



IFOAM TRAINING MANUAL *for Organic Agriculture in the Arid and Semiarid Tropics*

EDITED BY
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COMPILED BY



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Feedback and suggestions for improvements are welcome!

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Preface

The first IFOAM Training Manual for Organic Agriculture in the Tropics (the Basic Manual) was published in 2004. The Research Institute of Organic Agriculture (FiBL) together with partners of the organic movement in the Tropics were commissioned by IFOAM to complete two new training manuals that build on the Basic Manual. The new IFOAM training manuals address the two basic climatic zones of the Tropics, the Arid and Semi-Arid Tropics, and the Humid Tropics.

For both new manuals, already existing material was collected, screened and condensed into comprehensive training manuals. Additionally, a large number of farmers, trainers and scientists were asked for their experience. Partner institutions from the Tropics actively collaborated in the development of the manuals. The partners of the manual for the Arid and Semi-Arid Tropics are from Asia (India), Africa (Senegal and Tunisia) and Latin America (Chile).

The training manuals contain case studies of organic farming systems, describe successful organic marketing initiatives and offer guidelines for the main crops of the Tropics. With the informative text, transparencies and didactical recommendations the training manuals offer a resource basis for trainers with the idea of encouraging individual adaptation and further development of the material according to need. The training manuals are available on separate CDs in English, French and Spanish.

The training manuals were commissioned by IFOAM and funded through its program IFOAM-GROWING ORGANIC II (I-GO II). The Research Institute of Organic Agriculture (FiBL) and the Swiss Import Promotion Programme (SIPPO) provided co-funding.

The development of this manual was a much bigger and longer process than expected. The result is the start of a continuing process. The training manual shall be a living document, modified and further developed by those who use it. All copyrights are retained by IFOAM.

We hope that this training manual will be an inspiring source for all its users. We invite all to contribute their suggestions and material for further improvements of the manual. Contact: headoffice@ifoam.org.

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- IFOAM for funding, facilitating and providing feedback
- SIPPO for co-funding
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- Contributing partners

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Principles of Organic Agriculture

Preamble

These Principles are the roots from which organic agriculture grows and develops. They express the contribution that organic agriculture can make to the world, and a vision to improve all agriculture in a global context.

Agriculture is one of humankind's most basic activities because all people need to nourish themselves daily. History, culture and community values are embedded in agriculture. The Principles apply to agriculture in the broadest sense, including the way people tend soils, water, plants and animals in order to produce, prepare and distribute food and other goods. They concern the way people interact with living landscapes, relate to one another and shape the legacy of future generations.

The Principles of Organic Agriculture serve to inspire the organic movement in its full diversity. They guide IFOAM's development of positions, programs and standards. Furthermore, they are presented with a vision of their world-wide adoption.

Organic agriculture is based on:

- **The principle of health**
- **The principle of ecology**
- **The principle of fairness**
- **The principle of care**

Each principle is articulated through a statement followed by an explanation. The principles are to be used as a whole. They are composed as ethical principles to inspire action.

Principle of health

Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.

This principle points out that the health of individuals and communities cannot be separated from the health of ecosystems - healthy soils produce healthy crops that foster the health of animals and people.

Health is the wholeness and integrity of living systems. It is not simply the absence of illness, but the maintenance of physical, mental, social and ecological well-being. Immunity, resilience and regeneration are key characteristics of health.

The role of organic agriculture, whether in farming, processing, distribution, or consumption, is to sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings. In particular, organic agriculture is intended to produce high quality, nutritious food that contributes to preventive health care and well-being. In view of this it should avoid the use of fertilizers, pesticides, animal drugs and food additives that may have adverse health effects.

Principle of ecology

Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

This principle roots organic agriculture within living ecological systems. It states that production is to be based on ecological processes, and recycling. Nourishment and well-being are achieved through the ecology of the specific production environment. For example, in the case of crops this is the living soil; for animals it is the farm ecosystem; for fish and marine organisms, the aquatic environment.

Organic farming, pastoral and wild harvest systems should fit the cycles and ecological balances in nature. These cycles are universal but their operation is site-specific. Organic management must be adapted to local conditions, ecology, culture and scale. Inputs should be reduced by reuse, recycling and efficient management of materials and energy in order to

maintain and improve environmental quality and conserve resources.

Organic agriculture should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity. Those who produce, process, trade, or consume organic products should protect and benefit the common environment including landscapes, climate, habitats, biodiversity, air and water.

Principle of fairness

Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.

Fairness is characterized by equity, respect, justice and stewardship of the shared world, both among people and in their relations to other living beings.

This principle emphasizes that those involved in organic agriculture should conduct human relationships in a manner that ensures fairness at all levels and to all parties - farmers, workers, processors, distributors, traders and consumers. Organic agriculture should provide everyone involved with a good quality of life, and contribute to food sovereignty and reduction of poverty. It aims to produce a sufficient supply of good quality food and other products.

This principle insists that animals should be provided with the conditions and opportunities of life that accord with their physiology, natural behavior and well-being.

Natural and environmental resources that are used for production and consumption should be managed in a way that is socially and ecologically just and should be held in trust for future generations. Fairness requires systems of production, distribution and trade that are open and equitable and account for real environmental and social costs.

Principle of care

Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

Organic agriculture is a living and dynamic system that responds to internal and external demands and conditions. Practitioners of organic agriculture can enhance efficiency and increase productivity, but this should not be at the risk of jeopardizing health and well-being. Consequently, new technologies need to be assessed and existing methods reviewed. Given the incomplete understanding of ecosystems and agriculture, care must be taken.

This principle states that precaution and responsibility are the key concerns in management, development and technology choices in organic agriculture. Science is necessary to ensure that organic agriculture is healthy, safe and ecologically sound. However, scientific knowledge alone is not sufficient. Practical experience, accumulated wisdom and traditional and indigenous knowledge offer valid solutions, tested by time. Organic agriculture should prevent significant risks by adopting appropriate technologies and rejecting unpredictable ones, such as genetic engineering. Decisions should reflect the values and needs of all who might be affected, through transparent and participatory processes.

1 Introduction

1 Introduction

1.1 Description of climate and soil

1.1.1 Climatic conditions

Areas which are not irrigated, and which depend only on rainfall to produce crops are often called "drylands" and are the living resource base for almost one fifth of the world's population. They cover over 15% of the tropics and include the Sahel region, the Kalahari region and some regions of India, as well as parts of Northern and Southern America. The typical vegetation of semi-arid climatic zones are grasses, thorny shrubs and trees. The predominant agricultural systems are livestock ranching and rather extensive crop production, sometimes using shifting cultivation. In areas where there is water available for irrigation, intensive plant production can be found. In very dry regions, however, where annual rainfall is less than 300 mm, agricultural production is marginal.

The dry climatic zones in the tropics are characterized by a long dry season with a short, often intense, wet season of up to 2 months for arid areas and 4.5 to 7 months for semi-arid areas. Precipitation varies from 0 to 300 mm for arid areas, and 400 to 700 mm for semi-arid areas. Rainfall occurs mainly in violent storms during either summer or winter, depending on the area. The greater the distance from the equator in any given place, the shorter the rainy season.

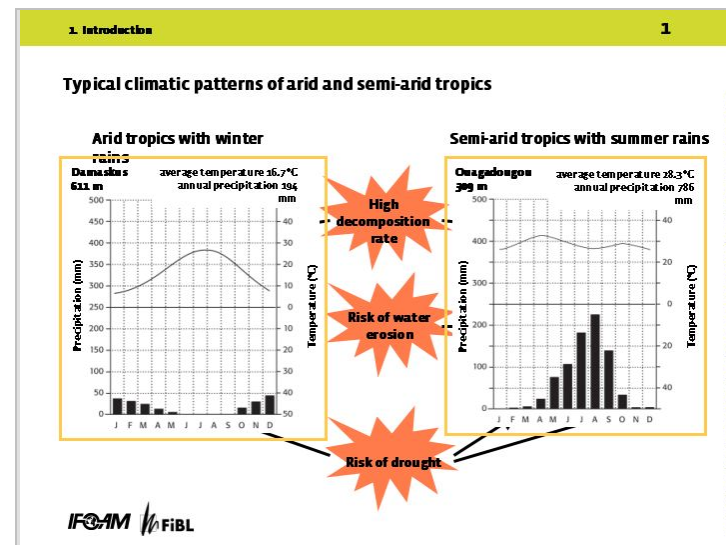
Average temperatures in the semi-arid and arid tropics are higher than in the humid tropics. These warm temperatures result in high water-evaporation levels from both the plants (transpiration) and the soil surface itself (evaporation), reducing humidity and soil moisture. While in humid climates evapo(transpi)ration is less than rainfall, in dry climatic zones water losses from evapotranspiration can exceed rainfall, sometimes reaching up to twice the level of rainfall. In most dry areas, hot, dry winds occur, increasing the already high evaporation rate. These strong winds often prevent moisture-bearing air from penetrating the soil. The resulting water scarcity significantly limits agricultural yields. However, when the level of moisture in the soil can be maintained above a certain level, the semi-arid conditions become suitable for cropping, since high day and low night temperatures prevail. However, if temperatures climb to 40 °C or more, plant productivity is limited. High temperatures and strong irradiation are harmful to soil organisms and therefore have a negative effect on the fertility of the soils.

Lessons to be learned:

- Water scarcity is the most limiting factor for agriculture in the arid and semi-arid tropics.
- Climate is variable and rainfall is unreliable.
- Soils in the drylands are vulnerable and tend to degrade.
- Building up and protecting soil organic matter is crucial for soil fertility.
- Agroforestry has considerable potential. However, it must be carefully adapted to local climatic conditions.
- Ecosystem diversity is an important tool for managing pests and diseases.

Group work: Local climate

Divide the participants into groups and let them draw graphs of the climatic pattern of their region (see transparency 1.1 (1)). Ask them to explain through individual presentations the challenges for agriculture under their own climatic conditions.



TRANSPARENCY 1.1 (1): CLIMATIC PATTERNS OF ARID AND SEMI-ARID REGIONS

1 Introduction

Despite the generalizations above, it is important to remember that the climate of the arid and semi-arid tropics is very variable and the rainy seasons unreliable. The distribution of the rains, as well as the total amount of rainfall, varies considerably from year to year. There is sometimes a complete absence of rain, particularly in the Sahel, where rainfall levels have declined by 20–40 % over recent decades. Increases in the frequency and severity of drought contribute substantially to dryland degradation and desertification, and have resulted in serious migration problems.

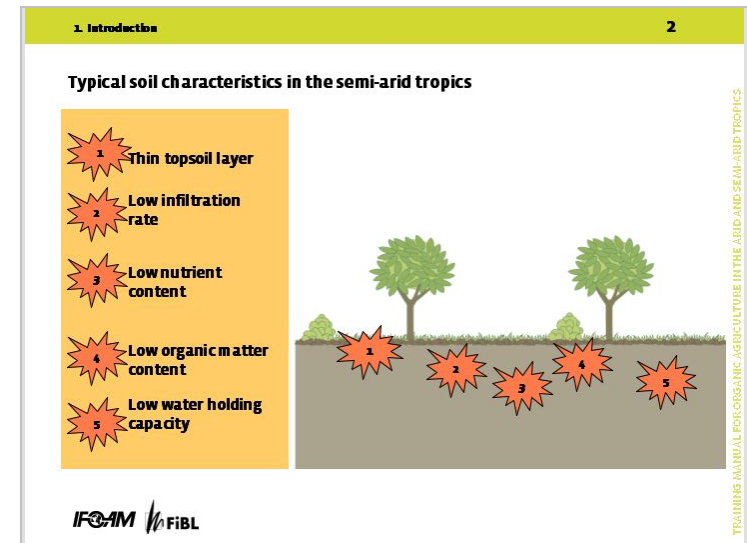
1.1.2 Soils of the arid and semi-arid tropics

The soils in the tropical drylands vary quite widely, as do their respective climatic and geological conditions. In spite of these differences, all of them are highly influenced by two factors: low annual rainfall and high temperatures. These give rise to two problems. First, these temperatures promote rapid soil organic matter oxidation which, together with low nutrient content, makes the soils vulnerable to overexploitation. Second, hot temperatures can lead to soil crusting, especially on bare land, which in turn leads to impermeable soil surfaces. As a consequence, a large part of the rainfall is lost as runoff.

The predominant soils in the arid tropics are Aridisols (mostly dry mineral soils with a high-pH, sometimes calcitic, sodic or saline). Moisture is the main limiting factor on plant growth in these soils. When there is sufficient water, the high calcium carbonate content may cause some fertility problems, such as reduced availability of phosphorous and increased salinity and alkalinity. Aridisols with high gypsum content can cause engineering problems for irrigation projects.

Psammments and lithic soils are commonly found in both arid and semi-arid tropics. They are dry, sandy soils with low water-holding capacities, with low nutrient exchange and water retention capacities. Poor soil structure makes these soils vulnerable to wind erosion. The agricultural potential of these sandy soils depends on the availability of sufficient water for crop cultivation and provision of sufficient nutrients. If appropriately managed, sandy soils can be highly productive.

Solonetz and Solonchaks, both saline soils, are formed where salts are present in moderate to high amounts in the parent material of the soil or where there is a saline water table close to ground level.



TRANSPARENCY 1.1 (2): GENERAL CHARACTERISTICS OF SOILS OF THE SEMI-ARID TROPICS

Discussion: The difficulty and potential of cultivating the typical soils of the semi-arid tropics

Collect samples of common soils in this region and exhibit them in the classroom. Ask the participants the following questions:

- Which of the exhibited soils do you know? What are their properties?
- What are the typical problems that arise when cultivating these soils?
- What is the agronomic potential of these soils?
- What (climatic and human) factors influence the productivity of the soils?

For further information about soil structure, soil organisms and soil testing consult chapter 3 on "Soil fertility" in the Basic Manual.

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Vertisols are mineral soils that have 30% or more clay and exhibit deep wide cracks when dry. They are often called heavy, cracking clay soils. When these soils become moist, the soil volume expands. This shrink/swell action can create serious engineering problems and generally prevents the formation of distinct, well-developed soil horizons.

Typical soils of the Mediterranean zones are Phaeozems, Rendzinas, Kastanozems and Cambisols. As these all have a high humus content good yields are possible when water is available.

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1.2 The influence of climate and soil conditions on farming practices

Water shortages and vulnerable soils are the most common limiting factors for agriculture in the semi-arid and arid tropics. In regions where irrigation is not feasible, the only production systems that can be sustained are those that improve water efficiency and soil fertility. Effective and efficient water management is therefore of paramount importance.

1.2.1 Water management

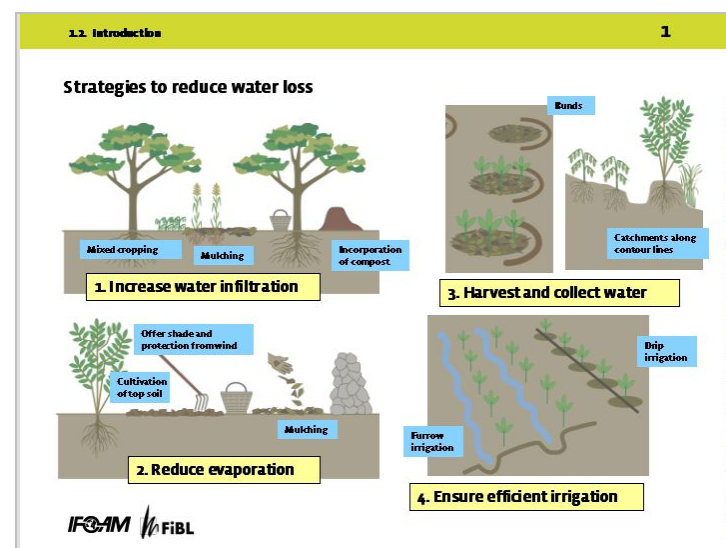
Water collecting, water saving and soil moisture conservation strategies should be given the highest priority in semi-arid and arid regions. As water is the limiting factor for crop yields, every drop of rain or irrigation water should be retained in the agricultural field and losses through evaporation and runoff must be avoided. Even where irrigation water is available, water application should be kept to the minimum, in order to avoid problems of salinity and the over-exploitation of water bodies (especially ground water). To improve water use efficiency the following strategies can be applied:

- 1. Increasing water infiltration:** It is important to achieve maximum infiltration of rainfall water through the soil surface and top layer. Crust formation and clogged soil pores (often a result of soil erosion) promote water runoff, and should be prevented. The application of compost, the incorporation of plant material in agroforestry systems, as well as mixed cropping and mulching are all important means to build up organic matter in the topsoil layer. This will increase infiltration and water conservation. Cover crops and mulches improve soil structure and prevent water from running off too easily.
- 2. Reducing evaporation:** Reduction of water evaporation is essential. Mulches and tree canopies decrease evaporation by shading. Hedges slow down winds and also reduce evaporation. Regular hoeing of the topsoil interrupts the soil capillarity.
- 3. Water harvesting and collection:** To avoid water losses after strong rains, surface runoff should be collected with bunds and brought close to the plant roots. Water runoff from fields, roads or roofs can also be directed into ponds, tanks or wells for storage. To reduce runoff from the field, the water can be retained with dyked furrows, micro-catchments, or through field contouring. Runoff water that has left the fields should be caught by terraces, bunds on contour lines, dams and hedges, and collected if possible.

Sharing experiences: Applied methods for water management

Invite the participants to speak about their experiences with water management by asking the following questions:

- What effective water collecting systems are used in the participants' home regions?
- Which methods increase the soil infiltration rate?
- Which methods save irrigation water?
- What other methods to avoid soil loss are known?



TRANSPARENCY 1.2 (1): METHODS FOR WATER CONSERVATION

For additional basic information about water conservation see chapter 3.5 of the Basic Manual.

1 Introduction

4. **Efficient irrigation:** The application of furrow and drip irrigation (see also chapter 4.8) instead of flood or sprinkler irrigation contributes considerably to the more sustainable use of water. It also reduces the potential negative impacts of the overuse of water (see also chapter 3.5.3 of the Basic Manual).

1.2.2 Soil protection and nutrient management

In nature, rangelands provide grasses and shrubs that are converted into animal protein by wildlife and nomadic herds. The ecological balance is maintained by natural defensive mechanisms such as the reduction of the number of animals during long droughts. The use of vegetation as fuel and building material has intensified with the increase in human and animal population, as has agriculture. This has disturbed the balance of nutrient supply and demand. Instead of being returned to the soil, crop residues are fed to cattle, used for burning or as construction material. As a result, permanent grasslands and forests disappear, organic matter content declines and the bare soil becomes more prone to erosion, thereby further aggravating an already unstable situation. The soils of the tropical drylands are thus very vulnerable to desertification. Regional climatic changes that increase water scarcity in the arid and semi-arid tropics turn formerly productive lands into deserts. Continuous and excessive use of artificial NPK-fertilizers leads to a depletion of micronutrients. In crop production areas with irrigation systems, salinity can be the result of poor water management. Increasing population density further stresses the productivity of the land.

In arid climates biomass productivity is low. This is due to lack of water and high soil temperatures. As soon as water becomes available, organic matter is decomposed. Consequently, most arable soils of the arid zones are low in soil organic matter and prone to degradation.

Efforts to protect the soil and improve soil fertility are thus absolutely essential for farming enterprises in arid and semi-arid climates aiming for sustainable development.

Soil protection

Soil protection measures in dry climates aim to reduce the erosive power of rain, wind and direct sunlight on the soil surface. This can be done by covering the soil with vegetation or mulch, or by providing shade through trees or shrubs.

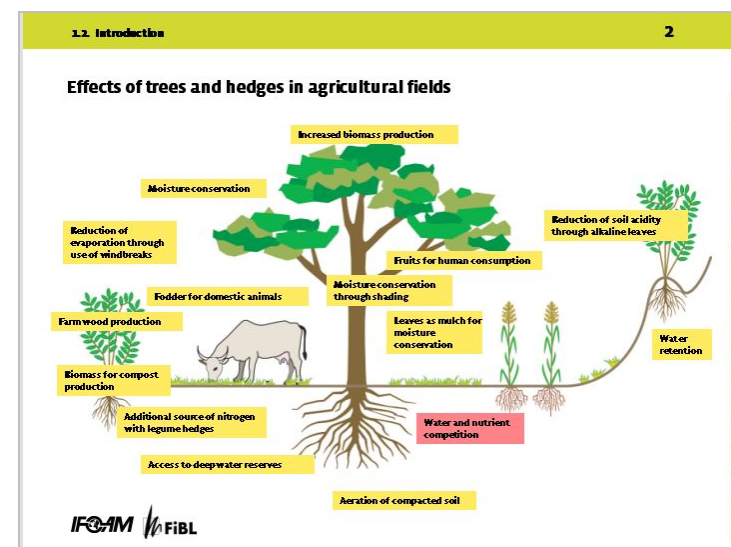
The integration of trees (especially nitrogen fixing trees) and hedges into the agricultural landscape can do much to improve and maintain soil fertility. The planting of windbreaks not only reduces erosion by slowing down strong winds, but also increases biomass production of the crops inside the windbreak zones. The benefits include more fodder, fuel and

1 Introduction

thatching material and, to some extent, more organic matter in the soil. The higher yields in plantations with windbreaks compensate for the reduced cultivation area. Farming systems that reduce the negative impacts of wind therefore have obvious advantages – especially in the long term. In very dry areas, of course, competition for water and nutrients can weaken the main crop. Proper spacing, root restriction and appropriate species selection are possible means for limiting competition.

The versatile functions of agroforestry with their benefits are listed in the table below:

Functions	Benefits
Shading	<ul style="list-style-type: none"> • Protection of the soil from strong irradiation • Moisture conservation
Deep rooting	<ul style="list-style-type: none"> • Moisture conservation • Aeration of compacted soil • Access to deep water reserves
N-fixation (depending on the species)	<ul style="list-style-type: none"> • Additional source of nitrogen
Mulch material	<ul style="list-style-type: none"> • Branches and leaves serve as mulch and thus help conserve moisture in the soil and protect the soil • Alkaline plant material reduces acidity of the soil
Compost material	<ul style="list-style-type: none"> • Branches and leaves may be used in compost production
Fodder	<ul style="list-style-type: none"> • Branches and leaves offer additional fodder for domestic animals
Fuel	<ul style="list-style-type: none"> • Wood produced on the farm reduces the overuse of forests
Fruits	<ul style="list-style-type: none"> • For human consumption
Windbreaks	<ul style="list-style-type: none"> • Reduction of evaporation • Increased biomass production of the crop
Water retention	<ul style="list-style-type: none"> • Reduction of water losses and soil erosion



TRANSPARENCY 1.2 (2): EFFECTS OF TREES AND HEDGES IN AGRICULTURAL FIELDS

Sharing experiences: Agroforestry

Find farmers who have already been involved in agroforestry integration programs in the region. Let them make a short presentation of their specific experiences (maybe with the help of the participants). The presentation should answer the following questions:

- What has been done?
- How was it initiated? By whom?
- Which specific areas were targeted?
- What positive and negative effects on the crops could be observed?
- If there were negative effects, what measures were initiated to counteract them?

1 Introduction

Measures of soil erosion control overlap with techniques of microclimate management and water management.

Technical solutions to overcome erosion problems can range from capital-intensive and mechanized measures (e.g. dams to retain runoff water and sediments) to low external input solutions. In organic agriculture, as in other sustainable farming methods, the emphasis is placed on biological techniques and improving traditional techniques of water and soil conservation.

1 Introduction

Soil fertility and nutrient management

The capacity of the soil to feed plants – its fertility – is strongly linked to the availability of water and nutrients. Humid conditions, moderate temperatures, air in the soil and organic material are all necessary to allow soil organisms to live and roots to grow. Insufficient soil moisture prevents proper decomposition of plant material and nutrient supply to the plants, and build-up of soil organic matter. Increased organic matter content is closely related to higher biological activity in the soil and a better soil structure. This leads to good drainage of water and greater stability in the face of erosion by water and wind. Organic farmers therefore focus on the management of nutrients through organic matter – a biologically active soil provides the foundation for successful organic farming. It is very difficult, though, to improve soil fertility in arid climates because both water and the possibilities of increasing biomass production to "feed the soil" are very limited.

The prevention of erosion, the protection of the topsoil and the collection or incorporation of crop residues and animal dung are important elements of efficient nutrient management, as they "close" the nutrient cycle of the farm unit. Animal manure should be collected and composted together with plant materials. If required, additional biomass from outside the farm can also be added to the cycle. Pruning of agroforestry trees and hedges helps to conserve natural ecosystems.

Measures necessary to maintain soil productivity are:

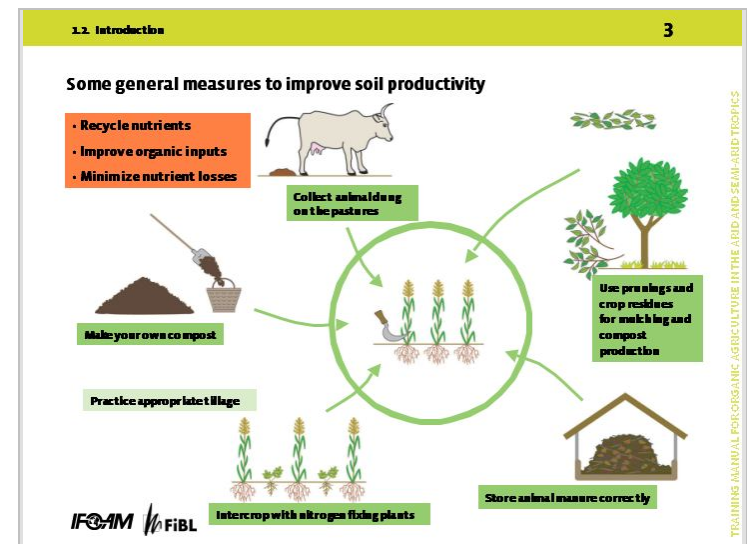
- Production, collection and incorporation of organic matter into the soil, ideally as humus, derived from compost production
- Appropriate tillage, involving minimal soil disturbance
- Maximum ground cover (mulch, vegetation) to avoid erosion of topsoil
- Crop rotation, including legumes with effective nodulation to replace nitrogen removed in products and encourage biological activity
- Agroforestry to create a more hospitable microclimate
- Avoidance of unmanaged fallow with bare soil left to be exploited by livestock

For additional information about soil erosion, as well as practical recommendations for soil protection measures read chapter 3.4. "Soil Erosion" of the Basic Manual.

The multiple benefits of mulching are also described in chapter 3.6 of the Basic Manual.

For additional information about the relevance of a soil's organic matter for soil fertility see chapter 4.1.2 of the Basic Manual.

