop. Roots of winter wheat were only scarcely colonized. Even when all soils were inoculated with active mycorrhizae, colonization was enhanced in organic soils (investigations of the Department of Botany, University of Basle). This indicates that, even at an inoculum in surplus, soil nutrients at elevated levels and plant protection suppress the symbiosis. This underlines the importance of appropriate living conditions for specific organisms.

The blue stained vesicles contain lipids;  
Photo: Paul Mäder (FiBL)

Longitudinal section of a root with and without mycorrhiza. The extraradical mycelium is visible (arrow). This mycelium takes up nutrients and aggregates soil particles. Photo: Department of Botany, University of Basle





# What's species diversity got to do with it?

Healthy ecosystems, well adapted to the site conditions, are distinguished by species diversity. The element cycles and food-web structures are closed and the nutrients are bound biologically. Ecosystem theory is in accordance with the principles of organic farming: the closed nutrient cycle on the farm level.

The DOK-trial is showing impressively, even without the intention to enhance species diversity, that organic land-management allows development of a relatively rich weed-flora as compared to conventional systems. In conventional farming, weeds are considered competitive to the crop and are eliminated by herbicides and dense crop stands. In organic systems, however, some of the «accompanying plants» of a crop are desired and considered useful.

The presence of a versatile flora attracts beneficial herbivores and other air-borne or above-ground organisms. Their presence improves the nourishment of the predatory arthropods. Populations of the very mobile ground beetles (carabids) in the DOK-trial not only differed in number and species composition. Of a total of 39 species identified, some specialized and particularly demanding species were exclusively present in the bio-organic field plots.

**Organic fields accommodate a greater variety of plants, animals and microorganisms. The organic agroecosystem is thus more resistant to stress and disturbance. Enhanced microbial diversity improves the utilization of the available energy and resources.**



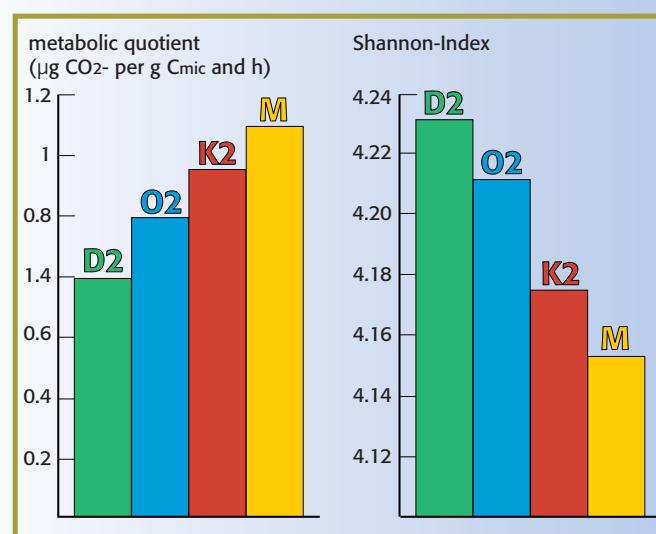
Photo: Paul Mäder (FiBL)

Even a small amount of weed flora is enough to enhance the attractiveness of arable crops for beneficial organisms like ground beetles (carabids).

## Number of species in the DOK-farming systems

	Weeds in the crop (88–91)	Stock of weed seeds in soil (96–98)	Ground beetles (88–91)	Earthworms (88–91)
D2	11	17	38	7
O2	9	19	35	8
K2	1	17	32	6

## Energy use and microbial diversity (1995 and 1996)



The number of substrates utilized by the soil microbial community is an indicator of the versatility of microbial functions, which in turn indicates microbial diversity in the soil. The diversity of microbial functions was higher in the bio-dynamic soils, particularly, as compared to the conventional soils. In spring samples

In the standing crop, the plots of the organic systems accommodated a much larger number of weed species than the conventional plots. However, even after 21 years no differences were found in the number and in species composition of the seedbank in the DOK field soils. Considering the size of the field plots the difference in the number of the mobile ground beetles is remarkable. The number of earthworms in the organic soils was also higher.

this result was confirmed, but no difference between the systems was found in samples taken after winter wheat harvest and application of manure.

When comparing diversity and the demand of energy for microbial maintenance (as indicated by the metabolic quotient), it becomes evident that diverse populations need less energy per unit biomass. A diverse microbial population, as present in the organic field plots, may divert a greater part of the available carbon to microbial growth rather than maintenance. In agricultural practice this may be interpreted as an increased turnover of organic matter with a faster mineralization and delivery of plant nutrients. Finally, more organic matter is diverted to build-up stable soil humus.



Each of the three farming systems D, O and K is performed at two intensities, the control treatments M and N only once. All systems are properly replicated in a Latin square and each appears once in row and column.

For statistical reasons of crop investigations and for demonstration the trial is repeated three times with the crop rotation temporally shifting on the subplots a, b and c. Thus, annual and spatial variability can be properly taken into consideration. The trial consists of 96 single plots of 100 m<sup>2</sup> each.

Entrance



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