For additional information about plant nutrition read the following chapters of the Basic Manual: 4 "Plant Nutrition", 4.1.4 "Nutrient cycling" and 4.4.2 on compost.



TRANSPARENCY 1.2 (3): SOME GENERAL MEASURES TO IMPROVE SOIL PRODUCTIVITY

1 Introduction

PEST AND DISEASE MANAGEMENT

Although there are large differences between the climates of drylands and the humid tropics, the main principles - and many of the challenges - of organic pest and disease management for plant protection are the same. With the exception of overhead-irrigated agriculture, the yields of organically grown crops in drylands are threatened most by pests. Hot temperatures promote the multiplication of insects and mites, while the spread of diseases is inhibited by low air humidity. Despite this, inadequate supplies of water and nutrients, as well as strong heat, make the plants prone to various diseases. There is a constant danger that pests such as locusts, borers and bugs will devastate a harvest. Birds and rodents can also cause serious damage.

Organic farmers approach the problems of pest and disease control by promoting a balanced ecosystem on their farms, rather than by having recourse to conventional pesticides. They do this by creating diversity, rotating crops and enhancing the natural defense mechanisms of the plants.

The main "Golden Rules" of preventative pest and disease management are:

- Use of healthy, pest-free seeds and planting materials.
- Use of varieties that are adapted to local conditions (i.e. short growing period, high pest and disease resistance, drought tolerance).
- Intercropping: the planting of different crops or varieties within the same area diversifies the available habitat and may inhibit build-up of pests.
- Crop rotation: interrupts the specific relationship between pests and host plants.
- Organic fertilizer application: well-balanced manure and compost application results in healthy plants.
- Timely planting helps crops to develop resistance before pests build up.
- Good sanitation in storage areas, farmyards and fields also helps prevent pests and diseases.
- Promotion of natural enemies by intercropping flowering plants and hedges, providing habitats for beneficial organisms.
- Appropriate spacing avoids competition between the crops, which would weaken the plants.
- Timely weed control to reduce competition and remove alternative sources of pests and diseases.
- Appropriate water management: water shortage as well as excess water (water logging) can make crops more susceptible to pests.

Sharing experiences: Preventative plant protection measures

Write the "Golden Rules" on the board in keywords. Discuss with the participants which of these preventative methods are used in the region and what has been experienced.

Encourage the participants to speak about the pest and disease control methods that they apply themselves to good effect.

1 Introduction

In rain-fed agriculture, plant growth occurs mainly during and after the rainy seasons. This is the period when pests are generally most active in the fields, making use of the available food sources, and when population rates are highest. In order to avoid the population and activity peaks of pests coinciding with the period of the crops' greatest susceptibility, organic farmers should time the cultivation of their fields carefully. Knowledge about the pests' life cycles and conditions under which they thrive is therefore crucial. For example, it is known that drought conditions can promote soil-inhabiting insects (i.e. termites) and the infection of legumes by mycotoxins (due to pod-splitting).

In overhead-irrigated agriculture, the humid microclimate means that diseases cause more problems in plant production. Additionally, pests in irrigated areas may find permanent food sources or hosts and thus may multiply more easily, as there is no period of food shortage. Irrigation systems that do not wet the leaves do not encourage the spread of diseases of the upper plant. Irrigated agriculture may also create more problems with diseases and pests if crops that are more prone to pest and disease attack are grown. Repeated and consecutive cultivation of the same crop (or even monoculture), low crop diversity and intensive cropping (with narrow stands) are all typical of irrigated agriculture and all these practices encourage the development of pests and disease. Intensively cropped fields may thus have negative effects on the resistance of plants to their natural enemies. Organic farmers who plan to cultivate their fields in such a way should expect considerable pest and disease pressure. In some cases, organic cultivation of crops that are particularly vulnerable to certain diseases or pests may be simply impossible.

Group work: Capacity building related to pests

Decide, together with the participants, which are the most important pests and crops in the region. Divide the participants into groups of four and let each group choose one pest and the respective host plant. Provide them with information about the chosen items. Let each group study and draw the life cycles and properties of "their" pest and the peaks of the highest vulnerability of the crops. Each group should prepare a short presentation of the results. Discuss in plenary these recommendations for the timing of cropping and other disease avoidance strategies that can be derived from this information.

For additional information about pest and disease management read chapter 5 "Pest, Disease and Weed Management" of the Basic Manual.

Recommended reading:

- A. Young. 1997. *Agroforestry for soil management*. CAB International and ICRAF.
- G. Stoll. 2000. *Natural Crop Protection in the Tropics*. Margraf Verlag, Weikersheim.
- M. Douglas. 1994. *Sustainable Use of Agricultural Soils*. University of Berne.
- W.C. Beets. 1990. *Raising and Sustaining Productivity of Smallholder Farming Systems in the Tropics*. AgBé Publishing, Holland. 176–225.

Recommended websites:

- www.cgiar.org/icarda/
- www.icrisat.org
- www.vasat.org

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

2 Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

2.1 Organic Maize and Beans

2.1.1 Description of the farming system

Cultivation of maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) in association with each other is practiced in many countries of the tropics and subtropics, especially in those of Latin America, but also in Eastern and Southern Africa. There is a long tradition of maize-bean farming systems. In Central America the crops evolved together, and human selection has resulted in a great genetic diversity. The association of leguminous and cereal crops has proved well suited to low-input farming conditions in various climates, including moderate ones. This chapter aims to take a closer look at the intercropping of maize and beans and discusses the potentials and the limits of this cropping system.

Traditional maize-bean farming systems are mostly based on continuous intercropping of maize and beans over a long period. In general, the crops are associated with other cereals such as sorghum, or with cucurbits such as squash or watermelon. After some years the field is put into fallow for up to ten years to allow the soil to recover. Soil preparation after fallow is traditionally done by slashing the vegetation and burning the remaining branches. The ashes supply minerals to the crops that will subsequently grow there.

Usually, maize and beans are sown at the same time during the main rainy season. Soil cultivation is done using animals or by hand, with a hoe. Sowing is done manually by putting several seeds of maize and beans into planting holes spaced about 50 cm apart. The usual distance between the rows is about 80 cm. Planting density for cucurbits varies more, in accordance with the needs of the farmer.

After sprouting, the maize plants are usually thinned-out to one plant per hole. In some areas, however, the number of maize plants is not reduced, resulting in 3 to 4 maize plants per planting hole. One or two bean plants are allowed to grow in each hole. Later the maize plants serve as supports for the climbing beans. The cucurbits that are grown in between progressively cover the soil and protect it from sun and rain. Traditionally no fertilizer is applied. In early growth, the crops are weeded once or twice.

Lessons to be learned:

- *Traditional (or indigenous) maize-bean farming systems have proved sustainable under a very wide range of circumstances. More intensive cultivation is less sustainable.*
- *Conventional (or industrialized) approaches to maize-bean farming based on chemical inputs are not sustainable, as these lead to degradation of the soil.*
- *Application of the principles of organic agriculture to maize-bean farming can result in a sustainable, productive, and economically viable farming system.*
- *In order to maintain soil fertility, soil organic matter needs to be properly managed and effective soil protection measures applied.*
- *Nitrogen fixation can be increased by appropriate cultivation measures, and by inoculation of seeds.*

Motivation: Characterize the local maize-bean farming system

If a maize-bean based farming system is practiced locally, invite the participants to describe it by listing its characteristics. This may be best done in groups.

Characteristics may include the crops grown/crop diversity/association of crops, cultural practices to improve soil fertility, prevent erosion and reduce drought vulnerability, inputs, and productivity.

Ask the participants to present the outcomes of the group work (and to note them on a board) and discuss them together.

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

The crops are harvested separately. Some farmers bend the maize plants at the node below the cob as the crop approaches maturity. This helps protect the maize cobs from birds and water when the crops are being continuously harvested, and improves the light availability for the associated crops (to allow their continued growth).

Management of the maize-bean intercropping system will vary according to whether the farmer wishes to give preference to the maize or bean crop. In Kenya, for example, preference is given to maize, whereas in parts of Uganda priority is given to a good bean harvest. In areas with two annual rainy seasons, maize is often given priority in the long rainy season, while beans are given priority in the short rainy season.

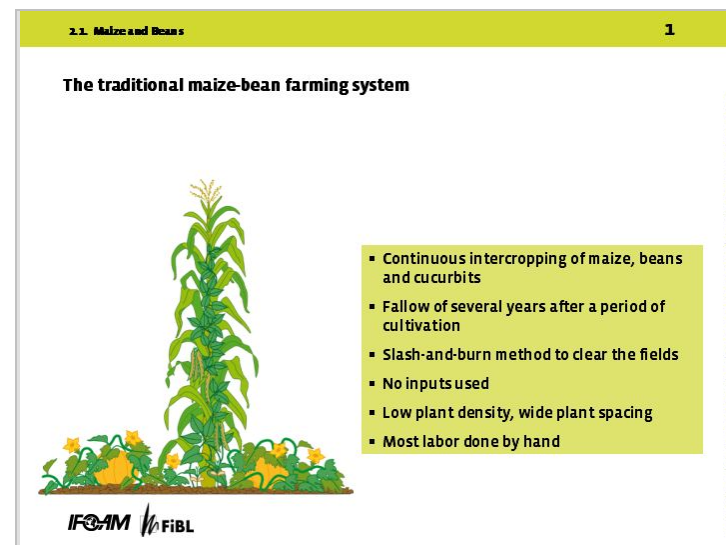
Productivity of this farming system is generally low to moderate. The crops are grown mainly for self-sufficiency. Surplus production depends on the land surface that is cultivated by a household. Nevertheless, the productivity of the maize-bean intercrop is greater than that of a maize monoculture.

Livestock usually plays only a small role in this farming system.

In areas where rains are scarce, especially during the maize crop's flowering period, long-cycle maize varieties are preferred which are tolerant of drought, lodging, local pests and diseases, are well adapted to the soil type and intercropping and require few inputs.

Changing circumstances

Traditional forms of maize-bean farming require considerable areas of land in order to maintain soil fertility, as they require a long fallow period. Increasing population density has forced many farmers to shorten the fallow period, bringing more land under cultivation in order to feed more people, or because the land has been divided among family members. As the maintenance of the soil fertility levels in these farming systems is highly dependant on a proper fallow, the increasing length of cultivation results in a decreasing level of soil fertility and productivity. Thus, traditional maize and beans farming systems in many areas are no longer able to cover family needs for staple foods. Decreasing soil fertility results in greater demands being placed on the land, losses through droughts, soil erosion, weed competition, a scarcity of trees and a drying-up of water resources.



TRANSPARENCY 2.1 (1): DESCRIPTION OF THE TRADITIONAL MAIZE-BEAN FARMING SYSTEM

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

In many areas the output of traditional farming systems that produce small amounts of diverse products, is increasingly at odds with market demand. As a result, interest in growing cash crops, such as citrus or coffee, has increased. These cash crops are mostly grown with the aid of purchased inputs (fertilizer, chemicals, etc.).

These changing social and economic circumstances have led many households into crisis, and many face the dilemma of deciding whether to grow crops for self-sufficiency or for cash. Organic farming, as well as other approaches to sustainable agriculture, have added new dimensions to maize-bean farming in recent years and opened up new possibilities to the farmers who are reliant on these crops.

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

2.1.2 Comparison of traditional, conventional and organic maize-bean farming systems

Traditional farming system

In traditional maize-bean farming systems, it is typical for low quantities of nutrients to enter the farm, yet for substantial amounts to leave it with the harvested crops. The productivity and sustainability of traditional maize-bean farming relies heavily on the fallow period and on the nitrogen fixation of the beans. As the grain legumes are harvested, the net nitrogen input is very low. The nutrients that are taken away far exceed the nutrient inputs when the land is under cultivation and the nutrient balance is only re-established through the fallow period. In general, beans fix less nitrogen than other legumes, such as lucerne. But the rate of fixation varies greatly according to the growing conditions (water, pH, soil conditions etc., and available nitrogen). The amount of nitrogen that is removed at harvest is not very important, compared to the low fixation rate. The traditional farming system therefore ensures ecological (and economical) land use only as long as population pressure is low enough to allow long fallow periods. The association of beans and maize is, in itself, not sufficient to maintain soil fertility. Furthermore, when applied on slopes, this cropping system also experiences considerable depletion of nutrients, through leaching and soil erosion. Loss of topsoil not only reduces soil fertility, but promotes further erosion.

The strategy of growing different crops on the same field aims at increasing the productivity of the field, and at reducing the risk of damage or total crop failure. Multicropped corn, beans and squash have shown to be less subject to attack by diseases and above-ground pests (such as caterpillars, leafhoppers and thrips) than if grown in isolation. If one of the crops in a multicropped field is damaged, it is likely that the other(s) will compensate for losses in yield. This is partially due to the diversity of plants, as this diversity makes it more difficult for pests to find the host plants that provide the appropriate habitat for predators and parasites (such as parasitic wasps). Also when a field is diversified, diseases do not spread as quickly as they would in a mono-cropped environment. Intercropped maize and beans have lower evapotranspiration rates than solo stands of maize and are more successful at suppressing weeds. Intercropping also enhances the root development of both species, facilitating the search for water and nutrient sources.

Discussion: Strengths and weaknesses of the traditional maize-bean farming system and comparison with the conventional approach

Split into groups and discuss the principles of traditional maize-beans farming. Then invite the participants to discuss the strengths and weaknesses of this farming system in plenary. If necessary, provide information given from the Training Manual.

Characterize the so-called "modern" or conventional approach to maize-bean farming. How does it differ from the traditional system? What are the strengths and weaknesses of this approach?

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

Traditional farming makes use of landraces that are genetically more heterogeneous than modern cultivars. In some cases these have good defense mechanisms against pests and diseases, and are adapted to local growing conditions (especially drought and low nutrient levels). Such landraces contribute considerably to avoiding great losses.

Smallholders give first priority to satisfying their family's nutritional needs. Pulses are excellent foods, as they are rich in fat, protein, fiber, minerals and vitamins, and are a useful component of a balanced diet.

Conventional approach to maize-bean farming

As a result of increased population density some farmers try to compensate for the shortage of land by reducing or abandoning the fallow period, and intensify cultivation by using synthetic NPK-fertilizers. These farmers mostly grow dense stands of pure maize and use high yielding or 'genetically improved' varieties. The use of herbicides is common. As pressures lead more farmers to change from a mixed to a solo cropping system labor becomes scarcer and more expensive. This leads to product specialization and an increase in costs, as inputs are required to control increasingly adverse environmental conditions.

Higher inputs increase productivity, but this increase is solely the result of using inputs. In general, little attention is paid to loss of nutrients through soil degradation or to improving natural soil fertility. The use of herbicides and mineral fertilizers is, to some extent, incompatible with the cultivation of beans and squash, as they can be contaminated by the herbicides, and the ability of legumes to use atmospheric nitrogen is greatly reduced by the use of mineral nitrogen fertilizers. Intensive farming that relies solely on the use of agrochemicals leads to a gradual reduction of soil fertility. The application of mineral nitrogen, phosphorus and potassium does little to satisfy the need that soil microorganisms have for carbon, and thus their development is not promoted. As a result, biological activity in the soil is low. Low biological activity and low organic matter content in the soil eventually lead to a decline in yields and increase the sensitivity of the crops to drought. An approach to maize-bean farming that substitutes chemicals for proper ecological processes (and thus does not develop ecosystem structure) is not sustainable in the long term.

2.1. Maize and Beans		2	
Main cultural practices in traditional, conventional and organic maize-bean farming			
	Traditional	Conventional	Organic
Soil fertility	<ul style="list-style-type: none"> Fallow and burning of crop debris Nitrogen fixation by beans 	<ul style="list-style-type: none"> Mineral NPK-fertilizers Beans mostly abandoned 	<ul style="list-style-type: none"> Maximizing biomass production Maximizing nitrogen fixation
Diversity	<ul style="list-style-type: none"> Continuous cultivation of maize, beans and cucurbits; several years of fallow 	<ul style="list-style-type: none"> (Continuous) cultivation of maize 	<ul style="list-style-type: none"> Combination of crop rotation, (relay) intercropping and agroforestry (permanent crops)
Soil protection / weed control	<ul style="list-style-type: none"> Cultivation of soil covering cucurbits Manual weeding 	<ul style="list-style-type: none"> Manual and chemical weeding 	<ul style="list-style-type: none"> Plant soil cover Mulching Manual weeding
Inputs	<ul style="list-style-type: none"> None 	<ul style="list-style-type: none"> Mineral fertilizers 	<ul style="list-style-type: none"> Organic material Organic fertilizers

TRANSPARENCY 2.1 (2): COMPARISON OF THE CHARACTERISTICS OF TRADITIONAL, CONVENTIONAL AND ORGANIC MAIZE-BEAN FARMING

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

The use of herbicides and mineral fertilizers, and the cultivation of single crops, permits more efficient use of labor and therefore reduces labor demand. However, the purchase of the inputs increases dependency on cash income. To ensure sufficient return from the crops, conventional farmers tend to concentrate on fertile soils or on areas with good access to markets. Marginal soils in less accessible areas are mostly abandoned.

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

Organic or sustainable approach to maize-bean farming

Farmers who wish to improve the sustainability of their farming system under conditions of intensified production, face the multiple challenges of maintaining their food security, producing for the market, minimizing exposure to debts and ensuring long-term soil fertility. The key to achieving these aims is to develop an understanding of the interrelations between the different elements within the farming ecosystem and to develop an appropriate farm ecosystem structure (for further information see chapter 2.1.1 of the Basic Manual). Several examples show that it is possible to simultaneously improve the productivity and sustainability of traditional maize-bean based farming systems (see literature and websites). The sustainable strategy consists of a series of interventions. These include increasing crop diversity, regenerating soil fertility through organic matter management, improving nutrient efficiency and soil conservation and incorporating farm animals and trees.

A key aim is to create a diverse cropping system. Ideally, this should consist of crops of different sizes, with different seasonal preferences in water, nutrients or temperature, as well as different light requirements. This strategy aims to minimize losses by pests and diseases, increase productivity and sustainability in general, and minimize risks.

In addition to maize, beans and cucurbits, other horticultural crops such as fruit trees, shrub forages and multipurpose trees are grown. The integration of trees offers many advantages. Material pruned from the trees can serve as mulch, animal feed or firewood. The trees play an important role in holding the topsoil and preventing land slides. Leguminous trees also fix additional nitrogen. The annual crops are grown in rotation, or are intercropped. A balanced crop rotation based on maize and beans is: maize-beans-zucchini // vegetables // leguminous crop // cereals // green manure. Aside from the traditional arrangement, there is a range of other options for intercropping maize and beans. One possibility is to use bush bean varieties and to alternate one planted line of maize with eight or more lines of beans. Alternatively bush beans and maize can be planted in the same line, but in separate positions. The beans can also be grown in rotation with maize.

Organic matter management plays a crucial role in soil fertility management, which is a major determinant of a farm's sustainability. The aim is to use the farm's own biomass production to supply high quantities of organic material to the soil in order to enhance biological activity and improve the condition of the soil (for details on soil fertility see chapter 3.2 of the Basic Manual). The main sources of additional organic material will be green manure crops, soil covers and trees. Composting and introducing farm animals into the system bring additional advantages (for more information see chapters 4.4.2 and 6.1.1 of the Basic Manual).

Discussion: Elaboration on possible interventions aimed at improving the farming system

Based on the results of the previous exercises, work in groups and discuss approaches for improving the farming system. Focus on crop/plant diversity, soil fertility, soil conservation, nutrient efficiency and economic sustainability (input to output, dependency on credits, labor, self-sufficiency and market potential).

If helpful, complete the exercise using the information given in the Training Manual. Show transparency 2.1.3 and ask whether it reflects the strengths and weaknesses of the three methods of maize-bean farming.

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics


To improve productivity, *Crotalaria* (*C. ochroleuca* G. Don.) is grown as a green manure in some maize-bean cropping systems. It can be grown either by relay intercropping with beans and then incorporating it into the soil or it can be sown early in pure stands and then mulched.

The adoption and adaptation of introduced legumes can help improve nutrient efficiency. The cultivation of legumes with high nitrogen fixing rates and high biomass production levels can be very beneficial. One example is the velvet bean (*Mucuna pruriens*), which can be used as a grain, fodder, or better still for green manure purposes. It considerably increases nitrogen input and the production of organic material for better soil fertility. Nitrogen fixation can also be improved by the inoculation of grain legumes with efficient nitrogen fixing bacteria. Recycling of organic material, such as household wastes or crop residues, and refraining from burning both, contribute to making more efficient use of farm nutrient resources.

Soil conservation measures are of major importance in preventing the degradation of soils, particularly in hilly areas. Soil erosion can be controlled by planting living barriers, such as crops, along contour lines, or by developing micro-catchments and ensuring continuous soil cover by mulching, cultivation of cover crops and relay intercropping (e.g. by ensuring that new crops are established before the previous crops are harvested). Apart from increasing yields, cover crops also reduce the labor needed for weeding as they suppress the weeds that would otherwise grow. Mulching decreases evaporation from the soil, and also contributes to weed suppression. Soils with higher levels of organic matter are more easily worked than those with lower levels. In arid areas, conservation and storage of water through mulching and water harvesting are of particular importance. Minimal tillage methods contribute to soil conservation, especially on slopes.

The integration of farm animals can contribute to better recycling of nutrients within the farm, especially if the animals are fed farm-grown forage legumes, crop residues, weeds, and leaves from trees and shrubs. The crops (especially those with a high nutrient demand) will benefit from the valuable manure the cattle, sheep, goats, pigs or chicken provide. Special attention must be paid to the collection, storage and application of manures, in order to minimize nutrient loss (see chapters 4.1.4 and 4.3.2 of the Basic Manual).

A diverse farming system with various crops and animals, and the application of labor intensive practices such as composting, necessarily requires more labor than a simple cropping system. This additional labour should be more than compensated for by reduced dependency on cash for inputs, more secure yields and higher productivity per unit area.

2.1. Maize and Beans		3
Comparison of traditional, conventional and organic maize-bean farming		
Traditional	Conventional	Organic
<ul style="list-style-type: none"> + Multicropping (resulting in lower pest and disease pressure, better use of water and nutrient resources) + Focus on self-sufficiency + Great genetic diversity of plants 	<ul style="list-style-type: none"> + Higher productivity + Less labor 	<ul style="list-style-type: none"> + Higher plant diversity + Multilayer cropping (including trees, soil cover) + Soil fertility management through increasing organic matter + Focus on soil protection + Nutrient recycling + Integration of farm animals + Increased nitrogen fixation
<ul style="list-style-type: none"> - Low nutrient inputs - High nutrient losses - Low to moderate productivity - Little attention to soil protection - No "modern" cash crops 	<ul style="list-style-type: none"> - Mostly monocropping, loss of diversity - Little concern for building up natural soil fertility - Little attention to soil protection - Dependency on cash to purchase inputs 	<ul style="list-style-type: none"> - More labor (but declines with increasing fertility and balance within the farming system)
		

TRANSPARENCY 2.1 (3): COMPARISON OF TRADITIONAL, CONVENTIONAL AND ORGANIC MAIZE-BEAN FARMING

Information on the principles of organic farming and on its differences to other farming methods is given in chapter 2.1 of the Basic Manual.

If possible, visit a farm that follows a sustainable approach to intensive farming and compare with what has been discussed earlier.

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

2.1.3 Special aspects: Improvement of nitrogen fixation and nitrogen dynamics in intercropped maize and beans

Legumes benefit the farming system via symbiotic fixation of nitrogen from the air. They also help reduce the risk of disease within cereal crops grown in rotation, provide food and fodder, and (depending on the species) produce considerable amounts of organic material. Legumes are also known to increase the availability of the phosphorus that is tied up in aluminum or iron oxides, and to substantially increase microbial activity in the soil, thereby increasing the nutrient supply. In organic cropping systems all of these functions are relevant.

Improving nitrogen fixation of legumes is of major interest. It is thus very important to know what factors and cultural measures help increase nitrogen fixation (for basic information on nitrogen fixation see chapter 4.5.3 of the Basic Manual).

Natural and cultural factors influencing nitrogen fixation

Nodulation (the development of nodules on the roots consisting of colonies of nitrogen fixing bacteria) occurs in response to low levels of nitrogen and is enhanced by high levels of phosphorous in the soil. The presence of effective bacteria in the soil also encourages nodulation, which can also be stimulated by inoculating the legume seeds with bacteria before sowing. Low soil acidity, low soil temperature and humid soil conditions are advantageous to the development of root nodules. Thus nitrogen fixation is lower in acid soils, under high soil temperatures, and when the plants are shaded. The optimum pH is between 6 and 7.5.

Legumes are more effective at fixing nitrogen under good growing conditions. The better these conditions are the more able the plants are to supply energy to the nitrogen fixing bacteria. When the pods of the plant start to fill, energy from photosynthesis is supplied to the pods instead of to the roots and the nitrogen fixing bacteria. Thus the longer the vegetative period is before flowering and pod filling, the more nitrogen will be fixed. Varieties with continuing (indeterminate) instead of simultaneous (determinate) flowering fix more nitrogen.

Phaseolus-beans are known to fix relatively small amounts of nitrogen (from 25 to 70 kg per hectare, depending on the variety) compared to other leguminous plants. Climbing beans fix the most nitrogen, bush beans the least. Thus the rate of nitrogen fixation among varieties of beans varies. Cultural measures can also make a considerable difference to nitrogen fixation

2.1. Maize and Beans		4
How to improve nitrogen fixation		
Natural factors favoring nitrogen fixation	Cultural measures to improve nitrogen fixation	
Presence of effective bacteria	<ul style="list-style-type: none"> ⇨ Regular cultivation of legumes ⇨ Inoculation of seeds with bacteria 	
Good conditions for inoculation and nitrogen fixation	<ul style="list-style-type: none"> ⇨ Increasing low soil pH ⇨ Mulching (for humidity and moderate temperature) 	
Good general growing conditions for legumes	<ul style="list-style-type: none"> ⇨ Not sowing into wet soils ⇨ Humid soil conditions ⇨ Not shading ⇨ No use of herbicides and fungicides 	
Appropriate nutrition of the legume (avoiding deficiencies in phosphorus, nitrogen, sulfur and molybdenum)	<ul style="list-style-type: none"> ⇨ Appropriate supply of phosphorus ⇨ Moderate nitrogen supply (particularly in poor soils) ⇨ No burning of plant residues and soil organic matter ⇨ No bean seeds from acidic fields ⇨ If necessary, application of fertilizers containing sulfur 	
Rate of nitrogen fixation	⇨ Selection of effective species and varieties	
Long vegetative period	⇨ Selection of late flowering species and varieties	

TRANSPARENCY 2.1 (4): HOW TO IMPROVE NITROGEN FIXATION

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

through ensuring optimum growing conditions. It is essential to try to ensure good growing conditions during the periods of sowing, emergence and early growth. Sowing legumes in wet soils, for example, can cause the growth of beans and other legumes to fail completely.

Mulching helps reduce the temperature of the topsoil and thereby increases nitrogen fixation and the yield of beans. Mulching also encourages greater humidity in the soil. The incorporation of organic material into the soil reduces soil acidity and thus improves nitrogen fixation.

In general, nitrogen fixation by the legumes is in inverse proportion to the availability of nitrogen within the soil. However, in poor soils, some initial nitrogen inputs (from organic sources) can serve to enhance the establishment of legumes by encouraging initial plant and root growth. Moderate quantities of organic fertilizers, such as animal manures or compost, do not have a negative impact on nodulation and nitrogen fixation, as nitrogen from these sources is released continuously.

Legumes do have relatively high phosphorus requirements. An appropriate phosphorus supply will result in an earlier start to nitrogen fixation and greater quantities fixed.

The micronutrients sulfur and molybdenum are also of major importance. Lack of molybdenum occurs predominantly in acid soils. Thus acidic soil conditions should be avoided and bean seeds originating from acidic fields should not be used. Burning crop residues or the practice of slash and burn leads to loss of sulfur in plant residues and soil organic matter. If necessary, organic fertilizers containing sulfur may be applied.

Herbicides, and in particular fungicides, have considerable negative effects on nitrogen fixing bacteria and thus reduce nitrogen fixation.

Plant densities and the ratio of maize and bean plants have a further influence on yields.

Nitrogen dynamics in maize-bean intercrop

The more nitrogen that is available in the soil, the less the legumes will build nodules on the roots and fix nitrogen from the air. Thus intercropped maize and beans do not compete for nitrogen.

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

Generally, the amount of nitrogen that comes from symbiotic fixation is synthesized within the legume plant at a rate that corresponds to the plant's requirements. The release of nitrogen by the bean plant's root nodules during cultivation is therefore not greater than a few kilograms per hectare and is of very little benefit to the maize plants. The nitrogen will mostly be available to the next crop planted in the same place. Thus, in intercroops of maize and beans, the maize plants only benefit to a very small extent from the nitrogen fixed by the beans.

When nitrogen rich fertilizer is applied, maize responds much better than the beans. However, maize and beans respond similarly to application of phosphorus under normal conditions.

Late sowing of beans (especially under favorable growing conditions) results in the beans growing in shade and this shading before flowering reduces their nitrogen fixation.

Beans leave considerable amounts of available nitrogen in the soil after they are harvested. It is important to conserve this nitrogen by avoiding losses. This is particularly an issue when heavy rains follow and no crop is grown. Therefore, it is necessary to sow a cover crop containing grass species, or a crop with high nitrogen demand, to prevent the nitrogen from being lost.

Shorter maize varieties with upright leaves are generally better suited to intercropping than tall varieties with hanging leaves.

5

2.1. Maize and Beans

Lessons learned



- Traditional (or indigenous) maize-bean farming systems have proved sustainable under a wide range of situations. Under more intensive cultivation their sustainability is questionable.
- The conventional (or industrialized) approach to maize-bean farming, based on chemical inputs is not sustainable, as it does not prevent degradation of the soil and does not conserve ecosystem structure.
- Application of the principles of organic agriculture to maize-bean farming can result in a sustainable, productive and an economically viable farming system.
- Soil fertility is maintained through proper management of soil organic matter and soil protection measures.
- Nitrogen fixation can be increased by appropriate cultivation measures.

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TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 2.1 (5): LESSONS LEARNED FROM STUDYING MAIZE-BEAN FARMING SYSTEMS

Recommended reading:

- Ruthenberg, H. 1980. *Farming systems in the tropics*. 3rd ed. Oxford University Press, New York.
- Francis, C.A. (ed.): *Multiple Cropping Systems*. Macmillan Publishing Company, New York and London.

Recommended websites:

- *Example of successful improvement of a maize-bean based farming system in Honduras focusing on agroforestry:* <http://www.tve.org/ho/doc.cfm?aid=675>
- *Example of an improved maize-bean farming system focusing on permanent soil cover and plant diversity:* <http://www.iirr.org/saem>
- *Experiences from agro-ecological approaches to improve sustainability of Latin American traditional farming systems:* http://agroeco.org/fatalharvest/articles/enhancing_prod_la_peasants.html

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

2.2 Oasis Garden

2.2.1 Description of the farming system

The oasis garden is a traditional farming system in arid climates, particularly in Northern Africa. In its conception it does, in many ways, represent a diverse, site appropriate and sustainable farming system, that fits with some aims of Organic Agriculture.

Oasis gardens are both diverse and productive. They are well adapted to the needs of the people who live on, and from them, and a large variety of cultivars flourish, which have adapted well to the ecological and economic pressures that the region faces. Historically oasis gardens have played an important social and political role by being a place where the spheres of production and leisure meet. These qualities make traditional oasis farming invaluable in its local context, and an interesting example for organic farmers to study.

In agricultural terms, traditional oasis gardens combine date palms with a great diversity of annual and perennial crops, which together form a multilayered structure. By necessity they are irrigated. Livestock is limited to a small number of sheep, goats, donkeys and/or camels, although most agriculturalists have frequent interactions with the surrounding steppe farmers, who predominantly breed livestock.

Typically the oasis garden has three layers of crops. The top layer consists of date palms, the middle layer hosts fruit trees such as apples, figs, pomegranates, etc. and the bottom layer is used for the production of annual crops such as forage crops, vegetables, cereals, condiments and ornamental plants. Each layer of the oasis garden has a specific function, creating the physical conditions needed by the next layer, and contains crops with different rooting structures (for further information on the characteristics of agroforestry systems see chapter 4.2.2 of the Basic Manual). Temperature and light are higher in the top layer and lower in the bottom one, whereas freshness and humidity are higher in the bottom layer.

The three layers have distinct functions, as described below:

Top layer: The high growing date palms are exceptionally resistant to high temperatures and dry atmospheric conditions (they do however require sufficient moisture in deeper soil layers.) They provide shade from the bright sunlight, protecting the lower crops from excessive radiation, and also help protect the other crops from strong winds.


Medium layer: The fruit trees benefit from the moderate light conditions and temperature, as well as the water that is given to the date palms.

Lessons to be learned:

- *Oasis gardens are complex farming systems that are generally highly adapted to local conditions.*
- *Organic oasis gardens have much in common with traditional oasis gardens, but add new aspects that further develop their potential.*
- *Organic oasis gardens must also consider socio-economic circumstances.*
- *In general, it is quite easy to convert a traditional oasis garden to an organic one, but it does demand additional effort and knowledge.*

2.2. Oasis garden 1

Characteristics of oasis garden farming systems



- Ideally 3 layers of crops: date palms, fruit trees, annual crops
- Favorable micro-climate for growing crops, using shade from the date palms
- Irrigation
- High production intensity
- Production adapted to the nutritional needs of farmer families and market potential
- Adapted to available labor
- Adapted to available inputs

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TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 2.2 (1): CHARACTERISTICS OF OASIS GARDEN FARMING SYSTEMS

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

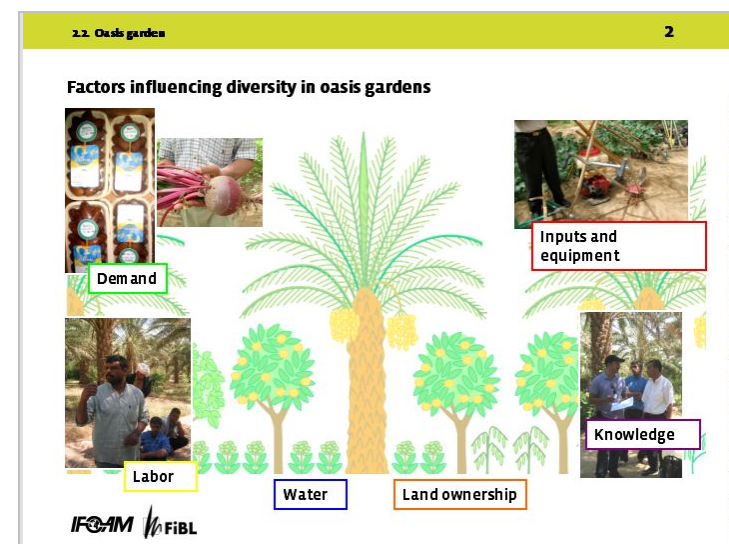
Bottom layer: The crops of the bottom layer store the humidity of the night, prevent erosion of the topsoil, contribute to the production of organic material, increase biological activity in the soil, and help, to a certain extent, to keep natural enemies of the fruit trees at bay.

This farming system has evolved with the socio-economic needs of the local population: new vegetables, fodder for the animals, new fruit tree species etc. have been introduced over time. Oasis gardens were thus designed to satisfy the basic food needs of the oasis population.

Traditional oasis farming appears to be a complex farming system, which is designed to maintain a fragile balance in a harsh environment. Diversity is an invaluable characteristic of this farming system. However, if one or more factors that contribute to diversity change, the farming system will alter. The introduction of a market economy, water shortages, soil erosion, lack of labor or intensification of production etc., have in many oases, already led to a strong reduction of crop and genetic diversity. Many other oases are under threat of this occurring.

How different factors influence diversity in oasis gardens:

- **Labor** - The availability of labor affects the diversity of the farming system, and also the quality and quantity of the produce. If labor, or interest in additional food crops, (e.g. by the oasis families) is low, the crops of the middle and the bottom stage are abandoned and maintenance of the fruit trees and bottom crops is neglected. If the fruit trees of the second stage and the palm trees are not pruned regularly, increased humidity and poor light conditions result in higher disease pressure. The changed micro-climate affects the quality and the yield of the lower crops.
- **Knowledge** - Knowledge about how to cultivate the different crops is necessary to grow them successfully.
- **Demand** - In the oasis, most of the attention is focused on the management of the date palms. The cultivation of additional crops greatly depends on the farming system and personal preference, as well as local demand for agricultural produce such as vegetables and fruit. Traditionally, a great diversity of date cultivars was grown for local and national markets, while newer plantations focused on high-yielding cultivars that grew dates of good quality (such as Deglet Nour) for international markets. The same trend can be observed nowadays in farmer-owned oasis gardens, as these cultivars cover the main part of the farmer families' net income. To be competitive, small oasis gardens must rely on diversity and quality of produce.



TRANSPARENCY 2.2 (2): FACTORS INFLUENCING DIVERSITY OF OASIS GARDENS

Group work: The characteristics of an oasis garden

Participants who are familiar with oasis gardens may be asked to discuss, in groups, the following questions:

- How can present oasis farms be characterized?
- Which factors influence present oasis garden farming and how do they do it?
- Compare the basic elements of the oasis with the principles of organic agriculture (Basic Manual 2.1.1). Are the potentials achieved? What are the constraints?

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

- **Water** - In case of water shortages, no fruit trees or annual crops are grown as priority is given to date palms. In many oases water resources have come under increased stress and consequently their long-term viability is threatened. Diversification of oasis gardens may thus depend on a more economical use of water.
- **Inputs and equipment** - The availability of external inputs, mainly machines and specific infrastructure, is necessary to cultivate vegetables and fruits and to improve productivity (for ploughing, weeding, plant protection, irrigation etc.).
- **Animals** - Sheep and goats are common in the oasis. The breeds that are kept are well adapted to the harsh climatic conditions. They contribute considerably to the oasis farmers' self-sufficiency by supplying milk and meat. Besides their direct socio-economic value, farm animals are also useful because of the manure that they supply to the farming system. Animal density, however, is very limited within the oasis. Most animals are kept outside the oasis itself (see also chapter 2.2.3).
- **Land ownership** - Land ownership can be a decisive factor for or against the diversification and improvement of oasis gardens. Family-owned gardens tend to be traditionally cultivated, while large and dense plantations are usually company owned. Such plantations do not allow any cultivation of other crops on a lower level. In most cases farmer-owned oasis gardens are cultivated in a more sustainable manner than those belonging to companies.

Ask the participants to present the results of their discussion to the others and draw conclusions together.

To participants who are familiar with other agricultural ecosystems, you may give the following exercise with some questions to be answered:

Characterize a typical agro-ecosystem from your area (such as olive tree orchard, vineyard, etc.). Are there any similarities with the oasis garden farming system concerning diversity, multilayer cropping, creating a specific microclimate, adaptation to the local conditions etc.? Can it be considered sustainable according to chapter 2.1 of the Basic Manual?

2.2. Oasis garden		3	
Comparison of traditional, conventional and organic oasis farming			
	Traditional	Conventional	Organic
Diversity	<ul style="list-style-type: none"> • Relatively high crop diversity • Very high genetic diversity 	<ul style="list-style-type: none"> • Low crop diversity • Low genetic diversity 	<ul style="list-style-type: none"> • High crop diversity (due to high crop diversity on the bottom layer) • High genetic diversity of crops • High biological diversity
Fertilization	<ul style="list-style-type: none"> • Limited use of animal manure 	<ul style="list-style-type: none"> • Mainly mineral fertilization 	<ul style="list-style-type: none"> • Compost • Animal manure • Green manures • Mineral fertilization only in cases of proven need
Disease and pest management	<ul style="list-style-type: none"> • Direct control mainly with chemical products (low input) 	<ul style="list-style-type: none"> • Direct control mainly with chemical products (often high input) 	<ul style="list-style-type: none"> • Prevention with cultivar selection, pruning, crop rotation etc., and by encouraging natural enemies • Direct control with natural and specific pesticides (by necessity)
Weed management	<ul style="list-style-type: none"> • Manual weed management 	<ul style="list-style-type: none"> • Chemical weed management 	<ul style="list-style-type: none"> • Preventative weed control • Manual and mechanical weeding
Water management	<ul style="list-style-type: none"> • Flooding and furrow irrigation in open channels 	<ul style="list-style-type: none"> • Flooding and furrow irrigation in closed channels 	<ul style="list-style-type: none"> • Water-saving irrigation • Improving soil water retention capacity • Improving water use efficiency
Market / Economy	<ul style="list-style-type: none"> • For personal use and local market (little economic diversity) 	<ul style="list-style-type: none"> • Cash crops (dates) for national and international markets (little economic diversity) 	<ul style="list-style-type: none"> • Economic diversification (products and markets) • Integrated supply chains for cash crops • Surplus for certified produce

TRANSPARENCY 2.2 (3): COMPARISON OF TRADITIONAL, CONVENTIONAL AND ORGANIC OASIS MANAGEMENT

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

2.2.2 Comparison of traditional, conventional and organic oases

In all oasis farming systems, cultural practices are mainly focused on the date palms, as these contribute most to income. In traditionally managed oasis gardens, the fruit trees underneath the date palms are selected to grow under the existing low input conditions. As a result, there is a great diversity of fruit trees in the traditional oasis system. Although in conventionally managed oases the three stages of the farming system are generally maintained (new date palm plantations are an exception), diversity in the bottom stage is often reduced and only a few crops are cultivated at higher intensity, often with the use of chemicals. With the conversion of oasis gardens to organic farming, diversity is generally increased, in order to establish a more natural equilibrium. The results are mostly visible at first sight.

In traditional oases, fertilization of the crops relies on the very limited quantities of animal manure that are available. Although most oasis farmers know about the value of animal manure, proper soil fertility management in the sense of organic agriculture is not practiced. Nevertheless, irregular application of animal manure to oasis gardens has so far contributed to better soil fertility than that of the surrounding desert land.

Conventional oasis farmers, in contrast, rely completely on mineral fertilizers to supply nutrients to the crops. With traditional farming methods, soil fertility will stay at a rather low level and cropping intensity and yield will also stay rather low. Conventional farming practices may result in a continuous decrease of soil fertility due to a lack of organic material. Organic oasis farmers pay much attention to the improvement of soil fertility by increasing the organic of the soil. This enhances soil biological activity, contributes towards balanced crop nutrition, and also improves the water holding capacity of the soil (see chapters 3.2.2 of the Basis Manual and chapter 1.2.2 of this manual also). The organic matter content of the soil is best improved through the application of compost. As organic materials for compost production are scarce in oases, besides using crop residues and leaves from date palms, fruit trees and bottom stage crops, additional plants may be "harvested" or specially cultivated to supply organic material for composting (such as shrubs and trees in hedges).

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

Green manure crops (e.g. drought tolerant legumes) are another important source of organic material, which are largely unknown by traditional oasis farmers. Manure from extensive livestock husbandry is either incorporated fresh into the soil or mixed with plant material for compost production. Natural fertilizers such as natural phosphate are used where necessary (for further information see chapter 4 of the Basic Manual).

For irrigation, water in a traditional oasis is directed through open channels to the gardens. In the hot climate and where soils are light, water losses are thus significant. One way of reducing such losses is to conduct the water to the gardens in closed tubes. Organic water management, however, not only aims at reducing water losses in the channels, but also at improving the efficiency of water use in the fields (for further information see chapter 1.2.1 of this manual and chapter 3.5 of the Basic Manual).

In conventional oases, weeds are eliminated with chemical herbicides in order to have clean fields and to save water. By contrast, in the organic oasis, weeds are welcomed to some extent to help control erosion, to feed and host predators' natural enemies, and to contribute to the oasis' fertility, after having been incorporated into the soil or composted.

As with other farming systems, the differences in pest and disease management between organic and conventional practices are fundamental. Traditional oasis farming uses few chemical products for pest and disease control. With the introduction of conventional practices, however, the use of (mostly unspecific) chemical sprays has increased. This strategy risks a selection of aggressive, chemical-resistant races and new pests and diseases developing that commonly result in the loss of ecological equilibrium. Organic oasis farmers, besides using biological control methods, work on reducing pest and disease pressure by encouraging beneficial insects, rotating crops in the bottom stage and practicing improved maintenance methods, such as the pruning of trees and the removal of infested plants, leaves and fruits. For direct pest and disease control farmers rely on natural (preferably specific) pesticides, biological control methods and mechanical methods such as the use of insect traps or insect-proof nets on date bunches.

In general, the conversion of traditional or conventional oasis gardens to organic farming proves relatively simple. Nevertheless, considerable changes may be necessary, particularly with regard to the implementation of a soil fertility improvement plan, the efficient use of natural resources, and the natural control of pests. In other words, with conversion to

Discussion: The impacts of different farming methods

After having presented the major differences between farming methods in oasis gardens, you may widen the discussion by asking the following questions:

- *What are the consequences of the use of chemical products on the soil, the plants and the human beings in the oasis garden?*
- *Do chemical products affect the quality of the dates or other produce from the oasis?*
- *What economic impact does conversion have (for example, amount of inputs and costs, outputs, labor, etc.)?*

Compare the potentials and constraints of the application of organic farming methods in the oasis (ecological, economic, and social).

If possible, visit both an organically and a conventionally managed oasis garden and discuss the observations you have made with the farmers. Consider what has been achieved, the improvements that could perhaps be made, as well as the difficulties and challenges that the farmers face. Compare the answers with those of other members of the group.

After having analyzed the different farming methods, draw conclusions regarding appropriate methods for oasis farming: Which factors encourage the adoption of organic farming practices? Which factors hinder the adoption of these practices?

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

organic farming major attention must be paid to recycling the farm's own residues for compost production and maximizing organic matter production, to applying a proper crop rotation in the bottom stage and ensuring crop hygiene, to encouraging natural enemies and of course to only using natural plant protection products. Additionally, planting of hedges may be recommended to prevent erosion by wind and to increase the supply of organic material. Furthermore, measures for improved water management should also be considered.

2.2.3 How oasis and steppe complement one another, and their consequent impact on the preservation of the environment

The systems of oasis garden and steppe pasture farming are very different. However, they offer interesting synergies on important levels.


The fodder crops of the bottom stage of the oasis system and the crop residues from trees, such as dates, fruits and leaves are, if not used for composting, welcome feed for the animals belonging to the steppe farmer. The oasis may also serve as a refuge for milked female animals, young animals, or those that are used for breeding. Furthermore, the palm and the fruit trees provide wood for domestic purposes, reducing the cutting of wood trees in the steppe. Thus the wood and the feed provided by the oasis contribute to the preservation of the steppe. Reciprocally, the animals provide valuable manure to the oasis. The manure is collected in the sheep pen and then applied directly to the soil in the oasis, or is first composted.

In the arid regions of Northern Africa and the Near East dates are a major food for the population, thanks to their high sugar content. Thus the oasis, and especially the organic oasis, offers good opportunities to the steppe people to improve their financial situation by working with the crops (e.g. pollinating the date palms, pruning fruit trees, harvesting fruits, working in pest and disease control, ploughing etc.) or in processing (e.g. of dates).

Marketing the organic dates and fruits at a good price in local markets provides a further economic opportunity for the steppe people. In general, it is the steppe people who sell the dates to tourists and to other people from different cities.

2.2. Oasis garden 4

Complementarities of oasis and steppe



- Fodder for animals
- Wood for domestic purposes
- Labor for steppe people
- Marketing of dates and other produce

- Manure to improve soil fertility

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TRANSPARENCY 2.2 (4): COMPLEMENTARITIES OF OASIS AND STEPPE

Discussion: Other ways in which the oasis and steppe systems complement one another

Invite the participants to discuss ideas or experiences (if they have had any) of the way in which organic oasis farming could complement other economic or social activities (e.g. sustainable forms of tourism).

2. Organic Farming Systems: Examples from the Arid and Semi-Arid Tropics

In some regions nomadic steppe farmers adapted oasis farming systems by associating gardens with livestock breeding to reduce the risks posed by drought.

A close interrelation of oasis and steppe reveals great potential, as it improves the productivity and production safety of both ecosystems. It comes close to the concept of the organic farm with a mostly closed nutrient cycle and the inclusion of animals in the farm.

Nevertheless, this interrelation may have to overcome different constraints, as it brings two very different farming systems and social cultures together.

2.2.4 Lessons learned from organic management of oasis gardens

The preliminary experiences of organic oasis management lead to the following conclusions:

- Organic oasis farming contributes to the improvement of farm revenues, mainly due to a higher price for organic dates (see chapter 4.6), and offers good opportunities for other agricultural produce from the oasis.
- Recycling of all available plant material is of high importance in order to reduce dependence on introduced fertilizers and to build up soil fertility.
- The integration of animals into the nutrient cycle of the farm offers considerable advantages due to the high fertilizing value of the manure for crops with a high nutrient demand, or to improve the composting process.
- Few difficulties are generally encountered when converting oasis gardens to organic cultivation, especially when converting those that have been farmed traditionally.
- Due to the scarcity of water, the successful establishment of such gardens strongly depends on the adoption of sustainable irrigation practices.
- In terms of certified production for both national and export markets, an association of farmers has proved to be of major importance in order to reduce certification fees and assist with the marketing of the produce.
- Certain areas, however, require specific research in order for the success of the project to continue. These include the development of appropriate and efficient measures of control for date worms and mites, the testing of appropriate rotations of annual crops and the selection of adapted cultivars.

Recommended reading:

- *Migration and agricultural transformations in the oasis of Morocco and Tunisia. 2001. Ed. by Hein de Haas.*
- *Agroéconomie des oasis. 1999. Edited by Ferry M. et al., Montpellier (F), Cirad Editions. ISBN: 2-87614-365-8.*
- *Other publications on oasis farming by the Estación Phoenix in Elche, Spain.*

3 Examples of Successful Initiatives: Participatory Technology Development

3 Examples of Successful Initiatives: Participatory Technology Development

3.1 Zayatine Sfax – An Organic Olive Initiative

3.1.1 Description of the initiative

Zayatine Sfax is an organization of organic olive producers; the name means 'the olive trees of Sfax'. The initiative was founded by a group of farmers with the goal of improving marketing opportunities for their olives.

The company was established in 1996 in Sfax, Tunisia, a coastal town located on the Mediterranean Sea. Sfax has short and mild winters and hot summers. On average the region receives about 350 mm of rain per year. Rainfall is, however, remarkably irregular. The natural vegetation of this region is semi-arid steppe.

The initiative started conversion to organic farming in 1998. By 2004, Zayatine Sfax comprised twenty-three certified organic and biodynamic farmers who, together, cultivate 700 hectares of olives. Olives are their main crop. Some farmers supplement the olives with a few almond and other fruit trees. Most farms have some pasture and keep 10 to 30 sheep, which is typical of farms in that region. Leguminous plants and fodder grasses are grown when possible. In general, the arid climate and irregular rainfall do not allow for the cultivation of arable crops between the olive trees.

As the orchards cannot be irrigated, they are planted in low densities, at around 17 trees per hectare. All the farmers grow the indigenous Chemlali variety, which is very well adapted to the arid conditions. It produces many small but very high quality olives.

Zayatine Sfax produces about 2000 tons of organic olive oil annually, most of which is exported to Europe.

The success of the initiative has encouraged other farmers in the Sfax region to convert their farms to organic agriculture. By the year 2002 another consortium had been established, consisting of seven organic farmers. There are also four similar initiatives growing organic dates.

Lessons to be learned:

- *Close cooperation and open dialogue are essential when developing a common vision. It is best if the vision is shared with partners in the supply chain.*
- *Cooperation makes it easier for the farmers to help themselves, to save costs and to organize continuing education.*
- *Cooperation between farmers is especially appropriate if they cultivate the same crops. Farmers find it easier to get access to the organic market when they are organized.*

3 Examples of Successful Initiatives: Participatory Technology Development

3.1. Zayatine Sfax – An Organic Olive Initiative 1

"Zayatine Sfax" – An Organic Olive Initiative

- Established in 1996 in Sfax, Tunisia
- Society of 23 organic and biodynamic farmers (in 2004)
- 700 hectares of olives
- Export to European market

Main objectives:

- *Technical advice*
- *Marketing*
- *Defence of interests*



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TRANSPARENCY 3.1 (1): DESCRIPTION OF ZAYATINE SFAX – AN ORGANIC OLIVE INITIATIVE IN TUNISIA

Motivation:

Ask the participants about their experiences with farmer associations: What are the advantages and benefits of cooperation? Note the key answers on the board and refer to them later.

3 Examples of Successful Initiatives: Participatory Technology Development

The three main objectives of Zayatine Sfax are:

- To optimize agricultural production by offering advice to the farmers about the production of organic olives, giving information about how soil fertility, crop quality and yield can be improved, promoting farming methods that respect the environment and biological equilibrium, and offering support in planning olive production and processing.
- To develop an economic advantage by expanding market opportunities, reducing production costs, and lowering the costs of certification. Also to develop international market opportunities by communicating the product's quality beyond the borders of Tunisia.
- To defend interests by organizing members and representing them in all organic networks.

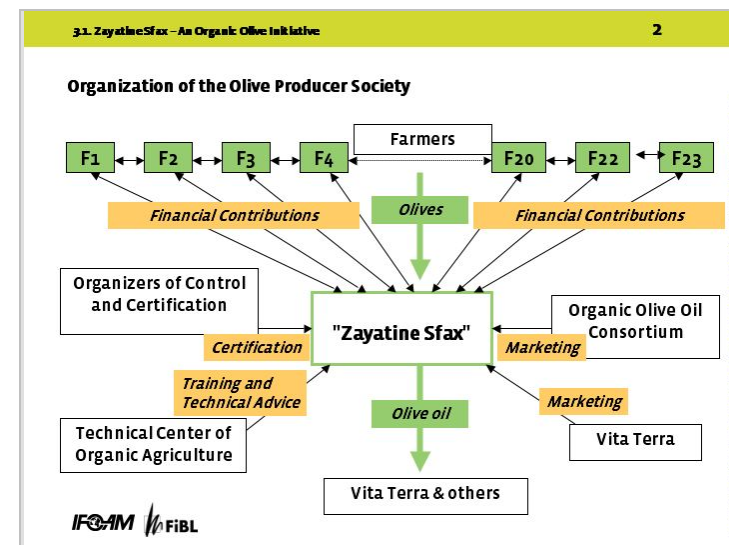
Organization

Zayatine Sfax is a limited company that the farmers all belong to. The company has a President, a Manager, a Secretariat and a General Assembly.

Responsibilities are distributed as follows:

- The President holds primary responsibility and directs all company meetings.
- The Chief Manager supervises all the activities of the company, from planning the harvesting and processing to marketing. He also manages production and the purchase of inputs, and is in charge of the finances.
- The General Assembly oversees technical and marketing activities, and approves new members.

Membership fees are used to pay employees and to fund activities decided upon by the members, such as soil analysis, storage and delivery of the oil, certification fees and marketing. The company purchases inputs for its members, who generally pay for them only after the harvest. Collectively produced compost is sold to members at cost price. The company rents a factory in Sfax where the olives are processed. The factory processes only organic and biodynamic olives and is controlled and certified by the same certification body as Zayatine Sfax.



TRANSPARENCY 3.1 (2): INTERNAL ORGANIZATION AND NETWORK OF ZAYATINE SFAUX

3 Examples of Successful Initiatives: Participatory Technology Development

Links with other bodies

The trading company Vita Terra is Zayatine Sfax's marketing partner in Europe. Vita Terra also offers technical assistance in olive oil production and participates in international market fairs such as the Biofach in Germany. Zayatine Sfax also participates in Tunisian and international market fairs.

Zayatine Sfax is a member of the Tunisian Organic Olive Oil Consortium, which assists with marketing and helps members to sell their oil to Vita Terra and other buyers. The consortium was founded by seven partners (producers, processors, exporters, etc.), who represent the majority of the Tunisian organic olive oil industry.

Zayatine Sfax maintains close relations with the Technical Center of Organic Agriculture, which offers regular training, extension services and exchanges amongst organic farmers, mainly engaged in olive oil production.

Zayatine Sfax is also a member of the National Federation of Organic Agriculture, which the majority of organic farmers belong to.

3 Examples of Successful Initiatives: Participatory Technology Development

3.1.2 Origins

Many farmers in southern Tunisia face growing ecological problems. The impacts of global warming (such as desertification, drought and erosion) are becoming increasingly evident. These problems are further exacerbated by the constant spread of intensive agriculture, including monoculture, and a growing use of pesticides.

In many ways, international trade in Tunisian agricultural products has not changed since colonial times. Olive oil and other farm products are mainly exported to Europe, unprocessed. Olive oil is traditionally sold to Italy at a low price. Most added value is realized outside of Tunisia, at least outside the hands of the farmers. Farmers' dependency on buyers who pay low prices, combined with small farm sizes and difficult climatic conditions, make farming unprofitable. As a result many farmers abandon agriculture.

Farmers set up Zayatine Sfax in order to overcome these difficulties in marketing their products. At the time, government support for marketing activities was poor. Since then, however, circumstances have changed.

The initiative began on a small scale, when a group of farmers joined forces to try to collectively market their olives. They met regularly to exchange ideas, to work on solving their problems, to find new markets and to defend their common interests. One of the farmers, an agronomist and expert in olives, took the lead. The farmers shared a common vision, and were deeply involved in and committed to the initiative. All of them were agricultural technicians.

The farmers were not organic growers at that time. Organic production was only beginning to develop in Tunisia. Growing foreign demand for organic products and the successes of similar initiatives in other agricultural sectors oriented the initiative towards organic farming. The farmers faced some serious problems in making the transition. Firstly, certification fees were very high for individual farmers and at the time there were no real market opportunities or established market structures. The certifying company had total control and farmers felt a loss of autonomy. Secondly, no financial support was available from the government, and the farmers were not aware of a development fund that could assist them. It was only in 1999 that a support network was established, and it took a further four years before proper market structures were developed.

Around this time they commissioned a study to evaluate the marketing potential for Tunisian organic products in Europe. Results showed that some products – including olive oil, dates and oranges – did have an export potential, provided that they were properly promoted. However no analysis of risks and potentials was carried out. The farmers had to seek information from other initiatives in both the organic and the conventional sectors, in order to orientate themselves within the new market.


Discussion: The circumstances at the start of an initiative

Invite the participants to discuss the following questions in groups.

- How can the circumstances at the start of Zayatine Sfax be described?
- What does the situation these farmers faced have in common with the participants' own circumstances? What is different?
- Describe the vision that the founders of Zayatine Sfax share. How important is it to have a vision to succeed with such a project?

3.1. Zayatine Sfax – An Organic Olive Initiative 3

Circumstances at the start of "Zayatine Sfax"



- Difficulties in marketing conventional olives
- Little or no financial support or advice in marketing
- Organic agriculture just beginning in Tunisia
- First organic initiatives successfully started in other sectors

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TRANSPARENCY 3.1 (3): CIRCUMSTANCES AT THE START OF ZAYATINE SFAUX

3 Examples of Successful Initiatives: Participatory Technology Development

3.1.3 Milestones

The major steps in the development of the initiative were as follows:

1996: Farmers agree to found a company and convert to organic agriculture. They opt for a limited company, which offers greater leeway in management and a distribution of the benefits that corresponds to members' contributions. Without any outside help, they set up a business plan and appoint a Manager and a Secretariat. Each member pays a membership fee and makes other contributions to cover the salaries of the staff. There is no specific marketing strategy. In the first years of the initiative, the oil is only marketed within Tunisia, to a number of different clients. Because of drought problems and low productivity, the farmers experience difficulties paying their fees.

1998: Conversion to organic farming begins.

1999: The farmers start receiving training in organic agriculture in general, and olive farming in particular. Marketing, planning and organization are important aspects of the training. Throughout the training, the lessons are reinforced by practicing and applying what has been learned, and by demonstrating respect towards one another as well as assuming responsibility for oneself.

2000: The first organic olive oil is sold.

2002: Zayatine Sfax becomes a fully-fledged member of the Tunisian Organic Olive Oil Consortium.

2003: Zayatine Sfax gets access to the European market by entering into a partnership with Vita Terra, a European marketing company dedicated to organic agriculture and to fair trade. The cooperation with Vita Terra offers long-term marketing possibilities at fair conditions.

2004: After three years of drought, the farmers experience their first financial successes due to a change in agricultural policy, their hard work and training, and favorable weather conditions.

The farmers of Zayatine Sfax now receive annual subsidies from the state for a maximum period of five years, to cover inspection and certification fees. These subsidies cover 70% of the inspection and certification costs, up to a maximum value of 5000 Tunisian Dinars. The certification fees depend on farm size, the kind of crops being cultivated, and the time spent on the property by the inspectors.

Together with Vita Terra, the farmers of Zayatine Sfax continue to look for new partners and additional marketing opportunities, for example by attending national and international trade fairs.

Discussion: The relevance of milestones

Whether you have a specific farming initiative in mind or not, ask the participants whether they think it is important to set milestones in advance. Should milestones be revised regularly? Which general milestones can be defined for an organic farming initiative?

3.1. Zayatine Sfax - An Organic Olive Initiative 4

Milestones in the development of Zayatine Sfax

- 1996:** The society is established, conventional olives are marketed within Tunisia
- 1998:** Conversion to organic farming started
- 1999:** Training in organic farming
- 2000:** The first organic olive oil is sold
- 2002:** Member of the Organic Olive Oil Consortium
- 2003:** Access to European market
- 2004:** First financial success
Continued marketing activities
Investments in a compost platform

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TRANSPARENCY 3.1 (4): MILESTONES IN THE DEVELOPMENT OF ZAYATINE SFX

3 Examples of Successful Initiatives: Participatory Technology Development

Future plans

To improve certainty in future marketing negotiations, detailed analysis of production costs will have to be made.

The initiative is currently planning to construct a composting platform on one of the farms. Some farmers have already installed their own small composting platforms and now partially satisfy their compost needs. Organic farmers can receive Government subsidies of up to 30% of the total value of such investments.

Zayatine Sfax's future plans include exporting all organic oil that it produces, as well as the conversion of all the farms in the initiative to the bio-dynamic method of agricultural production (and consequently getting them all Demeter certification). It also hopes to establish its own oil factories.

3.1.4 Strengths, weaknesses and challenges

Strengths


From the start, the initiative has instigated many positive economic and social changes. Thanks to the initiative, the farmers collaborate and complement one another and help each other to solve problems encountered by individuals within the group. Their main strengths are their association with one another and their will to work together to improve their situation. The joint planning of harvesting and processing leads to better organization and a good understanding amongst members.

The farmers in the initiative have much in common. Many are of similar age and have similar qualifications. They farm in the same area, and planted their first trees around the same time. All of them grow the indigenous Chemlali olive variety that is well adapted to the local agro-climatic conditions. These factors all help to unify members, giving strength to the initiative.

Collective certification results in a reduction of certification fees, and spreads much of the responsibility onto the company itself. This motivates farmers both to join the initiative and to participate actively in the way it is being run.

3.1. Zayatine Sfax – An Organic Olive Initiative 5

Strengths and weaknesses of Zayatine Sfax

<p>Strengths</p> <ul style="list-style-type: none">▪ Collaboration and dedication▪ Similar qualifications▪ Common organization and certification	
<p>Weaknesses</p> <ul style="list-style-type: none">▪ Lack of experience in organic techniques (fertilization, pesticide control)▪ Little information on international marketing of olive oil▪ Insufficient exploitation of on-farm sources of organic material▪ Few marketing partners	<p>Challenges</p> <ul style="list-style-type: none">▪ Reduce production costs▪ Increase farm biomass production for compost▪ Add value to the product▪ Access new markets▪ Increase flexibility in the market▪ Improve recognition of the product

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TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 3.1 (5): STRENGTHS, WEAKNESSES AND CHALLENGES OF ZAYATINE SFAX

3 Examples of Successful Initiatives: Participatory Technology Development

The collective purchase of inputs further reduces costs for each individual member.

Zayatine Sfax serves as a good example in the region, especially with regard to the way it is organized and managed. The good agricultural education of its members has helped considerably to improve the quality and quantity of the organic olive oil they produce.

Weaknesses

The conversion to organic farming highlighted two main weaknesses. Firstly, the farmers lacked experience in organic methods, especially in the fertilization of the olive trees and the protection of these trees from pests. Secondly, the farmers had little information about the international marketing of olive oil. As yet, farmers have not been able to make full use of their entire farms or of nearby sources of organic material, such as the by-products of olive oil production and animal manure. Their ignorance both of sources and of how to manufacture compost means that the farmers have been buying compost and organic fertilizers, which has raised their production costs considerably.

Despite the good quality of their oil, the farmers did experience some problems marketing their product because they lacked experience, had few connections in the marketing industry, and struggled with a low demand for their product. Historical links with Europe and geographic proximity mean that most of the conventionally produced olive oil from Tunisia is marketed in Europe and that producers are dependent on one market. Accessing new markets, such as the USA, Canada and Japan, is likely to improve marketing opportunities.

Challenges

After a few years of existence, and having overcome the most basic difficulties, the company faces some challenges, which appear to be critical for its further development:

- The farmers need to reduce their production costs by using local renewable resources and by improving yields.
- The farmers must improve the growth and health of the olive trees by setting up their own compost production and by refining crop protection measures. A challenge is to increase the amount of biomass for compost production.

Discussion:

- *Divide the participants into groups and ask them to discuss Zayatine Sfax's potential and the challenges for its further development. Then ask the groups to present proposals to the others and discuss the suggestions that they came up with.*
- *Strong marketing partnership or own label? Is it more profitable to stress independence in the market or to focus on partnership approaches? Discuss the advantages and drawbacks of the two marketing strategies. Compare Zayatine Sfax with other similar initiatives that the participants know well.*

3 Examples of Successful Initiatives: Participatory Technology Development

- The Demeter label demands an appropriate level of biological diversity on the farm. Due to the arid climate, possibilities of diversification within the olive orchards are limited, as competition for water must be avoided. The fact that the farmers do not own their land, but lease it from the government, also hinders investment. The farmers are investigating the possibility of buying the land.
- The installation of a bottling unit will add value to the product and raise profit margins within the company.
- To gain new national and international markets the company aims to advertise its product and present it at fairs.
- Farmers must regulate the quantities of oil sold during the production cycle and develop appropriate storage facilities.
- A label will be created to improve the marketing of Zayatine Sfax's products.

New markets, an olive processing factory, large oil storage capacity and a composting platform are all essential. They will give Zayatine Sfax more flexibility and independence in the market. The initiative may have reached a critical stage in the sense that experience and expertise in marketing large quantities of organic oil are missing.

The farmers in Zayatine Sfax are qualified in production techniques, committed to organic agriculture and organized in terms of control, certification, harvesting and processing. Their main challenges lie in marketing. The company therefore needs to increase its cooperation with national and international companies.

Two measures for increasing the product's market recognition are to create a logo and to apply for 'Protected Designation of Origin' status. A logo would offer a unique and recognizable trademark, while Protected Designation of Origin status would increase consumer awareness of the product's place of origin and production system – as has occurred with other geographically specific foods, such as Parma Ham.

3 Examples of Successful Initiatives: Participatory Technology Development

3.1.5 Lessons learned

The farmers of Zayatine Sfax see learning as part of the development of their farms and their company. Vita Terra, the company's main marketing partner, is also involved in the learning process, as lessons learned are shared and further steps are developed together. Learning is also part of the company's business plan: making good compost, improving soil fertility, and the common planning of harvest, processing and marketing all offer good platforms for learning. The dedication to and the responsibility for a common company, as well as the consideration of gained advantages, are all important factors of the learning process.

The following lessons have been learned so far:

- Close cooperation and open dialogue are essential when developing a common vision. Ideally the vision should also be shared with other partners in the product chain. Cooperation makes it easier for the farmers to help themselves, to save costs and to organize continuing education. Unification amongst farmers is particularly appropriate if they cultivate the same crops. Organized farmers find it easier to get access to the organic market. Common planning and management processes are, however, not yet evident.
- One of the principal ways in which Zayatine Sfax diverged from conventional farming methods was the level of attention that they paid to the management of organic matter. They realized how crucial the organic matter content in the soil is in order to reduce losses due to drought and to achieve good yields, especially under arid conditions. Recycling of crop residues and by-products from fruit processing has been given serious attention.
- Raising the value of the product within the company is essential. In addition to pressing, bottling of the oil will not only raise the product's value, but will also offer interesting new possibilities in product politics and communication, as the company will be able to offer a shelf-ready product. Combined with this, the introduction of an own label and the declaration of the geographical origin will raise the value of the product.
- Expertise and experience in marketing are essential. Partnerships with trading companies which are dedicated to fair trade and are well established in the organic sector can be invaluable in order to bring in much needed expertise. This, however, cannot replace the company's own initiatives in both marketing and diversification.


The experiences gained during the development of the Zayatine Sfax initiative have proved both interesting and valuable. The initiative has played a leading role in the development of organic agriculture in the Sfax region.

Discussion: Conclusions on the initiative

Ask the participants what they have learned from examining this initiative.

3.1. Zayatine Sfax - An Organic Olive Initiative 6

Lessons learned from Zayatine Sfax



- Cooperation makes many things easier. Many improvements could not have been achieved by individuals.
- Appropriate management of organic matter is crucial.
- Adding value to products within the company is essential.
- Expertise and experience in marketing are essential.
- Supporting structures are necessary to promote organic products.

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TRANSPARENCY 3.1 (6): LESSONS LEARNED BY THE FARMERS OF ZAYATINE SFAUX

3 Examples of Successful Initiatives: Participatory Technology Development

3.2 The Maikaal bioRe Cotton Initiative

3.2.1 Description of the initiative

Maikaal bioRe is an initiative in the State of Madhya Pradesh, Central India, which grows biodynamic (certified organic) cotton for the European market.

The farms that cultivate the cotton are situated in a traditional cotton growing area on both sides of the Narmada River. The Narmada belt is characterized by its mostly flat topography (less than 200 meters above sea level) with occasional intrusive rocks forming hills. The soils are deep (up to several meters), dark and rich in clay (predominantly vertisols). There are wells, tubewells and numerous irrigation pipelines from the Narmada and Beda Rivers, providing a comparatively good water supply. Sugarcane, bananas, guavas and vegetables make up a good part of the crops grown in this area.

The uplands are more heterogeneous due to their undulating profile. They have shallow, light, brownish soils in the elevated areas, and deep, dark, heavy soils in the depressions. Irrigation water is generally scarce, as there are no river pipelines and only a few channels from small dams are available. Sugarcane and banana cultivation is limited to the few pockets with good irrigation facilities.

The Maikaal bioRe initiative was started and promoted by Remei AG, a Swiss cotton yarn trading company, together with Maikaal Fibres Ltd., an Indian spinning mill. Remei AG worked on developing the market in Europe and providing links to the textile chain. A project team from the spinning mill worked with the farmers to convert their lands to organic agriculture.

The experiment developed into a commercial project, which has grown considerably and is now run by an independent company, Maikaal bioRe (India) Ltd, which is a subsidiary of Remei AG. In 2004 the company employed 36 people. The company's Managing Director is the original founder of the project. There is a Production Manager, who leads a team of extension people, a few administrative employees and labourers working on the experimental farm where research and development are carried out. The team, which has remained largely unchanged since the project was initiated, is made up of local people with a strong social mindset, who are committed to helping farmers. Farmers both supply cotton to the company and use its services (such as training, consulting, crop monitoring, inputs, etc.). A present aim is to involve farmers more in the decision-making process, for example by making them shareholders of the company. Two farmers already sit on the Board of Directors, ensuring that the farmers' perspective is heard. Every year an Open Day allows farmers to network with other farmers in the initiative, as well as with European customers.

Lessons to be learned:

- Importance of partnership between farmers and traders.
- Importance of establishing an integrated supply chain.
- Technical and administrative advice is essential.
- Social needs and constraints must be addressed.
- There is a constant need to develop and improve organic practices to reduce risk and improve results.

2.2. Maikaal bioRe Cotton Initiative 1



Maikaal bioRe Organic Initiative

Growing organic cotton for the European market

- **Started** 1992/93 as a personal initiative by an Indian spinning mill and Remei AG, a Swiss cotton yarn trading company
- **Located** in Madhya Pradesh, central India, a traditional cotton growing area
- **Promoted** by Remei AG (market development in Europe, linkages to the textile chain) and Maikaal Fibres (support to the farmers)
- **Now run by** the independent company Maikaal bioRe (India) Ltd, a subsidiary of Remei AG
- **2004:** 36 employees and 1,100 participating farmers in 75 villages, with 3000 ha of certified organic cotton

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TRANSPARENCY 3.2 (1): DESCRIPTION OF THE ORGANIC COTTON INITIATIVE IN INDIA

3 Examples of Successful Initiatives: Participatory Technology Development

Activities of Maikaal bioRe

The main task of Maikaal bioRe is to provide efficient extension support to local farmers, to enable them to convert their lands to organic agriculture and subsequently to improve organic practices while achieving consistently good yields.


Some of the essential components of the extension service are:

- Contracts with interested farmers. Each farmer enters into a contract with the company, committing to not use chemicals and genetically modified organisms (GMOs) on the land and to farm by biodynamic principles. The company commits to providing various services to the farmer, as well as to purchasing the entire crop and paying a premium price for it.
- Training. Before each season starts, training sessions are organized for all farmers. New farmers learn about the basics of organic farming (principles, practices, controls and certification) while experienced farmers attend advanced courses on specific aspects of organic farming (such as compost making, crop rotation, use of botanical sprays, etc.) and new methods (for example vermicompost). Farmers can ask questions and discuss the problems they are facing on their farms.
- Documentation of farming activities. The extension personnel visit each farmer to monitor crops, discuss daily problems and provide customized solutions.
- Inputs. Necessary inputs such as seeds, oil cakes, rock phosphate and neem formulations for pest control are all procured by the company and distributed to the farmers through the extension network.
- Certification. Field Officers ensure that farmers comply with the certification requirements in both practice and documentation.

The work of the field staff is governed and described in the company's Farm Operating Manual.

2.2 Maikaal bioRe Cotton Initiative 2

Services of Maikaal bioRe



Offering assistance to the farmers

- Organizing the farmers
- Providing training and advice to the farmers
- Helping with documentation
- Supplying organic inputs
- Crop monitoring
- Quality management
- Organizing certification and ICS
- Buying organic cotton from the farmers at 20% above the normal price
- Identifying organic markets for the food crops

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TRANSPARENCY 3.2 (2): THE SERVICES OF MAIKAAL BIORE

Discussion: Role of the company and involvement of the farmers

After having described the initiative and the activities of the company ask the participants the following questions.

- What makes collaboration with the company interesting for the farmers? What other forms of cooperation exist and what may be the differences?
- What role do the farmers have in this initiative?
- Do the participants know of similar organic or non-organic initiatives?

3 Examples of Successful Initiatives: Participatory Technology Development

3.2.2 Initial circumstances

Growing debt carried by farmers

In the Maikaal area, farmers typically go into debt for two reasons: either because of social obligations, such as marriages, or to finance their farming activities. Pesticides and irrigation represent major costs. Some farmers have not been able to repay their loans to the government, others can't access these sources because they cannot provide security. Many are forced to borrow money from local moneylenders and cotton merchants. These charge high interest rates (18–36 %) and often demand that farmers sell them their crops at a very low rate. Moneylenders often use brutal recovery methods, causing stress for farmers.

Variable crop yields

Crop quality is very variable. If the conditions (mainly rains) are good, the crop will also be good. If conditions are unfavourable, however, the crop will be very poor. This uncertainty means that farmers often cannot repay loans they took for seeds, fertilizers and pesticides. This uncertainty is made even more acute in the face of unstable, decreasing cotton prices on the global market and decreasing soil fertility.

Safety risks with conventional agriculture

Farmers are moving towards monoculture, with no crop rotation whatsoever. Genetically modified (GM) cotton varieties have been widely propagated since 2002 and have found their way into the region. GM seeds are very expensive and are more sensitive to climatic change, so in buying them farmers take a great financial risk. Farmers repeatedly suffer from poisoning due to the use of chemical pesticides.

Promoters looking for new perspectives


The local manager first contacted Remei AG while it was setting up a spinning mill and seeking foreign assistance to market the cotton yarn in Europe. Remei, through their experience in cotton growing countries, was aware of the socio-economic and environmental problems related to conventional cotton cultivation, which contravened their sense of business ethics.

At that time, green organizations promoted hand-plucked cotton because it does not use defoliants. Remei realised that defoliants are only one part of the problem. The company felt that in order to do things right in the fullest sense, they should turn to organics.


2.2. Maikaal bioCotton Initiative 3

Circumstances at the start

- Decreasing yields over the last 2 decades
- Increasing production costs, with no guarantee of returns
- Erratic rainfall, droughts
- Decreasing groundwater levels
- Decreasing cotton prices
- Increasing indebtedness
- Poisoning from pesticides



Remei's Vision: Trade must be based on partnership and be sustainable for all. Organic farming and linking the farmers into the textile chain are the way to do it.

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TRANSPARENCY 3.2 (3): CIRCUMSTANCES AT THE START AND MOTIVATIONS OF THE PROMOTERS

Discussion: Analysis of own situation

Ask the participants what the situation of the farmers in the Maikaal area has in common with their own circumstances. What circumstances are different? What are the reasons for this?

Depending on the situation the participants are in it may be interesting to discuss the risks and potentials (social, ecological and economic) of organic cultivation. What assets do we have for organic cultivation? Which measures may change the circumstances?

3 Examples of Successful Initiatives: Participatory Technology Development

Start of the Maikaal bioRe project

Driven by his personal vision of fair and healthy cotton, and seeing the market potential for such a product, the Director of Remei proposed to start an organic cotton project.

The organic project was given a few hectares of land behind the spinning mill on which cotton could be cultivated organically (the fields later became the experimental farm). A small office was established. Word of the project spread quickly amongst the farmers, even though there was no certain commercial prospect at this time.

As a next step, an experienced consultant was entrusted with the task of talking to the farmers and mill personnel, offering them an alternative and the technology to do it. Farmers were motivated to participate by the guaranteed premium price, the availability of essential inputs on credit and especially the free and ample support of the initiative's advisory service. The farmers were sceptical at first, but the fact that the initiative had its own experimental farm, and that the first organic cotton crop was reasonably successful, gave them confidence. Pest management and soil fertility were the main subjects of criticism, and the availability of farmyard manure and compost were also important issues.

Soon, however, the farmers who had adopted organic cultivation became the main factor motivating others to join. Several demonstration visits were organized for those considering the shift to organic production.

The only risk of involvement for the farmers was that the initiative might stop purchasing the organic cotton, or cease its extension service. The farmers thus would be left alone and perhaps would have to revert to conventional agriculture.

The region's major assets in terms of organic farming were the farmers themselves and the fact that animals were well integrated to the land. Furthermore, all farmers were already using farmyard manure, along with chemical fertilizers, while farming conventionally. The use of oxen for ploughing, weeding and intercultural operations was one of the basic practices of the farms in the area, and served to ensure that even conventional farmers did not use herbicides.

At the other end of the chain, Remei started to work on the market.

3 Examples of Successful Initiatives: Participatory Technology Development

3.2.3 Milestones of Maikaal bioRe

1992/93: Twenty farmers are involved in the first field trials of organic cotton.

1995: Remei AG and the Swiss retailer Coop start a partnership, which is later honoured with the Sustainable Development Partnership Award at the UN World Summit 2002. Coop's commitment is tangible and long-term: they reduce their margin to keep the prices of bioRe products competitive; they place regular orders every year; and they promote Maikaal bioRe through posters, television and newspaper articles. There is open dialogue between the project partners.

Coop also launches NATURALINE, an organic textile line, creating a major demand for organic cotton. The supply chain is completed. In 2004, Coop is the largest purchaser of organic cotton worldwide, with 1000 tons of raw cotton per year.

1997: The bioRe Foundation Switzerland is established and jointly managed by Remei AG and Coop Switzerland. The foundation funds social projects for farmers, such as interest-free loans for drip irrigation and other infrastructure projects.

2001: Another marketing step is taken with the establishment of the bioRe Platform. Swiss and German producers of high-grade textiles join to offer a wide range of textile products made of bioRe cotton. They have a common marketing strategy and appear jointly at fairs.

2002: In April the Maikaal project is formed into an independent company called Maikaal bioRe (India) Ltd, ceasing to be part of the spinning mill Maikaal Fibres Ltd. Decisions are now taken by the Board of Directors, which consists of Remei AG's Managing Director, the Managing Director of the company, two farmers (since November 2003) and a social activist (who furthers small farmers' interests).

2003: In January 2003, the Indian bioRe Association is founded to address the social needs of the Maikaal organic farming community (in terms of infrastructure development), to improve organic training by building and running an agricultural school, to ensure internal control, to disseminate organic farming practices, to address various social issues (such as the involvement of women and the working conditions of field labourers) and to develop and build communities. The bioRe Association is run by farmers and project staff and has nearly 200 farmers as its first members. The bioRe Association receives funds from the Swiss bioRe Foundation. The social commitment and financial assistance soon prove to be a major help to the farmers of the region.

2004: By the end of 2004, the bioRe Organic Agriculture School for farmers is near completion. The school will have nearly 10 acres of experimental farm.

A new internal control system is being developed as satellite projects in other regions are being taken on.

2.2. Maikaal bioRe Cotton Initiative 4

Milestones in the development of Maikaal bioRe

- **1992:** Begins as an experiment with a handful of farmers. A production profile for ecological and social garments is developed.
- **1995:** bioRe enters the mass market thanks to the partnership with Coop, a Swiss retail company.
- **1997:** Remei AG and Coop establish the bioRe Foundation to promote organic cotton and to support needy farmers.
- **2001:** Swiss and German high-grade cotton yarn producers establish the bioRe Platform for marketing bioRe cotton.
- **2003:** The bioRe Association (India) is established to spread organic farming and to run social projects for needy farmers.
- **2004:** Construction of the bioRe Association's Training Centre.

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TRANSPARENCY 3.2 (4): MILESTONES IN MAIKAAL'S DEVELOPMENT

Group work: Invent your own project

Divide the participants into groups and ask them to invent their own project and to develop a basic concept for it.

- *What is the aim of the project?*
 - *What would constitute major milestones?*
 - *What are the major inputs and outcomes?*
 - *How are the farmers involved? How is good cooperation ensured?*
 - *What are possible obstacles?*
 - *How is the project financed?*
 - *How is the project managed? What are the priorities?*
- Ask the groups to present their project ideas and invite the audience to give feedback on the presentations*

3 Examples of Successful Initiatives: Participatory Technology Development

Future milestones

It is intended that the farmers will become shareholders of Maikaal bioRe. For this, legal and other hurdles must first be overcome. From 1992-2004 the number of farmers has been increasing steadily, from a handful to more than 1000. A further growth of 10% per year is expected as Coop plans to convert its entire cotton range to organic by 2010 (In 2004 organic cotton products make up 40 % of Coop textiles).

3.2.4 Success factors and challenges

Success factors

Partnership. The fact that the farmers have always been considered partners has been one of the distinguishing factors of the initiative. The culture of dialogue and cooperation, based on mutual trust and appreciation, respect for differences and a fair division of efforts and benefits, have all been driving forces. Remei's management has spent entire days meeting with individuals and groups of farmers, and discussing their needs and concerns. This has meant commitment to details: for example, in cases where the cotton quality cannot be clearly categorized as first or second, it will be classed (and paid for) as first. Remei is committed to finding a way to transfer the company to its farmers, possibly by giving them shares.

BioRe blends traditional local farming know-how with Western scientific findings and management methods. The project and staff are well known and welcome in the villages. In 1994 bioRe Tanzania, a second organic cotton project, was started with the help and support of Remei AG; the two projects exchange knowledge.

Being treated as a partner brings a different quality to the relationship. Instead of being 'just a supplier', each farmer knows that he matters, and that the customer needs his crop. Farmers are proud to be partners. This generates enormous benefits for both sides. From Remei's perspective, the partnership with the farmers ensures a continuous supply of cotton, which is necessary in order to gain the trust of its customers.

Integrated supply chain. Maikaal bioRe is the starting point of an integrated textile supply chain covering raw material, processing and retail to customers. The chain produces organic cotton textiles and garments according to strict environmental and social criteria (such as no heavy metal in dyes, water effluent treatment plants, safe working environments, compliance with minimum wages, etc.). The chain has only a limited number of participants, which ensures transparency and helps bring costs down. The partnership with producers at

2.2. Maikaal bioRe Cotton Initiative 5

What makes the initiative a success?



- Shared vision and partnership
 - Instills confidence to invest
- Integrated supply chain
 - Secures sales channels and constant supply
- Clear profile and controls
 - Creates trust and marketability
- Well-trained extension personnel and farmers
 - Offer the required technical support
- Cooperation
 - An innovative and effective approach to expand the market
- Premium
 - A critical factor, especially during conversion
- Social concern
 - Builds confidence and adds stability to the cooperation

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TRANSPARENCY 3.2 (5): THE STRENGTHS OF MAIKAAL BIORE

3 Examples of Successful Initiatives: Participatory Technology Development

each production stage ensures maintenance of the highest standards. Partners are confident about making investments. Partnerships with retailers also secures sale channels. Each year an 'Open House Day' is organized, bringing the entire textile chain together in the Maikaal region.

Clear profile and controls. To create trust and marketability, and to maintain consistently high standards, Maikaal bioRe has a very strict quality control system which is further developed every year. Strict production criteria and controls also apply for the processing of the textiles made of bioRe cotton.

Education and training of the advisors and farmers. Offering the farmers committed and competent advice free of cost proved to be of major importance to the development of the project. The quality training and advice gives the farmers confidence. It helps them in difficult times (heavy rains, pest attack, etc.) and enables them to increase their yields. Training of the advisors by international experts has also proved to be very valuable. Coop, the Swiss retail partner, has recently developed an organic agricultural school in the Maikaal area.

Cooperation with small and large farmers. Maikaal bioRe works with all interested farmers regardless of landholding size. Small farmers with a few acres, who drive the project costs up but need organic farming all the more, are welcome, as well as the larger farmers who help reduce costs. A balance is maintained between social and economic requirements. Farmers are widespread amongst more than 75 villages in a large district. All castes are represented, and tribal farmers also participate.

Purchase guarantee and premium. Maikaal bioRe (India) Ltd, and consequently Remei AG, purchase farmers' entire cotton crop every year. Each farmer has a 5-year contract. It is up to Remei AG to find a market for the cotton.

The project pays a 20% premium above market price to farmers for full organic cotton, far above the average 8-10%. (Farmers receive 15% premium for second-year conversion cotton and even 10% for first-year conversion cotton, which normally has to be sold in the conventional market). These premiums are critical, especially during the conversion period as it helps farmers finance their inputs. For many farmers the extension service is what really matters, and in extreme circumstances they do without the premium.



TRANSPARENCY 3.2 (6) THE BIORE SUPPLY CHAIN

Exercise: Study of the supply chains of local initiatives

Together with the participants, examine local initiatives. Split into groups and ask each group to study the supply chain of one initiative. What are the characteristics? Is the cooperation purely economic or do those involved in it share investments and benefits? Invite the groups to present their results.

3 Examples of Successful Initiatives: Participatory Technology Development

Social concern. Remei AG supports organic farming as a means to solve many of the socio-economic problems facing farmers, such as constant indebtedness to and dependence on moneylenders due to the high cost of chemicals. Organic farming also sustains soil fertility and improves the health of the fields. Remei AG believes in cooperative forms of work and tries to nurture partnerships. Maikaal bioRe was conceived as an initiative to bring farmers together on a more sustainable path, while increasing their independence. The main purpose of the initiative is thus to make farmers stronger and to improve social relationships.

Remei is interested in identifying and solving actual social issues in an effective and sustainable manner. The focus is on understanding farmers' circumstances and providing additional support through various projects. Organic farming is thus a means to an end.

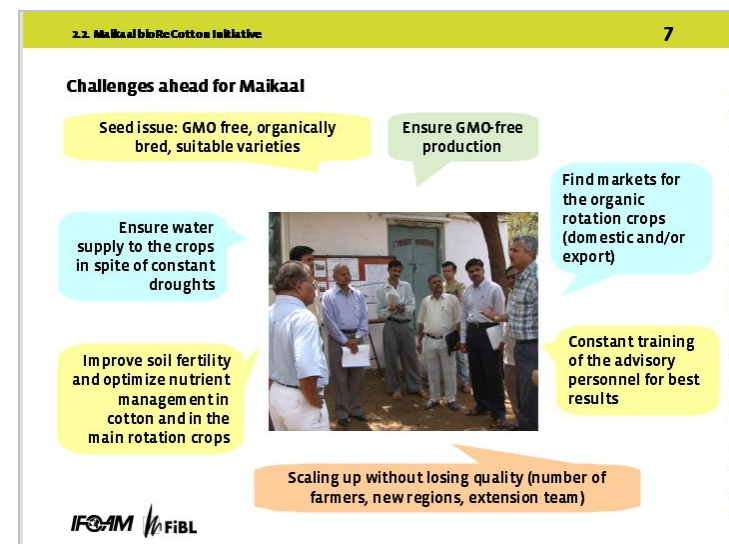
Satellite projects. In order to grow, Maikaal bioRe is willing to develop partnerships with other similar projects. It shares its farming and certification know-how, purchases the crop and pays a premium price.

3.2.5 Challenges

Although the Maikaal initiative has reached an impressive scale, it still experiences some difficulties.

Drought. The region constantly faces drought. This, combined with over-exploitation of groundwater, leads to a drastic reduction of water availability to farmers, reducing yields and causing economic crisis for the farmers. Farmers say that organic farming makes the soil softer and increases its water-holding capacity. To reduce water consumption and bring production costs down Maikaal bioRe farmers increasingly use drip irrigation systems. These, and other agricultural practices for better drought resistance, are currently being studied by the International Water Management Institute in a research project (see chapter 3.3.6).

Soil fertility. Soil fertility is a critical issue. As the land-to-animal ratio decreases, the availability of cow dung for compost becomes a problem, and the need to find alternative sources of inputs for soil fertility becomes a critical task. The challenge is to find alternative suitable organic manures to improve soil fertility and thus crop safety.



TRANSPARENCY 3.2 (7): CHALLENGES AHEAD FOR MAIKAAL

3 Examples of Successful Initiatives: Participatory Technology Development

Availability and suitability of composite seed varieties. Most cotton seeds available in the region are chemically treated hybrids and most of the local varieties available do not meet the fibre needs of the textile industry. Developing suitable composite seed varieties that fit the requirements of the textile industry, while being drought and pest resistant, is a high priority. At present, seeds have to be organically grown, which is complicated and costly. As seed companies are not interested in this very small market, it may well become necessary to organize seed production with farmers, which requires both know-how and financial inputs.

Coexistence with GMOs. The Indian government has given the go ahead for the commercial production of BT cotton. This is now finding its way in amongst the farmers, despite criticisms. In the Maikaal area, most farmers are now experimenting with BT cotton due to high yields in 2003 as a result of favourable weather conditions.

Several Maikaal bioRe farmers have been defaulted for experimenting with BT, in spite of repeated warnings. The company has to develop new prevention strategies and find more effective ways of communicating the related risks to farmers. Risks of BT cotton include propagation, resistant pests and ineffective organic pesticides. The main risk for farmers is, however, financial, as BT cotton involves high production costs and a higher risk of crop failure due to a lower drought tolerance.

Marketing of alternative crops. Farmers are eager to market their rotation crops at an organic premium price. However, for cost reasons, the entire project is certified organic and it is not possible to deliver individual certificates to farmers. Finding new organic markets for the other rotation crops would make full farm conversion easier for the farmers and help them increase their incomes. Given the lack of a domestic organic market for food crops this is not an easy job and the project does not have enough resources (especially human) to direct towards it. However, it does recognize how critical this marketing is to help farmers improve their living standards. Maikaal bioRe is looking for a local market for certain food crops (like wheat and chilli) and is also working on a plan to set up small-scale processing facilities.

Farmers' constraints. The small size of holdings is a significant issue and makes crop rotation difficult. As farmers have large money needs (for their social obligations) they tend to plant cotton continuously, as it is their main cash crop. Another big issue is irrigation. Some farmers only have irrigation in one field, or in a part of their fields, which makes a big

Discussion:

Following are possible questions that may be discussed in plenary or in groups.

- *How would you handle the GMO issue? What would you recommend as a prevention strategy?*
- *What strategy would you recommend for spreading this message?*
- *How would you involve family members and women? The strategy may differ depending on the social and cultural set-up.*
- *What is the proper way to handle defaulters? Should they be given a second chance? Or are they putting the project at risk?*
- *What strategy would you recommend to reduce the number of people defaulting because of climatic problems?*
- *Recommend a selection procedure for new farmers (to avoid defaulters).*
- *How would you go about supplying/producing organic seeds?*

3 Examples of Successful Initiatives: Participatory Technology Development

difference in terms of yield. Irrigation is very costly, and the required power supply is also irregular (at times farmers have to wake up at 2am to irrigate their fields).

Cooperation within farmers' families. There are instances when farmers default, saying it was a family member or a labourer who applied chemicals during their absence. As a result of this the company is trying to get more people to attend training sessions. There is also an attempt to educate and inform women during inspection visits, for example. This is still difficult, as women are usually not allowed to attend training sessions or even speak to men. The precise involvement of women in decision-making has to be ascertained and depends on both caste and family.

3.2.6 Research and technology improvement

Improving the system through research and dissemination

With the Maikaal bioRe project having grown to a considerable size, the question has been raised whether organic cotton farming could be a viable option for more farmers in India. In 2002, Maikaal bioRe and Remei initiated a three-year research project to study the initiative's impact on farmers' livelihoods. A systematic comparison study of organic and conventional farms analyzes whether farmers in the project have become better off both economically and socially since adopting organic farming. In its second stage, the research investigates the process of adoption and tries to identify the obstacles and success factors for conversion to organic production. The research project also aims to improve the production system and to develop suitable extension tools such as crop guidelines and training manuals. The final results of the research project will soon be available.

The research project was funded by the Swiss Agency for Development and Cooperation and the World Wide Fund for Nature, and was implemented by the Swiss Research Institute for Organic Agriculture (FiBL) in close collaboration with a field research team employed by Maikaal bioRe. The International Water Management Institute (IWMI) investigated drip irrigation and other water saving technologies, as water scarcity is one of the main constraints to farming in this region.

Studying the economy of organic cotton farming

To compare the performance of organic cotton farming with the conventional system, it is not sufficient to simply compare yields. The most relevant factor for farmers is revenue: the income received for the yields of all crops (cotton, intercrop, subsequent crop if any) minus all production costs. The research project selected a random sample of 60 organic and 60



TRANSPARENCY 3.2 (8): METHODS INVOLVED IN ANALYZING THE ECONOMY OF ORGANIC COTTON FARMING

Discussion:

Ask the participants how they would analyze the economic performance of organic agriculture in their context.

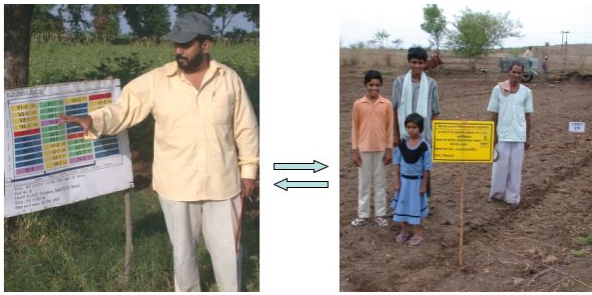
3 Examples of Successful Initiatives: Participatory Technology Development

Participatory technology development

Together with the Maikaal bioRe extension team and participating farmers, the research team works on the improvement of the cropping system through plot trials and on-farm trials. The first step is for the extension team and farmers' groups to identify the major challenges in organic cotton farming. Promising ideas for ways to overcome these problems are collected from the practitioners, from other organic cotton projects and from literature and web sources. In order to investigate the potential of these innovations in local conditions, systematic cotton plot trials are set up at the Maikaal experimental farm. The plot trials test cotton varieties, manures, green manures and pest management methods in four replications so as to reduce the effects of the heterogeneous field conditions. The results of the plot trials are shared with the farmers participating in the research project. In groups, they discuss which of these or other innovations they would like to try out on a part of their land. The research team guides the selected farmers in how to set up and monitor simple trials. These on-farm trials help the project find out whether suggested innovations match with farmers' conditions and help the farmers to try new things.

2.2. Maikaal bioRe Cotton Initiative 9

Participatory Technology Development in Maikaal



Plot trials. Promising innovations identified by the extension team are tested in plot trials on the experimental farm.

On-farm trials. Farmers decide which innovations they want to try out in simple comparison trials facilitated by the extension team.

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TRANSPARENCY 3.2 (9): FARMERS, EXTENSION WORKERS AND SCIENTISTS DESIGN PLOT TRIALS AT THE EXPERIMENTAL FARM AND ON-FARM TRIALS ON FARMERS' FIELDS IN ORDER TO FURTHER IMPROVE THE CROPPING SYSTEM

Discussion:

Ask the participants which problems and potential solutions, in their own initiative or another that they are familiar with, may be examined with a participatory technology development approach and with field trials.

3 Examples of Successful Initiatives: Participatory Technology Development

Sharing the results and innovations

The results and innovations generated in the research project flow into the development of extension tools: crop guidelines, training manuals, videos, etc. The results and tools are shared with extension workers of bioRe and other organic cotton projects through training workshops, stakeholder meetings and newsletters. The farmers get the opportunity to visit other organic cotton projects in India so that innovations and approaches can be directly exchanged from farmer to farmer.

The research team takes care that each farmer who participates in the data collection gets the processed results from his fields. The soil sample results help both organic and conventional farmers to improve their manure or fertilizer application. Field economy sheets with the processed input-output data help them to optimize their overall farming system.

2.2. Maikaal bioRe Cotton Initiative 10

Sharing the results and innovations



Workshop on soil fertility

Extension tools

- Crop guidelines
- Training manuals
- Video for group discussions



Stakeholder meeting

Direct exchange

- Stakeholder meetings with other organic cotton projects
- Newsletters
- Farmer-to-farmer exchange and field visits

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TRANSPARENCY 3.2 (10): RESULTS AND INNOVATIONS OF THE MAIKAAL COTTON RESEARCH PROJECT ARE DOCUMENTED IN EXTENSION TOOLS AND SHARED AMONG THE VARIOUS STAKEHOLDERS

3 Examples of Successful Initiatives: Participatory Technology Development

3.2.7 Lessons learned

Many farmers are fed up with conventional agricultural systems and are looking for alternatives. Many, however, are also hesitant because they are afraid that crop yields will drop. In fact, harvests do drop during the conversion period (2-5 years), because the soil quality is poor. The integration of the farmers into the supply chain, and the premium payment, give them security and support which, are critical in the first years. Farmers are willing to adopt organic farming, provided there is a ready market for the goods produced and there are partner organisations willing to support farmers during conversion.

Individual constraints also influence interest in organic farming. Farmers with good irrigation facilities get good results from chemical farming, for example, whereas farmers with rain-fed fields find real solutions with organic farming. Some farmers have an intrinsic and even a philosophical motivation for farming organically while others convert to organic farming out of a more opportunistic mindset. The latter are more likely to leave the project earlier, to default by using chemicals when the rains are heavy or by experimenting with GMOs.


Organic certification requirements are very strict and may be difficult for certain farmers to meet. For example, in India there are many extremely small farms. Some families have less than 5 acres (2 ha) of land with good enough soil quality and irrigation for cotton, so following a proper crop rotation pattern creates problems.

As most farmers do not maintain a written accounting system, it is difficult to compare the cost-profit structure before and after conversion. Furthermore farms are so different (location, soil quality and history, irrigation, size) that it is hardly possible to compare between two different ones. Farmers' conviction of the benefits of the organic approach is tangible but cannot be proven with figures. The research study conducted by FiBL and IWMI (see chapter 3.3.6) tried to find hard facts and work out a scientific dissemination strategy.

While organic farming can do little about social obligations, it can make a big difference by replacing expensive purchased chemicals with locally available resources. The lower cost of organic inputs helps to reduce farmers' debts and therefore dependence on moneylenders. Farmers who have been with Maikaal bioRe for a certain period can finance their inputs themselves with the premium. Farmers have repeatedly communicated that reduction in debts brings more peace in the family as tensions disappear.

2.2. Maikaal bioRe Cotton Initiative 11

Lessons learned:



- Many farmers are looking for alternatives to conventional agriculture and need support in this.
- Conversion is easier with a qualified extension service.
- The farmer must become a partner in the textile chain and get a premium from the partnership.
- Mutual trust and cooperation are necessary on all levels (farmers, extension team, processors, trade).
- The farmers must share responsibility for quality management (product quality and internal control).
- Continuous capacity building for the extension team is necessary, but time consuming.
- Continuous innovation in production technology (participatory on-farm trials) and organizational structures are important.
- Thorough controls are crucial.
- Much is possible with consumer support and an established chain.

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TRANSPARENCY 3.2 (11): LESSONS LEARNED FROM THE MAIKAAL INITIATIVE SO FAR

3 Examples of Successful Initiatives: Participatory Technology Development

The bioRe Association gives farmers interest-free loans to purchase drip irrigation systems. In addition, farmers note that organically managed soil has a greater water-holding capacity, which means the need for irrigation is less.

In general, organically grown crops are observed to be healthier and much more stable over the years, with less dependency on climatic conditions. After the conversion period, harvests usually reach the regional average. This is true in Maikaal's specific context (climate, soil, cropping system etc.), but not necessarily so everywhere.

An extension service that can guide and assist the farmers in reducing cultivation costs, and ensuring they understand the alternative methods, makes conversion easier. The transfer of organic know-how through quality training and extension services is very important to farmers, more so than the premium. Personnel must be developed over a period of time. The training of the advisors is a time consuming process. The lack of trained personnel can be a hindrance to expanding the project.

Nurturing a relationship of trust and cooperation between the parties involved, and developing it into a partnership, is crucial for socio-economic innovation. Partnership means an unconditional commitment in all areas, including financially if need be. Mutual respect and understanding, gained through listening to and learning from one another, is of major importance. It can take years of dialogue to understand each other's circumstances and learn how to work effectively together. Solutions to social problems have to be found experimentally, through a slow but constant dialogue between promoters and farmers. As a general rule, no culture or social class should be excluded from an initiative. At the same time, trust alone is not enough. Now that the project is well established and has grown, controls have become more and more necessary.

The initiative shows that with the support of the customers and the chain, a great deal is possible. The active support of consumers still needs to be enhanced, and ways must be found to do this.

Recommended websites:

- *Information about Remei and Maikaal bioRe:*
www.remei.ch
- *Information about the research project:*
www.fibl.org/english/cooperation

3 Examples of Successful Initiatives: Participatory Technology Development

3.3 Cooperativa Campesina Las Nieves: A Quinoa Cooperative in Chile

3.3.1 Description of the initiative

Customs and traditions are important in the life of Chilean farmers. Farmers in the Paredones area in Chile's region VI have traditionally cultivated quinoa, a kind of cereal grown in the area since pre-colonial times. Quinoa used to provide the main protein base in the people's diet in that region.

The Paredones area, where this organic initiative is situated, is a dry coastal area between the Pacific Ocean and the Andes mountain range. With an elevation of up to 1000 meters it has a nearly flat topography and very poor soils. Historically, the area has been dedicated to wheat production and has therefore developed its economy based on wheat over the centuries.

The Cooperativa Campesina (farmer cooperative) Las Nieves is a non-profit organization which promotes the development of small-scale farmers. The cooperative offers technical support through an advisory team and provides management services such as organizing production, crop monitoring, documentation, quality management and further education, as well as explaining which practices are allowed by organic standards. The cooperative also organizes certification and looks for good marketing opportunities for the harvested quinoa. The quinoa initiative started in 2000/2001 and was supported by Chilean institutions such as INDAP (for agricultural development) and ProChile (for export promotion).

After four years of development, the initiative is in a phase of consolidation and careful extension towards other farmers and agricultural companies.

The Cooperative's main body is the General Assembly, where all the farmers meet. The Assembly elects the Board of Directors, which meets once a month to define the general policy. The General Manager, who is responsible for the quinoa project, is helped by technical and administrative staff comprising dedicated local people. There is a project team of three people – a Stock and Warehouse Manager, a Secretary, and an Agronomist, who is responsible for ensuring that quality is high at each stage of production and processing.

The technical support and continuous monitoring provided by the cooperative's Advisory Team ensures that it conforms to the demands of the official certification body.

Lessons to be learned:

- *Involvement of the farmers is essential to ensure long-term success.*
- *Technical and administrative advice is invaluable in order to ensure a high product quality and a smooth certification process.*
- *Marketing initiatives must respond to the economic needs of the farmers.*
- *Direct communication between the farmers and the traders (the two ends of the supply chain) increases the sense of responsibility of both partners and encourages mutual understanding.*

3.3. Quinoa Initiative 1

The Organic Quinoa Initiative

- Located in the coastal dry climate area of central Chile, in a traditional cereal growing area
- Started 2000/2001 as a local initiative by the Chilean Cooperativa Campesina Las Nieves, a peasant company
- Promoted by Chilean Institutions including INDAP (Agricultural Development) and ProChile (Export Promotion)

Today:

- A non-profit organization offering assistance to the farmers
- Consolidation of the initiative and careful extension to other farmers and agricultural companies

Chile

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TRANSPARENCY 3.3 (1): DESCRIPTION OF THE ORGANIC QUINOA INITIATIVE, COOPERATIVA LAS NIEVES

3 Examples of Successful Initiatives: Participatory Technology Development

3.3.2 Origins

The Cooperativa Campesina Las Nieves was founded in 1969 with syndicates already established in the area. The cooperative worked well until the 1980s, when prices for conventionally grown agricultural goods dropped and the local economy experienced a recession. The agricultural production methods of the time proved too costly and lacked a guarantee of returns.

The Board of Directors of the Cooperativa Las Nieves looked for an economically and ecologically viable alternative. This was the origin of the quinoa project.

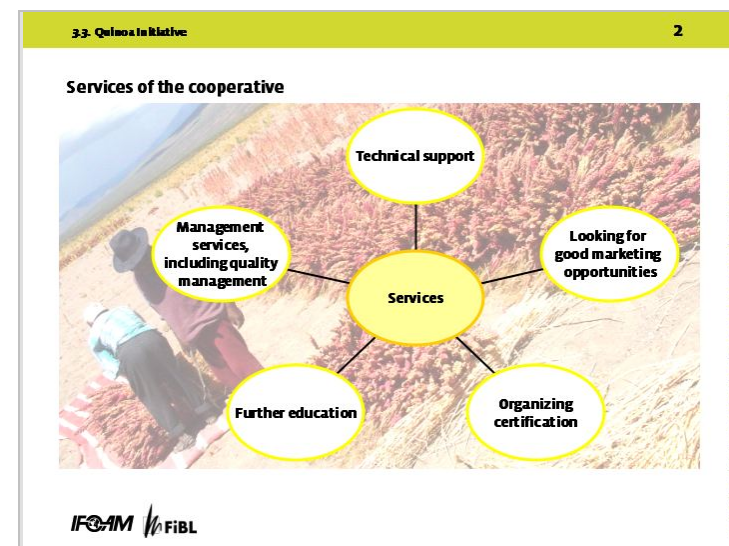
In 1993, the Cooperative was reorganized out of Paredones town. Little by little, interest in developing the project's export potential grew. At that time, a new national cooperative law was introduced, which reduced income taxes for non-profit organizations. Cultivating quinoa appeared to be the most interesting of various options available, particularly as quinoa had been cultivated in the area for centuries and because worldwide consumption was increasing.

Quinoa has excellent nutritional properties: it contains 18% protein and enough amino acids for a balanced diet, has a high mineral and vitamin content, and it supplies on average 350 calories per 100 grams. Its nutritional properties alone make it an excellent dietary supplement for people in general, and for vegetarians in particular. Due to its low sugar level, quinoa is also recognized as a good food for diabetics. Furthermore quinoa can be grown organically without using any pesticides. The varieties that are grown in the Paredones area are well adapted to the region's arid climate.

Until the 1990s, quinoa had been grown only for home consumption (processed into flour) and had practically disappeared from the region.

As one of the first steps in the new project, the cooperative members decided to reintroduce quinoa. The organic quinoa project started with a few farmers, using office space in a warehouse. The first sales were good, but delayed payment was an obstacle: the majority of the farmers in the cooperative were too poor to await late payments.

On the other hand, the guaranteed market, the easy availability of organic matter inputs and especially the free and ample support of the initiative's advisory service all encouraged farmers to participate.



TRANSPARENCY 3.3 (2): SERVICES OF THE COOPERATIVE LAS NIEVES

Discussion: Role of the company and involvement of the farmers

After having described the initiative and the activities of the company, ask the participants the following questions.

- What makes cooperation with the company interesting for the farmers?
- What other forms of cooperation exist? What are the differences?
- What role do the farmers in this initiative have?
- Do you know any similar (organic or non-organic) initiatives in your area?

3 Examples of Successful Initiatives: Participatory Technology Development

The ease of cultivating quinoa gave the farmers confidence. However, soil fertility started to become a critical issue when the availability of farmyard manure decreased. It thus became clear that improving soil fertility should be of highest priority.

3.3. Quinoa Initiative 3

Initial circumstances

Increasing problems:

- Decreasing prices for conventional crops, especially wheat
- Excessive production costs with no guarantee of returns
- Decreasing (and low) soil fertility
- Erratic rainfall, droughts
- New national law encouraging non-profit organizations

Quinoa – an alternative to wheat?

- Traditional crop, well-adapted local varieties, ancestral know-how
- No chemical inputs required
- Increasing consumption throughout the world
- Excellent nutritional properties

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TRANSPARENCY 3.3 (3): CIRCUMSTANCES AT THE START OF THE QUINOA INITIATIVE

Discussion: Analysis of the situation

Find out in an open discussion what the situation of the farmers in the Paredones area has in common with the situation that the participants are in. Which circumstances are different? What are the reasons for these differences?

Group work: Risks and potentials of organic cultivation

Divide the participants into groups to discuss the social, ecological and economic risks and potentials of organic cultivation.

- *What are the arguments for and against organic agriculture?*
- *Which assets do the participants have for organic cultivation?*
- *What may be done to change the circumstances?*

3 Examples of Successful Initiatives: Participatory Technology Development

3.3.3 Milestones of the Cooperativa Campesina Las Nieves

1969: The Cooperative of Las Nieves is founded with regional syndicates to enhance development in the area.

1975: Due to the persecution of socially minded initiatives by the ruling government, and a national economic crisis, the Cooperative stops its activities and many farmers leave the area to live in town.

1993: The new democratic government encourages the efforts of rural development initiatives. The Cooperative is reactivated in the Paredones municipality.

2000: The **first organic cultivation** of quinoa is finally launched in Paredones. The Cooperative staff begin the certification process in order to access foreign markets.

2002: The quinoa project generates its first income with the export of the first container (22 tons) of organic quinoa to Canada.

Some Bolivian quinoa varieties are tested, but no satisfactory results are obtained.

2003: The Cooperative studies the French market to find new prospects. A second container is sent to Canada.

2004: The third container of quinoa is exported. The sale price is increased thanks to better marketing and improved quality. The Cooperative finds new market partners in Italy with an international company and the Slow Food Foundation. From the year 2000 to 2004 the number of farmers involved in the project has slowly but surely increased.

Future milestones:

Four years after the first cultivation of organic quinoa, the initiative has successfully developed this crop as an economically viable alternative to wheat. The main aim of the initiative is however, to improve the incomes of as many farmers as possible. Thus increasing the number of farmers involved in the Cooperative would be an important future milestone. This would mean that more members would be available to participate in the project, thereby increasing the production volumes of organic quinoa.

However, the initiative also faces some problems, which must be addressed:

- The Cooperative's production of its own seeds must be improved.
- Financial stress caused by delayed payment must be reduced. A capital fund to pay the farmers in advance could encourage participation.

4

3.3. Quinoa Initiative

Milestones of the Quinoa Initiative

1969:	Formation of the cooperative with regional syndicates
1975:	Political crisis and beginning of a recession period
1993:	Reactivation of the cooperative in Paredones
2000:	First organic cultivation of quinoa in Paredones
2002:	Export of first organic quinoa container to Canada
2003:	The cooperative studies the French market
2004:	Export of the third container, the sale price is increased
2004:	New partnership with an Italian company and the Slowfood Foundation

Future goals:

Recruit additional farmers for the initiative
Improve seed production
Reduce financial stress by partial advance payment

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TRANSPARENCY 3.3 (4): MILESTONES OF THE COOPERATIVE LAS NIEVES

Group work: Design your own project

Divide the participants into groups and ask them to design their own project and to develop a basic concept for it.

- *What is the aim of the project?*
- *What are the major milestones of the project?*
- *How are the farmers involved? How is good cooperation ensured?*
- *What are possible obstacles?*
- *How is the project financed?*
- *How is the project managed? What are the priorities?*

Ask the groups to present their project ideas and invite the audience to give feedback on the presentations.

3 Examples of Successful Initiatives: Participatory Technology Development

3.3.4 Strengths (and weaknesses) of the initiative

The following factors have contributed to the success of the initiative:

Familiar farming system. Quinoa is an indigenous crop, which is traditionally grown without any chemical inputs, as pest and disease pressure is low. Therefore, conversion to organic cultivation does not present any additional difficulty. However, the farmers are confronted with some organizational changes related to certification.

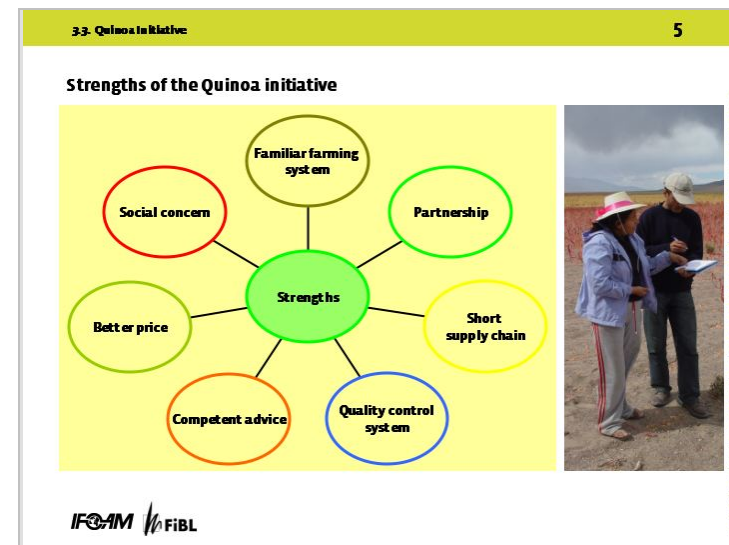
Partnership. The fact that the farmers are owners of the Cooperative is one of the distinguishing factors of the initiative. A culture of dialogue and cooperation within the Cooperative has been one of the driving motivational aspects. It has proved important that the farmers know that they are the Cooperative's motor, and that the administrative and technical staff are their employees. The Cooperative's management has spent time meeting individuals and groups of farmers to discuss their needs and concerns. Farmers' participation in the General Assemblies is crucial, because these meetings define the Cooperative's policy as well as setting priorities based on the farmers' needs.

Short supply chain. The cooperative is the starting point of an integrated supply chain covering raw material (harvested grains), processing (cleaning of the grains) and retail to the customers. Potentially, the involvement of producers at each production stage ensures that high quality is maintained. The Cooperative is considering organizing a 'Quinoa Day' to bring the buyers into contact with the producers, and to promote the consumption of quinoa at both the local and national level.

Quality control system. To create trust and marketability, as well as to meet extremely high quality standards, the Cooperative has established a rigorous quality control system, which is further developed every year. Strict production criteria and controls also apply to the processing of the quinoa grains.

Competent advice. The commitment to offering farmers competent advice free of charge has proved to be of major importance for the development of the project. The quality training and advice give the farmers confidence, help them in difficult times and enable them to increase their yields. Training of the advisors by international experts and transferring technology and knowledge has also proved to be extremely valuable.

Better price. The Cooperative manages to sell the entire quinoa production every year, thanks to a marketing and production plan which is set up with the growers. The price obtained for the quinoa is much better than the one for wheat. This is a decisive factor which attracts new farmers to organic farming.



TRANSPARENCY 3.3 (5): STRENGTHS OF THE QUINOA INITIATIVE

Exercise: Study of the supply chains of local initiatives

Together with the participants, find similar initiatives in the local area. Divide into groups and ask each group to study the supply chain of one initiative.

- What are the characteristics of this initiative's supply chain?
- Is the cooperation purely economic, or is there sharing of management responsibilities and profits?
- What are the characteristics of fair trade? What advantages and inconveniences does the model have from the farmer's perspective?
- What changes would be necessary to overcome the inconveniences?

3 Examples of Successful Initiatives: Participatory Technology Development

Social concern. Organic farming is seen by the Cooperative partners as a measure to solve many of the area's socio-economic problems, as it raises members' incomes, improves soil fertility, etc. The main purpose of the initiative is thus to make farmers stronger and to enhance social development in the area.

3.3.5 Challenges

The initiative still faces some major challenges, including:

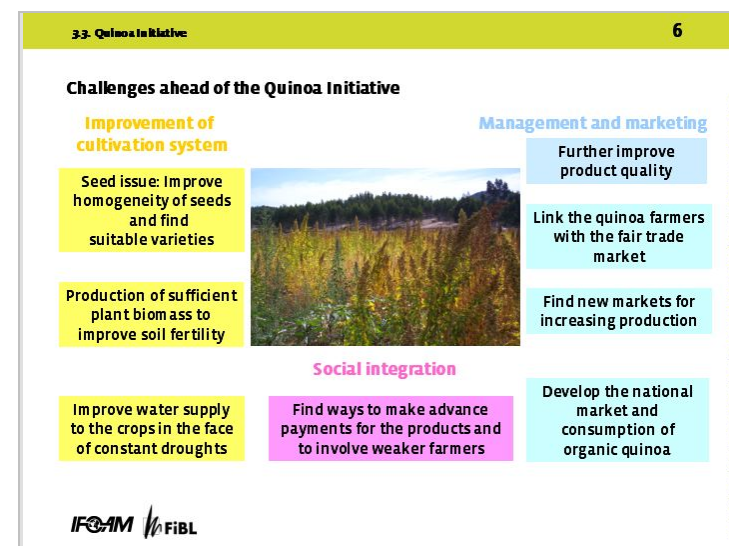
Seed production. At present, farmers use their own seeds for the following season. The positive side of this system is that it ensures independence of the individual farmer. Unfortunately these seeds are not homogeneous. It has proven important to get the technical team involved to ensure the same quality of seeds for all the farmers. As a result, a plot for seed production was sown for the first time in 2004. The field is managed by the technical team, in association with the farmers, in order to get the best seed for all producers in the initiative. Previously, tests were carried out with Bolivian cultivars, but as these did not satisfy the needs of the Cooperative, the decision was made to establish a well defined local cultivar.

Soil fertility. Soil fertility is very fragile in this region. The lack of nitrogen is the greatest obstacle for farming. In the beginning, it was possible to obtain organic material from a public organization thanks to a public program to rehabilitate degraded soils. Now, however, the availability of cow dung has decreased and sourcing manure or organic fertilizer has become critical for the farmers.

At present, farmers work within a convenient rotation framework, which includes wheat (*Avena sativa*) and a Vicia bean, a nitrogen-fixing green manure crop. Possible future approaches include increasing the availability of farmyard manure by introducing animals to the farms and developing proper composting practices.

Drought. The region constantly faces drought. The combination of drought and the over-exploitation of groundwater leads to a drastic reduction of water availability. This again leads to reduced yields and to an economic crisis amongst the farmers.

Organic farmers say that organic farming makes the soil softer and increases its water-holding capacity. To reduce water consumption and bring production costs down, the Cooperative farmers increasingly use drip irrigation systems.



TRANSPARENCY 3.3 (6): CHALLENGES AHEAD OF LAS NIEVES

3 Examples of Successful Initiatives: Participatory Technology Development

Marketing. So far only 20% of the total sales have gone to the national market. Quinoa is still a relatively unknown food. New markets must therefore be opened in order to allow an expansion of production. To develop the domestic organic market for quinoa, major efforts are necessary. One attempt will focus on improving the quality of the product to increase its marketability in supermarkets and specialized shops. An interesting alternative is to link the quinoa farmers to the fair trade market, which will ensure good prices.

In addition, the farmers are eager to market their rotation crops at an organic premium price. Finding new organic markets for the other crops would make full farm conversion easier. This is an enormous job, however, and at present the project does not have sufficient resources to invest in it.

Quality improvement. Quality improvements are still possible and are necessary to reach new markets. The timing of harvest, for example, needs to be improved to ensure the best quality grains.

Farmers' constraints. It is possible to increase yields and surfaces by involving more farmers in quinoa production, but it must be done in accordance with the market.

Commercially, the most problematic issue is delayed payment. The Cooperative receives just 50% of the product's value before the container is exported, and does not have the resources to pay immediately for the farmers' entire production. The farmers must wait for the importer to complete the payment before receiving their full share of money. To make quinoa cultivation sustainable, especially for the weaker farmers, the Cooperative must find a way to pay the farmers in advance.

Discussion: How would you approach the challenges?

Every initiative constantly faces new challenges. Having presented to the participants the challenges facing the quinoa initiative, it may be interesting to discuss, in plenary or in groups, how these challenges could be addressed.

Possible questions are:

- *How would you involve the weaker farmers?*
- *What market strategy would you recommend?*
- *How would you go about supplying/producing organic seeds?*
- *Recommend a selection procedure for new farmers (the aim being to improve product quality).*
- *What measures would you recommend to approach the climatic problems (the aim being to keep farmers involved in the project)?*

3 Examples of Successful Initiatives: Participatory Technology Development

3.3.6 Lessons learned

Some of the major lessons learned so far include the following:

Support. Many farmers see the quinoa project as an alternative for development and are interested in organic farming. However, in order to commit to organic farming and give up their conventional agricultural methods and crops, the farmers need to be assured of safe marketing opportunities and technical support. During the certification process the farmers need assistance to ensure that they fulfill all the requirements of the organic certification body.

Organic farming becomes more easily accessible to small farmers with the assistance of a competent extension service. In the case of Las Nieves it proved vital to help farmers reduce their cultivation costs and to ensure that the alternative methods were understood. The communication of organic know-how is very valuable for the farmer and may even be more important than the premium.

Sharing knowledge. The Cooperative learned that it can be extremely valuable to exchange knowledge and experiences with experts from other regions and countries. In 2004, for example, the Cooperative invited a French expert to help it explore commercial opportunities for its products in the European market.

Through on-farm trials the Cooperative's technical team teaches selected farmers how to set up and monitor simple trials in their quinoa fields. These trials help the project monitor whether suggested innovations match the farmers' conditions, and help them to try out new practices independently. These can then be compared and discussed within the group. The research orientation was also defined by the farmers in the Assemblies. The participatory organization of the Cooperative has helped to encourage the development of appropriate technologies.

Sharing responsibility. The initiative's experience shows that the farmers must be partners in the organic chain so that they feel a sense of responsibility and commitment. In order to involve the farmers in the new management system, they need to be involved in quality management – both product quality and internal control. However, this cannot replace additional thorough quality control from other sources.

3.3. Quinoa Initiative 7

Lessons learned:



Competent market and technical support are necessary to start an initiative and to ensure continuity.

Sharing knowledge with the initiative (and including farmers) enhances motivation & helps develop appropriate methods.

Sharing knowledge with outside experts can be very valuable.

Sharing responsibility - the farmers must become partners of the organic chain and must share responsibility for quality management.

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TRANSPARENCY 3.3 (7): LESSONS LEARNED OF THE COOPERATIVE LAS NIEVES

Related websites:

- www.agrupacionorganica.cl
- www.slowfood.com

Recommended website:

- www.fairtrade.net

4 Management Guide for Crops

4 Management Guide for Crops

4.1 Millet

Introduction

Millet is a fast growing and robust annual crop. It is an important staple of the African semi-arid tropics, is the principle cereal of the Sahel area of Africa, and is also grown in the dry regions of Asia.

Of the different races of millet that exist, pearl or candle millet (*Pennisetum glaucum*) is by far the most important in terms of area under cultivation. It is predominantly grown in West Africa (Nigeria, Niger, Burkina Faso, Chad, Mali, Mauritania and Senegal) and Asia (India). Finger millet, foxtail millet and other varieties are cultivated in small amounts in marginal areas only. The information in this chapter mostly refers to the production of pearl millet.

Millet is known for its wide adaptability to different growing conditions. Due to its excellent tolerance to drought, the crop is mostly grown as a rain-fed crop in areas where rainfalls are low and irregular, and where other crops such as maize or sorghum yield poorly or fail. It is widely grown on poor, marginal soils without the use of any inputs. As a result, registered yields of millet are very low.

Millet plants typically have a thick stem and grow to a size of 2.5 to 4.0 meters. Millet has a C₄-photosynthesis mechanism (as do maize and sorghum), which allows it to grow fast and produce large quantities of biomass. The grains of millet are smaller than those of sorghum. They typically contain 55 to 65% starch and 12 to 14% protein, which is somewhat higher than most other cereals. Pearl millet is grown for various human purposes, but also as a fodder crop.

As yet, most farmers have paid little attention to the application of improved cultural practices in millet production such as green manuring, appropriate crop rotation or planned recycling of animal manure. Such practices are not only important in order to prevent further depletion of the soil, but also improve soil fertility and result in higher productivity and yield safety of both millet and other crops. Millet responds particularly well to improvements in growing conditions. Improved cultural practices also build the basis for successful organic production.

Lessons to be learned:

- *Millet is the cereal crop with the highest tolerance to heat and drought.*
- *Application of improved cultural practices results in higher and more secure yields.*
- *Millet's potential under low rainfall conditions should not be underestimated.*
- *Different cropping patterns may increase total yield and improve soil fertility.*

Motivation: What are the characteristics of the crop?

To start with, collect information on the participants' attitudes to and knowledge about millet. Ask the following questions and note the answers. Later you may come back to the answers and discuss them.

- *What are the characteristics of millet? Under what conditions is millet presently grown? Under what conditions is it not grown? What are its strengths and weaknesses? What is the role of millet in local agriculture (compared to other crops)?*
- *What ecological, economic and personal factors influence the cultivation of millet (e.g. soil characteristics, household preferences, market demand, national and international economic policies, infrastructure, marketing structures etc.)?*
- *Do you see any potential improvements to millet production and marketing?*

4 Management Guide for Crops

4.1.1 Agro-ecological requirements

Temperature

Millet is well adapted to high temperatures. It is more heat tolerant than sorghum or maize. For germination, high temperatures of between 33 and 35 °C are best, as warm soils encourage rapid germination. In its main production area in Africa, the planting period coincides with the period of very high temperatures. Seeds do not germinate below 12 °C. The optimum temperature for plant development is between 21 and 25 °C. Very high temperatures before flowering reduce the size of the panicles and the density of the spikelets. Low temperatures reduce seed setting. Temperatures of at least 20 °C are needed for the grain to ripen. Millet likes to be situated in open, unshaded areas.

Water

Millet is mostly grown as a rain-fed crop in dry climates with a rainy season of three to five months and 200 to 400 mm of annual rainfall. Millet is very drought resistant. Its tolerance to water stress is higher than that of sorghum. Under conditions of low soil humidity the crop is therefore more productive than both sorghum and maize. Its greater tolerance to dry conditions is due to its rapid, dense and deep rooting system (that can reach 1.5 or even 3.5 meters of soil depth), its ability to compensate for water stress by making additional tillers and its roots being well-protected from desiccation. If drought occurs before flowering (or if the main stem is damaged) millet plants can produce new tillers from the upper nodes of the stems and partially compensate for earlier losses.

Millet needs little water after germination: a small amount as the leaves appear, light rain during the growing period. Moisture stress during the vegetative period reduces the seedset, as does heavy rainfall. Rain during flowering may cause the crop to fail completely. Hot and dry weather is needed for grain development.

Soils


Millet grows on a wide range of soils. It grows best, however, on well-drained, light, sandy to clayey soils. Millet performs better than most other crops in light soils and acid soils being less susceptible to nematodes than sorghum.

Millet does not tolerate waterlogging, and is less tolerant to flooding than sorghum. Established millet crops are tolerant of salinity.

Due to its large and dense root system, millet can access nutrients in poor soils and thus can be grown in soils with low fertility.

4.1. Millet 1

Agro-ecological requirements of millet



- Temperature**
 - 33-35 °C is ideal for germination (minimum 12 °C)
 - Optimum for plant development is 21-25 °C
 - Moderate temperature at flowering
 - Hot weather during grain development
- Water/Humidity**
 - Tolerant of water stress
 - Moderate water from sowing through plant development
 - No rain at flowering
 - Dry weather during grain development
- Soil**
 - Well-drained soils (no risk of waterlogging)
 - Can grow in soils with low fertility
 - Tolerant of salinity when established

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TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.1 (1): AGRO-ECOLOGICAL REQUIREMENTS OF MILLET

Group work: Comparison with other cereals

Ask the participants to work in groups and compare the agro-ecological requirements of millet with the requirements of other cereals grown in the area, such as sorghum and maize.

4 Management Guide for Crops

4.1.2 Diversification strategies

Selection of cultivars

Cultivars of pearl millet can be divided into two categories: cultivars that need short day length to flower and produce grains, and those that are not sensitive to day length. Cultivars that depend on short days to start flowering have a long growing period, while varieties that are not photo-sensitive, or are less photo-sensitive, tend to mature early. Photo-sensitive cultivars are thus grown as a long season crop, while the less sensitive cultivars can be grown as a short season crop. The use of early maturing cultivars increases yield security in climates with low rainfall, as periods of drought are more likely to be avoided. The production of short-season cultivars may allow a second crop, such as a legume, to be grown.

Traditional photo-sensitive varieties have poor yield potential, but have the advantage of being well adapted to local growing conditions. Improved cultivars and single-cross hybrids grow quickly and may attain higher yields under conditions of drought-stress and even low nutrient status. They may also be more tolerant to some pests and diseases and show improved quality at the processing stage. Pearl millet is considered to have high potential in terms of further genetic improvement. In India, most farmers use improved cultivars and single-cross hybrids, whereas in Africa both photo-sensitive and indifferent cultivars are grown.

For best results and to minimize risk of crop failures, cultivar selection should be made with due consideration being given to average rainfall, response to day length, vigor at emergence (which must be good), potential grain yield, tillering (should be abundant), and resistance or tolerance to downy mildew, smut, earworm and striga. Hairy corncobs prevent the grains from being eaten by birds. For processing, the consistency of the grains and the vitreosity of the endosperm are also important. Cultivars also differ widely in grain color.

Crop planning, intercropping and crop rotation

Pearl millet takes 75 (or less) to 180 days from planting to maturity depending on the cultivar. The crop is sown before or with the first rains to reduce the risk of losses by drought and pests. Cultivation of short-duration cultivars reduces the risk of crop failure. Long-duration cultivars are sown later. In areas with two rainy seasons, millet can be grown during the short rains. Where rainfall is sufficient, double cropping is possible after short-duration millet.

Sharing experiences: Millet cultivars

Invite the participants to share their experiences with cultivar selection in millet. Possible questions are:

- *What attention do you pay to cultivar selection?*
- *What traits are considered, when selecting appropriate cultivars?*
- *What relevance does cultivar selection have compared to the improvement of other cultural practices?*
- *Have any experiments been made with improved varieties?*

4 Management Guide for Crops

Millet can be grown as a sole crop, a mixed crop or as an intercrop. In traditional cropping systems, millet is commonly grown together with other crops. The reason lies in the numerous advantages associated with intercropping and mixed cropping, such as higher and more reliable yields, better use of resources, and cultural advantages such as better weed control and soil protection (see chapter 4.2 of the Basic Manual also). In some countries a small percentage of millet is grown under irrigation as the sole crop.

In West Africa, pearl millet is often intercropped with cereals such as other millets or sorghum, or with legumes such as cowpea or groundnut. Depending on rainfall, intercropping partner(s) and the importance of millet vary (e.g. with increasing rainfall the role of sorghum increases). In India, pearl millet is often intercropped with pulses such as hyacinth bean, mung bean or horse gram (*Macrotyloma uniflorum*), or with other crops such as castor or cotton. In northern India, short-duration pearl millet is often double-cropped with wheat and sometimes finger millet if rainfall is sufficient. In intercrops, both short season and long season millets are used.

Intercropped legume and millet are usually sown in alternating rows. In the case of cowpea, growing two rows of millet and four rows of cowpea has proved more productive than alternating single rows of both crops. Sowing times, cultivars and the cropping pattern should be chosen in a way that avoids competition by the legume for water, nutrients and light. Cowpea may be sown two to four weeks after millet. Longer growing seasons offer greater possibilities for adapting the system to the farmer's specific needs. The intercropping of millet with a drought-tolerant legume generally increases the productivity of both crops.

Rotating millet with legumes allows legumes to be grown at a higher density than is possible in an intercropping system. Depending on the species, the nitrogen fixation rate and the use of the legume (e.g. livestock feed or incorporation into the soil as green manure), it will have a more or less positive impact on the yield of the following millet crop. To maximize the benefits of legumes on soil structure and soil fertility, a rotation of three years legume and one year millet may be necessary. Rotation (and to a smaller extent intercropping) of millet with legumes furthermore reduces the infestation levels of the parasitic weed striga (for further information see chapter 4.2.3). Millet is sometimes traditionally also alternated with a fallow period, this also contributes to the better growth of millet, but in general not as much as intercropping with a legume crop.

Sharing experiences: Diversification of the millet cropping system

Invite the participants to share their experiences of growing millet alone, or in rotation with other crops. Ask the following questions:

- *What relevance do you attribute to intercropping and crop rotation for yield, yield reliability and soil fertility?*
- *Do you see any advantages and inconveniences in intercropping and rotating millet with other crops?*
- *How much attention is paid to cultivating leguminous crops?*
- *Have legumes also been grown as green manure? What advantages and inconveniences does incorporating a legume as green manure before flowering have, compared to the incorporation of the crop residues after the harvest of the beans?*
- *Have there been any experiments in alley cropping leguminous trees? Under what conditions is it advantageous to combine trees with annual crops?*

For further information on potentials and constraints of green manures see chapter 4.5.2 of the Basic Manual.

4 Management Guide for Crops

The cultivation of nitrogen fixing trees (in rows) increases the diversity of the cropping system, while offering additional highly nutritious forage for livestock, enriching and protecting the topsoil with fallen leaves in the wet season, fixing nitrogen on its roots and drawing nutrients from deep soil layers. All these effects contribute to an improvement of the yields of annual crops, such as millet or sorghum. Although millet and sorghum prefer unshaded conditions, they will profit from the improved nitrogen supply and soil conditions in proximity of the trees. Drought stress and phosphorus deficiency may, however, limit the advantages of the diversification of the farming system with trees.


Establishing the crop

Short-duration millet needs only limited land preparation; rigorous seedbed preparations are not necessary. Compared to pearl millet, finger millet requires a carefully prepared seedbed with a fine tilth. Land preparation for long-duration cultivars, which are sown later, is done more thoroughly. In Africa the ground is usually dug over with a hoe and weeded prior to sowing, and in India farmers make two to three passes with the plough. When a green manure crop is grown before millet, good soil preparation involves careful incorporation of the plant biomass into the soil.

The seed is mostly broadcast and is then covered lightly with soil (e.g. by using a brush harrow). The exact seeding rate is not really critical, because pearl millet can compensate to some extent for a poor stand by increasing the number of tillers. If the crop is drilled directly into the soil, the seeds are sown at a row distance of 35 to 70 cm or more, usually on flat soil. Ideal spacing depends on the availability of soil moisture and the organic matter content in the soil (affecting the fertility of the soil). The better the growing conditions, the higher the ideal plant density. On sandy soils, wider row spacing may be better since it will allow individual plants to develop more lateral roots. Wide distances between the rows also allow a cultivator to be used for weed control. On the other hand, small distances between the rows will result in better, and earlier, ground shading by millet and will better suppress weeds. Depending on the sowing density, seed rates vary from 3 to 11 kg per hectare (with a weight of 3 to 15 grams per 1000 seeds) with lower rates being used for broadcasting and higher rates for drilling. Plant density ranges from between 6,000 to 50,000 plants per hectare in pure stands. Sowing depth varies from 13 to 50 mm.


4.1. MILLET 2

Diversification of millet cultivation



Intercropping

- + Diversity within the crop
- + Higher productivity compared to single crop
- + Reduced pest and disease pressure
- Risk of competition from legumes



Crop rotation

- + Higher productivity compared to single crop
- + Legumes can be grown at higher density
- + Good Striga control

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TRANSPARENCY 4.1 (2): SOME INTERESTING ASPECTS OF DIVERSIFICATION IN MILLET CULTIVATION

4 Management Guide for Crops

Pearl millet can also be sown in pockets on hills or ridges at a distance of 0.75 to 0.80 m, or more, apart. After emergence, the stands are thinned to 2 to 6 plants per hole. In drier areas and on light soils millet is sometimes sown in furrows to improve access to soil humidity.

Instead of sowing millet, some farmers in the African Sahel and Sudano zones drop a few seeds in holes dug with a hoe, 45 cm to 1 meter apart, and cover them with soil. Sometimes millet seeds are also sown in nurseries and transplanted to the field after 3 weeks.

The crop can also be sown into dry seedbeds before the onset of the rains or after a productive rain of 20 mm. Prolonged droughts after sowing and during the early seedling stage greatly hinder growth. As the seeds of pearl millet are very small, soil crusting must be prevented to ensure the establishment of a good crop.

In dry areas, mounding the topsoil around the feet of the plants thirty days after sowing may improve the yield considerably.

4 Management Guide for Crops

4.1.3 Soil protection and weed management

Soil protection

Millet cropping systems do require soil protection measures. Special attention needs to be given to prevent losses in soil fertility, as the soils that are favorable for millet production are generally sandy and extremely prone to degradation. Proper management of organic matter will improve soil quality and thereby reduce susceptibility to erosion. Depending on the circumstances, soil protection measures such as growing a cover crop, mulching, relay intercropping or construction of barriers and terraces, may be of essential to prevent further depletion of soil. When growing millet on slopes, the most basic soil protection measure to apply is to sow millet horizontally across the slope in order to reduce soil erosion by water run-off. (For further information on soil protection measures see chapter 3.4 of the Basic Manual).

Weed management and thinning-out

Pearl millet has a rather slow early growth. This makes the crop sensitive to competition from other plants during this time. Thus thorough weed control prior to planting and until the crop has been established is important. However, due to labor shortages, millet is often not weeded properly or not weeded at all. Poor early weed control and subsequent competition may inhibit crop growth. Once established however, millet plants produce considerable biomass and compete well with late-emerging weeds (depending on spacing and the intercrop).

Preventive measures should be applied in order to reduce weed pressure in the crop. These include using weed-free seed, mixing crop(s) that have good weed suppressing qualities, choosing appropriate spacing, selecting varieties that are vigorous at emergence and have a strong tillering capacity and applying proper crop rotation.

The combination of different weed management practices can effectively suppress the proliferation of weeds. Hoeing or harrowing should be combined with hand weeding. In Africa, weeding is traditionally done with a hand hoe. In India pearl millet is weeded using a bullock-drawn harrow, followed by hand weeding. For harrowing, wide row spacing is necessary.

Farm visit or group work: Potentials and constraints to soil fertility improvement

Visit a farm and closely examine soil protection measures and measures that improve soil fertility. Discuss the following questions with the participants.

- *How do you consider soil fertility on the farm (or more generally in the area)?*
- *What factors determine soil fertility? (for information on soil fertility see chapter 3.2 of the Basic Manual)*
- *What makes it difficult to improve the fertility of poor soils?*
- *What soil protection measures do you know about that have been applied, and been effective, in the area?*
- *How could soil fertility be improved? Discuss (perhaps in groups) possibilities for improving the farming system.*

Sharing experiences: Weeding

Discuss the relevance of weeding millet. Is weeding necessary? Why? When should competition by weeds be avoided? What is considered a good agricultural practice for weed control in millet? Is it possible to reduce labor-intensive manual weeding? Have any experiments been performed with mulching, cover crops, specific intercropping patterns or other practices?

For basic information on weed control see chapter 5.4.2 of the Basic Manual.

4 Management Guide for Crops

Before sowing millet, weeds, bushes and residues from the previous crop should be removed. In cases where no weeding is done with pulled or drawn tools, the crop residues and weeds can be used to cover the soil immediately after the first rain, in order to protect the soil and inhibit new weed growth. Otherwise they should be collected and used for making compost. If time allows, two pre-plant tillage operations are recommended (especially when there is high weed pressure). The first passage is used to stimulate the germination of weed seeds, the second passage, which is done several days later, serves to kill the weed seedlings prior to planting the crop.

Millet usually requires two weeding and thinning-out operations. Eight to fifteen days after emergence (and preferably after rain) of the plants they should be thinned to 3 plants per pocket. The first weeding should take place about ten days after the first rain, but not later than 15 to 20 days after emergence. Weeding can either be performed manually or mechanically. If the millet is sown in rows, weeding can be done as soon as the rows are visible. The second weeding should be done manually, 10 to 15 days after the first. Additional weeding should then be performed as needed.

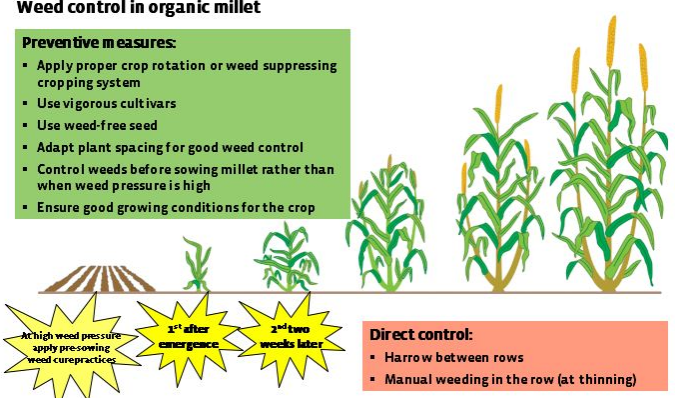
In West Africa pearl millet may be subject to serious attacks from the parasitic weed *Striga hermonthica*, while in Northern India the white-flowered *Striga asiatica* is more common. In Southern Africa the red-flowered *Striga asiatica* is widespread, however, it does not attack pearl millet.

4.1. Millet 3

Weed control in organic millet

Preventive measures:

- Apply proper crop rotation or weed suppressing cropping system
- Use vigorous cultivars
- Use weed-free seed
- Adapt plant spacing for good weed control
- Control weeds before sowing millet rather than when weed pressure is high
- Ensure good growing conditions for the crop



Direct control:

- Harrow between rows
- Manual weeding in the row (at thinning)

High weed pressure apply pre-sowing weed control practices

1st after emergence

2nd two weeks later

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TRANSPARENCY 4.1 (3): WEED CONTROL IN MILLET

4 Management Guide for Crops

4.1.4 Supplying nutrients and organic fertilization

Due to their deep root system, millet plants are able to exploit deeper soil layers for nutrients and water (more so than sorghum) and thus manage to grow in poor soils. In traditional farming systems, millet is mostly grown without fertilizers. Under such conditions the crop has a relatively low nutrient demand (with the exception of potassium). One ton of millet grain will remove about 45 kg of N, 10 kg of P, 20 kg of K and 10 kg of Ca from the field.

Under favorable conditions of water supply pearl millet will respond well to improvements in soil fertility and nutrient supply. Nutrient uptake under irrigation is doubled, as the level of available soil moisture strongly influences nutrient uptake. However, a high nutrient supply may promote early growth that is too vigorous, which may result in consumption of water that will be required for later crop development.

Long-term soil fertility management is necessary in order to improve the nutrient supply available to millet grown in poor soils. This includes increasing the supply of organic material to the soil, maximizing biological nitrogen fixation and improving manure management. (For general information on soil fertility management see chapter 3.2 of the Basic Manual).

In a crop rotation or intercropping system, millet benefits from being preceded by legumes. Legumes are the primary source of fertilization. If the green parts of the legume are fed to livestock, only the nitrogen fixed in the roots will be available to the following crop (depending on the return rate of animal manure to the fields). If the legume is incorporated into the soil however, when green plant mass is at its maximum, large amounts of organic material are added to the soil. These will enhance microbial activity in the soil and increase nutrient supply to the millet crop. If millet follows a legume, no additional nitrogen is generally needed.

Farmyard manure if available, or composted millet stalks applied at 2 to 4 tons per hectare to land in preparation for sowing, will boost crop growth. The management of manure can be improved by rotating animals on plots destined for millet production. Ten cows may fertilize one hectare in forty-five days in this manner.


Group work: Reasons for low soil fertility

In groups, identify the reasons for low soil fertility.

- *Has the fertility of the soil always been low?*
- *What relevance does depletion of nutrients have? How does it occur? What are the reasons for it?*
- *Are the farmers limited in their ability to maintain fertility? What are the reasons for this?*
- *Is it worthwhile to invest in soil fertility improvements? What factors lower the returns on investments?*



Ask the groups to present their results to the others. Ask them to show the interactions with arrows, by writing the key-words on the board.

4.1. MILLET4



Nutrient supply for millet

- Can grow under low nutrient conditions, but will yield poorly
- Responds well to improved supply of nitrogen and phosphorous
- Appropriate long-term soil fertility management should increase the nutrient supply base
- Intercropping, or rotation with a leguminous (green manure) crop, improves nitrogen supply
- Farm manures or compost supply most nutrients
- Additional phosphorous fertilizer may be necessary for poor soils



TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.1 (4): ASPECTS TO CONSIDER IN THE NUTRITION OF MILLET

4 Management Guide for Crops

Although not needed in great amounts, a sufficient supply of phosphorus is of major importance for the proper development of millet as well as of the legumes. Phosphorus is often the key limiting factor to crop growth when nitrogen and water are available. Application of a phosphorus rich source during early stages of the development of millet will improve the competitiveness of the cereal in intercrops. Purchase and application of phosphorus fertilizer may be necessary in order to overcome a lack of this nutrient.

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4.1.5 Pest and disease management


Downy mildew, smut, rust and ergot are common diseases in the areas ofin Asia and Africa where millet is grown. Stemborer, earworm and millet midge are the most problematic pests with millet, but the crop may also be attacked by grasshoppers, locusts, white grubs and various butterflies. Insect pests are less problematic in India than in West Africa.

Downy mildew (*Sclerospora graminicola*) is the most devastating disease in millet and is particularly significant in India and parts of Africa. The disease is transmitted through soil, crop residues, contaminated seeds and tools. As a result of infection, inflorescences and glumes become twisted. The treatment of seeds with antagonistic microorganisms has proved effective. As the disease spreads most in alkaline soil, reduction of alkalinity also contributes to its control. Preventive application of farmyard manure also reduces the occurrence of disease. The risk of the disease spreading can be reduced by destroying prematurely infested tillers and infested crop residues. As a preventive measure, select varieties, wherever possible which are resistant to downy mildew.

Smut (*Tolyposporium penicillariae*) attacks millet plants during the flowering period after rainfall with air-borne spores. Infections are most significant when the humidity of the air and air temperatures are high. This disease should be controlled through preventive measures such as the use of tolerant or resistant plant varieties, by timing the flowering of the crop so that this does not occur during the rainy season and by applying cultural measures that contribute to crop hygiene.

Rust (*Puccinia penniseti*) and ergot (*Claviceps microcephala*) show at flowering time. These diseases can be controlled by early sowing, by growing resistant varieties (applies to rust only) and by ensuring a moderate nutrient supply. Prematurely infested plants and infested crop residues should be destroyed.

Birds are the major pest in pearl millet cultivation. They are attracted to millet grains because of their small size. Preventive measures against bird attack include using cultivars with long, hard bristles, as these are attacked less severely than cultivars without awns. Planting pearl millet away from tree lines or woods can reduce risk of damage. Scaring birds away for several weeks before the harvest with efficient bird scaring methods is essential.

4.1. MILLET		5
Control of diseases in millet		
Diseases	Preventive control measures	Direct control measures
Smut (<i>Tolyposporium penicillariae</i>)	<ul style="list-style-type: none"> ▪ Proper incorporation of plant residues ▪ Use of tolerant/resistant cultivars ▪ Use of disease-free seeds ▪ Hot water treatment of seeds ▪ Adjustment of sowing time to avoid rain during flowering ▪ Moderate fertilization 	<ul style="list-style-type: none"> ▪ Removal and destruction of prematurely infested plants
Downy mildew (<i>Sclerospora graminicola</i>)	<ul style="list-style-type: none"> ▪ Properly dry seeds ▪ Treat seeds with antagonistic microorganisms (e.g. <i>Pseudomonas fluorescens</i>) ▪ Application of farmyard manure ▪ Acidification of alkaline soils ▪ Deep plowing of infested residues 	
Ergot (<i>Claviceps microcephala</i>)	<ul style="list-style-type: none"> ▪ Crop rotation/intercropping with legumes (e.g. mungbean) ▪ Use resistant varieties ▪ Use disease-free seeds ▪ Early sowing ▪ Deep plowing of infested residues 	<ul style="list-style-type: none"> ▪ Removal and destruction of prematurely infested plants
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TRANSPARENCY 4.1 (5): DISEASES OF MILLET AND APPROACHES FOR CONTROL

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Coniesta igenfusalis is the stemborer that most affects pearl millet. However, several natural enemies attack this pest at different stages of its cycle. Good soil preparation and the destruction of crop residues, or covering them with soil can help control stemborers. Proper crop rotation breaks the pest's life cycle. Mixed cropping of millet with other species also confuses the pest and promotes natural enemies. Control of cereal stemborers with the push-pull method, as used for sorghum (see chapter 4.2.5 and transparency 4.2.9) may also be applied to millet. Direct control is possible with application of neem during the evening.

Millet midge (*Geiromiya penniseti*) is abundant during the rainy season. The larvae of the fly feed on the developing seeds. As a result, the infested grains do not develop and panicles have a blasted appearance. Appropriate rotation with non-host crops and intercropping can reduce pest damage. After harvest the crop residues should be destroyed. Fields should ideally be ploughed after harvest and shortly before sowing. The spraying of natural pyrethrum is possible, but in general is not economically viable.

4.1.6 Water management and irrigation

In Africa pearl millet is generally grown as a rain-fed crop, and depends largely on rainfall and residual soil water, while in India the crop is also grown under irrigation.

Pearl millet responds well to irrigation, producing much higher yields under these conditions.

4.1. Millet		6
Control of pests in millet		
Pests	Preventive control measures	Direct control measures
Birds	<ul style="list-style-type: none"> Plant away from trees Use cultivars with long and hard bristles 	<ul style="list-style-type: none"> Scaring of birds from dough stage of grains onwards
Stem borer (<i>Coniesta igenfusalis</i>)	<ul style="list-style-type: none"> Proper soil preparation Early sowing Intercropping/simultaneous growing trap crops around the field and repellent plants within the millet crop Promote natural enemies Destroy stubbles after harvest 	<ul style="list-style-type: none"> Apply a neem-sawdust/clay mixture into funnel of young plants Spray fish bean plant extract
Millet midge (<i>Geiromiya penniseti</i>)	<ul style="list-style-type: none"> Early and uniform sowing Use of resistant cultivars Crop rotation with non-host crops Intercropping Removal of host weed species Destroy stubbles after harvest and plow before sowing 	<ul style="list-style-type: none"> Spray pyrethrum
Earworm (<i>Heliocheilus albipunctella</i>)		<ul style="list-style-type: none"> Spraying <i>Bacillus thuringiensis</i>

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TRANSPARENCY 4.1 (6): PESTS OF MILLET AND APPROACHES FOR CONTROL

Sharing experiences: Pest and disease management in millet production

Share experiences of prevalent pests and diseases and effective measures of preventive control.

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4.1.7 Harvest and post-harvest handling

Compared to other cereal crops, millet provides relatively low yields of grain. This is partially due to the crop's typically low grain production in relation to the mass of leaves and stems (harvest index), but is also due to millet generally being cultivated on poor soils with no, or very few, inputs. In the main production areas, between 500 and 1500 kg of grain millet is usually harvested per hectare. The average yields in West Africa and India are about 600 kg per hectare. Under low rainfall conditions, yields of pearl millet may be as low as 250 kg per hectare. However in India, yields under irrigation reach 1000 kg and more per hectare. Although the crop's yield potential is lower than other cereals, it can reach 3000 kg and more under optimal growing conditions.

In the tropics pearl millet is usually harvested by hand. Either the panicles are picked or whole plants are harvested. Cultivars that produce many tillers must be harvested in several passages, as they ripen unevenly. Due to the small seeds of millet, air speed and size of threshing screens must be adjusted when using a combine harvester, to avoid losses and obtain clean seed.

The crop is harvested when the plant is fully dry. To avoid unnecessary grain loss to birds or lodging caused by storms, the seeds should be harvested as soon as the grains are mature. The harvested panicles or plants are dried in the sun for a few days. In Africa the grains are stored on the panicles and threshed when needed, while in India grains are threshed soon after drying and preferably stored in containers. Threshing tends to be done manually by beating the panicles with a mortar and pestle or a stick, or by trampling them with cattle. Today, however, threshing machines for millet also exist. Panicles are commonly stored in elevated granaries or sometimes in pits.

Millet grains store very well. They can be kept for longer than those of maize or sorghum. Pearl millet can be stored as either heads or grains. If stored adequately at cool temperatures, grain kept for seed can be stored for several years. To reduce losses during storage, the grains should be dry, clean and healthy. Moisture within the storage facility should not exceed 12 to 13%. Compared to the grains of other cereals or pulses, pearl millet grains are rarely attacked by weevils during storage. Nevertheless, to reduce insect damage the grains may be covered with sand or mixed with Neem leaves. Food grains should be separated from seeds.

Discussion: Harvest and post-harvest losses

Ask a participant to describe the harvest and post-harvest processes and write the keywords on the board. Analyze, step by step, where losses occur. Discuss together how losses can be reduced.

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Pearl millet grains are usually cooked and eaten. Their protein content is similar to sorghum, but the total protein yield per hectare is lower due to lower yields. The straw can be used as valuable livestock feed, fuel and building material.

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4.1.8 Economy and marketing

Nearly the entire millet crop is consumed within the countries of production, as millet is mainly used for subsistence. Millet tends to be consumed in poor rural conditions, whereas households with better incomes or in urban areas prefer rice or maize. Small amounts of millet grains are fed to animals, used to prepare alcoholic beverages or used as seed.

As with sorghum, only a small percentage of millet is traded nationally or internationally (usually with neighboring countries). There are few assured markets for this crop and supply chains for millet are usually poorly organized. There is, however, a growing demand for millet grains in processed food products.

In Africa, the area and yield of millet have remained constant in recent decades, while in India the cultivated area has declined steadily, although this has been compensated for by an increase in yields. In comparison to other cereals, millet consumption has declined. The production of millet for organic livestock feed markets in developed countries may be an interesting option, as they are prepared to pay a premium price for feed materials.

Discussion: Marketing of millet

What is the marketing of millet produced in the area? Would it make a difference to millet production if there was a developed export market for it? What potentials and limits do you see for future millet markets?

If appropriate and possible, invite a guest speaker to inform farmers about market potential, and the requirements for better marketing millet.

Recommended reading:

- *Sorghum and millet in human nutrition. FAO Food and Nutrition Series, No. 27). ISBN 92-5-103381-1*
- *Standards of the Codex Alimentarius for sorghum and pearl millet grains and flours. FAO/WHO Food Standards Programme.*
- *Norman M.J.T, Pearson C.J; and Searle. 1995. Ecology of Tropical Crops. Cambridge University Press. 430pp.*
- *Purseglove, J.W. 1988. Tropical Crops. Monocotyledons. Longman Group UK Ltd, Longman House, England. 607pp.*

Recommended websites:

- *Production, post-harvest handling, economies, nutritional aspects: www.fao.org*
- *Cultivars, improved varieties: www.icrisat.org*

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4.2 Sorghum

Introduction

Grain sorghum (*Sorghum bicolor*) is the fifth most important cereal crop grown in the world after wheat, rice, corn and barley (although it makes up less than 5 % of world cereal production). It is one of the main staple cereals in the hot, dry tropics. In many African countries the crop accounts for more than 50 % of cereal production, and comprises 20 % of that of Africa as a whole. The main producers of grain sorghum in the subtropics and tropics are (in Africa) Nigeria, Sudan, Burkina Faso, Ethiopia, Mali and Egypt, and (in Asia) India and Pakistan. In the last 50 years, worldwide cultivation has decreased due to changing eating habits in the cultivating countries, leading to the replacement of sorghum by cash crops such as wheat, rice, cotton or potato. While the cultivated surface has nearly halved in South Asia, it has increased in Africa (as has that of maize).

Sorghum is a vigorous perennial grass, but is mostly cultivated as an annual crop. It grows up to 4 meters high and shows considerable tolerance to difficult growing conditions. Sorghum has the ability to go dormant during drought, and then to reawaken after a period of rain. It also has an efficient root system, which makes it more drought resistant than most other cereal crops (the exception being millet). This is why it is most commonly grown in marginalized cereal production areas. The growing interest in sorghum in Africa is largely due to its drought tolerance. In humid areas the crop is of little importance.

In Africa and Asia sorghum is mostly grown for human consumption (mainly for subsistence). Outside the tropics the crop is grown in the hot and dry regions of China, North and South America and Australia (amongst others), where rainfall is not sufficient for corn. In these countries sorghum grains have become an important feedstock for livestock, pigs and poultry. Interest in sorghum for animal feed is also growing in many tropical countries, due to the increasing demand for meat and dairy products. Where more intensive production is possible, the cultivation of sorghum as a forage crop for cattle is an interesting option. Sorghum is also grown as a raw material for industrial processes such as syrup, sugar and fibers.

There are five basic varieties of sorghum (durra, kafir, guinea, bicolor, caudatum), with different appearances. The combination of these five basic varieties, gives ten groups of cultivars. As different types of sorghum are cultivated for specific uses, sorghum varieties are also distinguished as grain, fodder or forage types. Cultivars with large, juicy stems and a

Lessons to be learned:

- *Due to its drought tolerance sorghum is especially suited to hot and dry conditions and thus can contribute to sustainable agriculture in such climates.*
- *Where sorghum is grown with no inputs, considerable increases in yield are possible with improved management practices (e.g. timing of the crop, rotation, soil fertility management, cultivar selection, cropping system, etc.).*
- *Proper crop rotation is essential in order to prevent soil fertility decreasing and reduce problems with soil-borne pests and diseases (e.g. Striga).*
- *The demand for sorghum grain is expected to increase (in Africa mainly for human consumption, whereas in Asia and Latin America the demand will be largely for feed). To improve the market potential of sorghum and overcome various constraints, concerted action along the whole supply chain will be necessary.*

Motivation: Participants' knowledge and opinions

To introduce the participants to the organic cultivation of sorghum, you should first inquire about their knowledge and experiences of growing this crop.

Possible questions are: What comes to mind when thinking of sorghum? What are the good reasons for growing it? What constrains sorghum cultivation? Is more or less sorghum being grown in the region? Why? From an agronomic perspective, is there potential to improve the level and reliability of yields? What do consumers think about sorghum?

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high sucrose content are used for sugar and syrup extraction and for animal feed. Varieties with waxy endosperm are used to produce starch. One unwelcome sorghum species in agricultural land, is the Johnson Grass (*S. halepense*), a very competitive, noxious weed. (Cross-breeds of grain sorghum with wild species can also become weeds).

Sorghum has similar growth characteristics to maize (e.g. few tillers, prop roots, broad, waxy leaves) and also has a so-called C₄-photosynthesis-metabolism, which results in a high productivity in biomass or grain. Under favorable growing conditions, sorghum produces only half of the amount of edible energy per surface area as maize, but yields 2/3 as much protein, due to the higher protein content of the grains. Sorghum's protein content is similar to that of wheat, but its fat content is higher.

For human consumption, grains are roughly ground and made into bread-like preparations, or cooked like rice, or mixed with wheat flour for bread. Sorghum grains do not contain any gluten and are not suitable for making bread if used alone. The grains are also used to make native beers. If grains are to be fed to large livestock, they must first be ground. They can also be fed to pigs or poultry.

Crop residues of grain sorghum are also a valuable livestock feed. Forage types of sorghum are considered one of the best crops for silage because of their high yields and high sugar content as well as the juiciness of the stalks. In frost-free areas, sorghum will continue to tiller and will make new green leaves for grazing as long as there is some moisture in the soil. These green grain sorghum plants contain, to differing degrees between varieties, hydrocyanic acid and the alkaloid hordenine, which converts to prussic acid and is poisonous to livestock, with ruminants being the most susceptible. In India this intoxication is known as jowar poisoning. Danger of poisoning is greatest from young plants and suckers, especially when suffering from drought, and is slight when the grains are nearly mature. Grain and forage sorghums are thus not suitable for pasturage, but may be used to produce silage or hay, as this process destroys the poisonous substances.

In Africa and Asia, where sorghum has mainly been grown for subsistence, yields are generally low, ranging from 500 to 900 kg per hectare, which is far below the potential of the crop. The low yields are mainly due to inappropriate production practices, lack of inputs, damage by insects and diseases, the Striga parasitic weed and drought. In countries where sorghum is grown commercially for livestock feed, it is grown intensively using hybrid seed, fertilizers and improved water management technologies.

Write the answers on cards and stick them to the pin-board. Next, sort the cards on the board to get a better overview. Ask which aspects have not yet been identified and put a card with a question mark for each missing aspect. Are there any specific questions related to the organic cultivation of sorghum?

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Smallholders working in areas with limited moisture find sorghum an interesting grain crop. The crop is particularly well suited for subsistence or local market farming. There is hardly any international market for human consumption of sorghum. For most farmers, the possibilities for improvements through technological means are very limited. Nevertheless, knowledge of the factors limiting production of the crop and of methods in line with the principles of organic farming, is important for successful organic cultivation.

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4.2.1 Agro-ecological requirements

Sorghum is known to have a higher tolerance to drought, soil toxicities and temperature extremes than other cereals. It grows from 40 ° south to 45 ° north and from sea level to higher altitudes. Its capacity to adapt to such extremes, especially to drought, makes the crop particularly important in arid and semi-arid regions.

Rain/water

Sorghum has similar, or slightly lower, water needs than other grain crops, including corn. Water needs for the entire growing season amount to 450 to 650 mm. Variation in water needs result largely from the length of the growing period needed to attain maturity and the growing conditions (e.g. high temperature, winds).


Sorghum's reduced water requirement (compared to other crops) is due to several factors. Firstly, it can tolerate drought as a result of its deep and dense root system. Secondly, sorghum has effective mechanisms to control evapotranspiration, and thirdly, it becomes dormant under adverse conditions, and resumes growth even after relatively severe droughts. Sorghum plants build twice as many root tips as maize and get more than 50 % of their water from soil layers below 90 cm. This makes the crop less sensitive to moisture deficits in the soil than maize. Therefore sorghum is a popular alternative to maize where less than 500 mm of water is available during the growing season.

Low soil moisture levels are most critical in the stages of head flowering and grain filling. Severe and extended drought stress in these stages will result in reduced yield. Drought stress during grain filling may result in shriveled seeds. Moderate moisture stress is tolerated during early vegetative growth. If sorghum is grown for grazing, adequate soil moisture and temperature are necessary over the whole growing period.

The successful cultivation of sorghum in climates with a long dry period thus strongly depends on the amount of water stored in the soil, if the crop is not irrigated.

4.2. Sorghum 1

Agro-ecological requirements of sorghum



Water

- Similar requirements to other grain crops
- High drought tolerance
- 450-650 mm of water needed during the growing season
- Highest demand between heading and grain filling

Temperature

- Great heat tolerance
- Optimum growth between 25 and 30 °C
- No grain production below a mean temperature of 15 °C
- Not tolerant of frost

Soil

- Tolerant of acid, alkaline pH
- Moderately tolerant of saline soil conditions
- Good drainage necessary, but tolerance of temporary waterlogging
- Grows in soils with low fertility, but benefits from good soil fertility

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TRANSPARENCY 4.2 (1): AGRO-ECOLOGICAL REQUIREMENTS OF SORGHUM

Group work: Comparing sorghum with other grain crops

Together with the participants, select other grain crops (ideally ones that are grown in the area) that can be used as a comparison with sorghum.

Ask the participants to form groups and to characterize the requirements of these crops. Collect the results in plenary and discuss the potential and limitations of the crops.

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Temperature

Sorghum tolerates a wide range of temperatures. It is known to be particularly heat tolerant, but on the other hand can also grow under cooler conditions. The optimum growth temperature is between 25 and 30 °C. Seeds germinate best at temperatures of 20 to 30 °C. Temperatures below 15 °C during flowering and yield formation, and temperatures above 35 °C lead to poor seed set, problems with ripening and reduced yields. Temperatures below 10 °C cause yellow leaves and inadequate pollination. Frost kills the sorghum plants.

At a mean daily temperature of between 10 and 15 °C, sorghum can only be grown as a forage crop, as it does not set seed and grains do not mature. Elevated temperatures in early growth result in earlier flowering.

Soil

Sorghum is grown in a wide range of soils, from deep sands to heavy clays, and the crop is quite tolerant to alkalinity, acidity and aluminum toxicity in the soil. Sorghum also shows considerable tolerance to salinity (more so than maize). High salinity, however, can hinder the germination of the seeds and injure young plants. Sorghum grows in soils with a pH of between 4.5 and 8.5. In light soils sorghum may, however, be affected by nematodes (more so than millet). Cultivars adapted to different soil conditions should be selected.

Good drainage is considered necessary. Nevertheless, sorghum withstands temporary water logging better than maize and millet. The cultivation of appropriate varieties of sorghum in clay is thus possible, as they can withstand high humidity. Good soil water retention is essential in dry climates.

Although sorghum does grow in poor soils and can produce grain where other crops would fail, the crop does respond very well to good nutrient and water supply.

Light

Most of the African varieties of sorghum are short day photo periodicals and mature faster in short daylight periods. The crop needs full sunlight.

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4.2.2 Diversification strategies

Under arid conditions, sorghum tends to be intercropped, rather than grown in rotation, as a response to water shortage. Under higher rainfall conditions or irrigation, rotation with other crops is common. Simultaneous cultivation of different cultivars, even with different maturity periods, is widespread.

Rotation of sorghum with other non-host crops reduces the abundance of insect pests (especially those with a limited host range, few generations per year and low mobility), soil-borne diseases and weeds (e.g. Striga). A well planned rotation also enhances soil fertility. A combination of different crops and a diversity of varieties within one crop improves yield security in case of rain failure and increases returns from the land as a result of the different crops being complementary.

Crop rotation



The repeated cultivation of sorghum on the same field is not recommended as for most arable crops with a high nutrient demand. This also increases the risk of a build-up of pests and diseases. Rotation (e.g. with cotton and soybean) reduces the abundance of soil borne pests, such as wireworm and white grubs and some cutworms, as they all depend on a grass-type crop, have a long life cycle and are soil-bound due to their underground larval stage. Sorghum thrives when planted after a legume and in rotation with a broad-leaf or tap-rooted crop (e.g. cotton or soybean) that does not host the same pests or diseases. Other plants in the grass family should not be planted in the same rotation. If Sorghum is grown after a pulse crop a midge resistant variety must be used. Sorghum should only be grown every 2 to 3 years in the same place. It does not take so much water out of the soil as other crops (such as maize, sunflower or soybean), but exhausts nutrients and can hinder the growth of the following crop due to allelopathy (chemicals produced by plants that are secreted into the soil and inhibit germination and growth of other plants).

Crop rotation is of major relevance in Striga control. The spread of this parasitic weed is enhanced by consecutive cultivation of cereals and the abandonment of fallow which also results in a reduction of soil fertility. The Striga weed attacks maize, millet and rice, whereas cotton, soybean, pigeon pea, bambara bean and groundnut are trap crops (in decreasing order of efficiency) as are sunflowers, field peas, cowpeas, lucerne, sunnhemp, sesame, linseed and castor beans. The trap crops induce germination of Striga, but do not serve as hosts. As a result the weed dies and the seed bank is reduced. Thus rotating sorghum with

4.2. Sorghum 2

Diversification in sorghum cultivation

Rotation <ul style="list-style-type: none">▪ Avoid repeated cultivation of sorghum and other cereals▪ Best grown after a legume crop▪ Consider rotation (trap crops) for Striga prevention and control	Intercropping <ul style="list-style-type: none">▪ Reduces pest and weed pressure▪ Improves yield security and increases returns▪ Most advantageous when intercropped with a legume
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Sorghum intercropped with black gram

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TRANSPARENCY 4.2 (2): CROP ROTATION AND INTERCROPPING

Discussion: Diversification in sorghum

Discuss the necessity of diversity in sorghum based on experiences in the area. Are crops rotated? What experiments have been performed with rotation (and rotation of sorghum in particular)? What compelling and optional criteria should be taken into consideration when designing a rotation?

Together, formulate sorghum rotations that ideally fulfill the criteria for crop rotations listed in transparency 4.2.3a of the Basic Manual and the information provided in his section.

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Striga trap crops (ideally with legumes to improve soil fertility) is an important preventive, as well as curative, control measure against Striga.

Sorghum is generally rotated with cotton, groundnuts, sunflowers or sugarcane. In Brazil, sorghum is mainly cultivated in rotation with soybeans (soybeans in summer, sorghum in winter). In India, rotation with cotton is common. Recommended rotations may be: groundnut – sorghum – pigeon pea/cowpea; or finger millet – field bean and amaranth – castor – sorghum – chilies.

Intercropping

For commercial production sorghum is usually grown as a pure stand. Intercropping in rows is more common in village crop production.

In Africa, sorghum is generally produced as the main crop after flooding in association with Niebe (for which provides physical support) or with watermelon, both of which cover the soil well. Otherwise it is intercropped with maize, millet species, groundnut or cowpea. Intercropping with sweet potatoes or manioc is also practiced. In India, sorghum is generally intercropped with pigeon peas, cotton, soybeans, cowpeas, safflower or other legumes. In rain-fed conditions, sorghum is sometimes used for separating or fencing groundnuts or cotton plots.

Damage due to sorghum midge is reduced when sorghum is intercropped with leguminous crops. Intercropping of sorghum with trap crops of Striga can contribute to reducing the level of infestation (the higher the density of non-host plants the more effective the Striga control).

When intercropped with pigeon pea, both crops are planted at the beginning of the rainy season. Sorghum is harvested after 100 days, while pigeon pea is left to use the remaining soil moisture and nutrients until harvesting after 160 days.

If grown for forage, sorghum can be intercropped with legumes such as cowpea to improve the nutritional value.

Field visit: Experiences with intercropping

Visit a nearby farmer's field or a prepared demonstration plot to discuss the possibilities and limits of intercropping sorghum with other crops. Is sorghum intercropped? What are the advantages of intercropping? Study the root patterns of the different crops. (For further information see also chapter 4.2.2 of the Basic Manual). What combinations have proved to do well? What has not been tried out? Why? Discuss possible improvements in terms of diversification.

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Timing and establishment of the crop

The crop is mostly grown as a rain-fed crop and is sown after the beginning of the rains in spring or summer and grown into the dry season. In semi-arid areas in Africa, indigenous cropping systems, such as after-flood cropping and transplanting crops also exist. Both of these cropping systems follow the rainy season and tap into ground water resources in clayey soils that are flooded during the rainy season.

When grown under rain-fed conditions the soil-moisture should have penetrated to a depth of one meter at the time of planting to ensure a sufficient supply of water. Extreme heat during flowering should be avoided. Early and uniform sowing over large areas is an efficient measure to reduce the damage by sorghum midge and sorghum shoot fly. In practice, this is difficult to achieve, as under rain-fed conditions it is often difficult to sow the entire crop at the same time and a proportion of the crop is always sown later.

Early maturing sorghum types take about 100 to 120 days to mature, whereas longer maturing varieties may require up to 7 months.

Sorghum is usually grown from seed. However, the crop can also be grown in a nursery and transplanted into the field early in the dry season. This results in late flowering and strongly increases the risk of damage by sorghum midge. Seeds from unknown sources should be washed in water to separate them from Striga seeds (Striga seeds will float, whereas healthy sorghum seeds will lie on the bottom) thereby preventing infestation of Striga-free fields. The crop can also be grown from tillers split-off from established plants. The latter method is often used by farmers to fill gaps in a sown crop. Ratooning is not recommended for grain production, as it gives low yields.

Poor crop establishment, low seedling vigor and weed competition are major factors that reduce yields, apart from moisture stress, damage by pests and Striga. Ensuring uniform stands is thus essential. To ensure good stands and plants that are able to compete only cultivars or seeds with a good germination rate should be used. Coating the seeds with cow urine or with a watery solution of Neem can help reduce damage by seedling pests.

Many farmers sow sorghum into a basic seedbed. For good performance, however, the crop requires thorough seedbed preparation. A well-prepared seedbed speeds germination of the seeds and growth of the seedlings and thus contributes to a reduction of damage by seed-

Sharing experiences: Crop establishment

Is crop establishment considered to be a critical factor in sorghum cultivation in the area? If so, what makes the establishment of uniform stands difficult? What principles may be defined for seedbed preparation and sowing? Are different methods of soil preparation practiced?

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pests. Shallow incorporation of organic manure, compost or crop wastes during land preparation improves the growing conditions.

It is common to sow seeds in rows. The ideal sowing depth is 4 to 5 cm. If the seeds are broadcast, they should be harrowed into the soil. In soils with a high salt content the seeds may be drilled into shallow furrows at the same sowing depth, as this reduces the salt concentration around the seeds. If sown by hand, the small seeds may be mixed with some soil to ensure more even distribution.

Row and plant spacing depends on the desired use of the crop, expected rainfall and availability of irrigation. In dry climates and in subsistence farming, sorghum is sown in wide rows 75 to 100 cm apart, (similar to maize) at a rate of 3 to 9 kg per hectare. Under favorable water conditions (e.g. irrigation) row spacing of 45 to 60 cm and a space of between 12 and 20 cm between the plants is common. Denser stands result in greater leaf growth, lighter stems and better suppression of weeds. It also helps to reduce insect damage by reducing the insect density per plant or per unit area. However it does increase the risk of lodging and does not allow intercropping. Forage production requires a denser stand, demanding up to 12 kg of seed per hectare. Very dense broadcasting (at about 4 times the normal rate) and thinning out 3 to 5 weeks later is a measure that is recommended for reducing the seed bank of Striga in the soil, as this kills Striga plants that are attached to the roots and newly germinated Striga seeds.


Selection of cultivars

The selection of appropriate cultivars is essential. Ideally, selected cultivars are adapted to the local growing conditions, show tolerance or resistance to major insect pests and diseases, are resistant to lodging and may have open panicles, as this reduces vulnerability to pests. Over the centuries farmers have developed many cultivars of sorghum that are well adapted to specific local conditions: different soil types, climatic variations and water conditions. Unfortunately yields of these varieties have remained relatively low. By contrast many varieties bred for improved yields have shown greater susceptibility to weathering, head bugs, grain moulds (due to earlier maturity, often within the rainy season) and processing and food properties that do not satisfy consumer requirements.



Growing cultivars with good resistance to insect pests and diseases can be vital. Resistance can be based on panicle form, early and uniform maturity, and good adaptation to local growing conditions. Varieties also exist that are tolerant of and resistant to pests and

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Criteria for selecting sorghum cultivars



- Sorghum type corresponding to the intended use
- Good seed germination
- Rapid growth
- Good adaptation to the duration of the rainy season
- Resistance to the main local pests (e.g. striga, leaf diseases, mildew, greenbugs, sorghum midge, stem borers, panicle feeding bugs)
- Tolerance of drought and iron-deficiency (if appropriate)
- Early and uniform maturity
- High grain/fodder ratio
- Well-adapted to processing requirements and consumer preference
- Tan plant and grain colour (when marketed)



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TRANSPARENCY 4.2 (3): CRITERIA FOR CULTIVAR SELECTION

Discussion: Would you grow improved or hybrid varieties?
Ask the participants whether they have experience with growing improved or hybrid varieties. How do such varieties compare with local cultivars? Collect arguments for and against improved varieties and hybrids. In which cases can the use of hybrid seed be recommended? What traits are the most important for growing sorghum in the area? Have preferences changed over time?

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diseases such as Striga, mildew and other leaf diseases, sorghum midge, greenbug, stem borers and panicle feeding bugs. Cultivars with open panicles are generally less sensitive to attack by the larvae of pests that feed on the developing kernels and they are more tolerant to weathering than those with compact panicles. Transmission of viruses is best avoided by growing virus-resistant varieties. Awned cultivars are less prone to losses by grain eating birds.

The cultivars should have a maturity time that is adapted to the local climate and available soil moisture. Good tolerance to moisture stress is generally important in arid climates. Varieties that mature early and uniformly may escape infestation by some pests. Under irrigation, however, cultivars with longer maturity yield best. Iron-tolerant sorghum varieties should be used in areas where iron deficiency is a problem. In addition to physiological criteria, tan-colored plants and tan seed color are much preferred by consumers (as colored plants stain the grains). Varieties that give high quality flour are of special interest. Recent breeding programs have also focused on the improvement of grain quality.

Red and brown grains are preferred for animal feed and for brewing. In general the differences in the nutritional properties of different cultivars are less than the variability brought about by environmental factors. For grazing, forage or grass sorghums, such as Sudan grass, are best. There is a growing interest in sorghum varieties that give a good grain yield and also produce considerable amounts of leaves for animal feed. These are known as dual purpose varieties.

Hybrid varieties of sorghum are available (including hybrids between the different types of sorghum). Hybrids tend to be more sensitive to low soil pH and low availability of phosphorus and potassium, and do require improved agronomic practices. On irrigated land they are more productive than other seed. If hybrid seed is used in a certified organic farm, close attention must be paid in order to avoid the use of seed that has received chemical treatment.

Field visit: Trials

Field trials that compare different cultivars of sorghum under low input conditions may be very informative, and can be used to stimulate discussions on the relevance of cultivar selection for successful sorghum cultivation. What relevance does cultivar selection have compared to cultural practices?

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4.2.3 Soil protection and weed management

Soil protection measures and weed management vary according to whether the crop is grown during the rainy season or after a flood.

Soil protection

Wind and water, but also high temperatures and strong radiation, can erode soil or reduce its fertility (for further information see chapter 1). In rain-fed cropping systems the most effective techniques to protect soil from erosion are the following:

- Zai - Sowing sorghum into small holes dug in the ground and filled with compost retains run off water and avoids soil degradation.
- Compost - Regular application of compost contributes to the development of a good soil structure and thus to reduced water erosion.
- Soil cover - Intercropping sorghum with soil covering crops such as Niebe or watermelon protects the soil from radiation, high temperatures and erosion by wind and water.

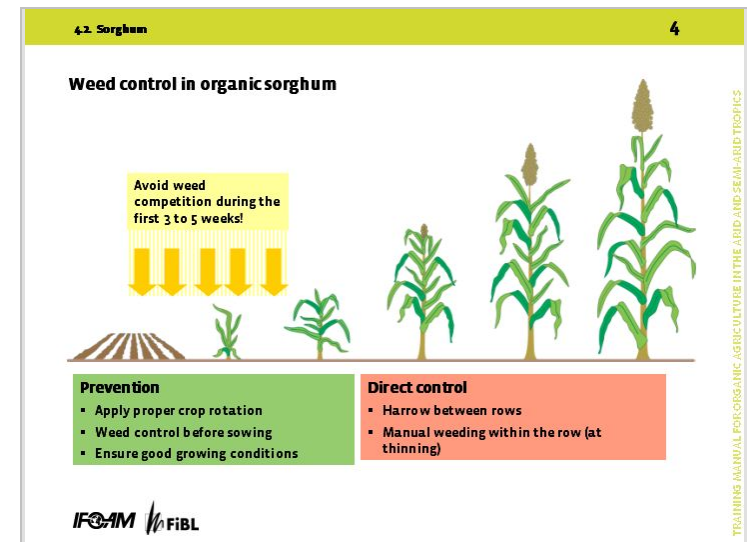
In after-flood conditions, there is little degradation of soil since inundations tend to generate slow expansion of waters, gradually depositing useful alluvium, which contributes to maintaining soil fertility.

Weed control

Sorghum plants have a slow early growth and thus demand special attention to avoid competition by weeds. Significant yield losses may occur if weeds are not controlled during the first four to five weeks after planting. Once the plants have built a dense canopy and have grown taller, weeds are efficiently controlled. The duration of the weed sensitive period depends in part on plant spacing.

Problems due to weed competition are strongly reduced by proper crop rotation (e.g. with densely growing legumes), through the effective control of weeds prior to planting and also by thorough seed-bed preparation (to ensure uniform stands).

Under rain-fed conditions weed control measures during the cropping season are more usually required on sandy to sandy/clayey soils, which are more vulnerable to infestation by graminaceous plants. Under after-flood cropping conditions, the proliferation of weeds is restricted as the weed seeds are stifled and rotted by flooding.



TRANSPARENCY 4.2 (4): ASPECTS TO CONSIDER IN WEED MANAGEMENT IN SORGHUM AND CONTROL MEASURES IN ORGANIC CULTIVATION

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Recommended procedures for weed control are similar to those for wheat (see chapter 4.3). In cases of low weed pressure, a single cultivation with the harrow after emergence of the crop may be enough. In case of higher weed pressure, up to three consecutive passages at two weekly intervals may be necessary. For pre-emergence control the use of tine weeder, as practiced in wheat cultivation, is also possible.

For inter-row weed control, animal or tractor-drawn harrows can be used. Within the rows themselves, manual weeding is necessary. Traditionally, manual weeding is combined with thinning. When using mechanical devices shallow cultivation is necessary to avoid damage to the surface roots of sorghum. Broadcast sorghum can only be mechanically weeded using a tine weeder.

Striga control

The parasitic weed *Striga hermonthica* can cause major damage to sorghum and can even make its cultivation impossible. The weed is dispersed by tiny seeds through wind, water, people, tools, animals, and by crop seeds. It is widespread in both Africa and India. The cultivation of host crops such as sorghum, maize, millet and rice (cereal crops) encourages the germination of *Striga* seeds, which grow towards the host plant and attach themselves to it using root level suckers, which draw nutrients, water and energy from the host crop. Infested hosts will become stunted and yellowish or wilted and will give poor yields. Crops grown in soil with poor fertility will suffer greater damage.


Eliminating this weed from a field takes years and demands considerable patience. Effort put into controlling *Striga* is worthwhile, as cereal crops will yield much better when the field is free of *Striga*. Control measures involve reducing the seed bank within the soil, minimizing seed dispersal and improving soil fertility.

Removal of *Striga* weeds before they produce seeds reduces re-infestation. This control measure will only have limited success as, by the time, the weed emerges, much damage has already been caused to the crop. It is also both time-consuming and labor-intensive. Therefore, any control strategy has to begin within the soil.

The most effective control measure is to rotate host and non-host crops (see section 2 in this chapter, on the role of trap crops). The repeated uprooting of *Striga* plants at the beginning

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Control of *Striga* parasitic weed



Striga weed attached to maize roots

- Apply different methods and practice them for several years.
- Rotate host and non-host crops. Do not grow cereal crops for more than one consecutive year.
- Improve soil fertility. Apply manures to the crop. Grow (leguminous) green manure crops.
- Sow the host crop early, if possible.
- Uproot *Striga* at the beginning of flowering.
- Remove uprooted *Striga* from the field and bury or burn them.
- Grow cover crops to increase competition.
- Prevent infestation of new fields by washing the seed and avoiding dispersal from one field to the other during harvest.
- Grow *Desmodium* (Silverleaf and Greenleaf), a nitrogen fixing fodder plant, as a ground cover between the sorghum rows. Its nitrogen fixation and the chemicals produced by the roots suppress the weed.

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TRANSPARENCY 4.2 (5): HOW TO CONTROL STRIGA IN INFESTED FIELDS

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of flowering reduces the dispersal of seeds. Improving the soil fertility with green manures and animal manure, as well as the cultivation of leguminous grain crops increases resistance of the crop to *Striga* and suppresses the weed. Control is most effective if practiced on a larger scale, for example in the whole village community.

Additionally, growing the ground cover *Desmodium* (Silverleaf and Greenleaf), a nitrogen fixing fodder plant, between the sorghum rows reduces *Striga* weed. The nitrogen fixed by *Desmodium* and the chemicals produced by the roots suppress the weed.

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4.2.4 Supplying nutrients and organic fertilization

Many farmers in the tropics grow sorghum without any fertilizer. Sorghum can produce a crop under low nutrient conditions. It is, for example, much more tolerant to low soil phosphorus levels than wheat or barley. Yields will, of course, be poor under such low input conditions especially if grown in low fertility soils. Nevertheless, cultivation on certain soils can result in some nutrient deficiencies, or conversely an oversupply of some nutrients.

Like other cereal crops, sorghum responds well to an adequate nutrient supply, especially of nitrogen. Nitrogen deficiency in the early stages results in a reduced yield, while a deficiency in later stages results in a low protein level in the grains. However, an excessive nitrogen supply makes the sorghum plants particularly succulent and attractive to insect pests. It also extends the time to maturity and thus increases the period in which the crop is vulnerable to pests and diseases. On fertile soils, after a leguminous crop, or after flood cropping (due to considerable amounts of nutrients supplied by alluvium brought about by flooding), additional fertilization may not be necessary (although still recommended, if possible). A leguminous pre-crop will supply more nitrogen to the sorghum crop than a long fallow and thus will result in higher sorghum yields.

As sorghum is grown in a wide range of soils, deficiencies or oversupply of nutrients can occur and with a knowledge of the soil these can be predicted. In acid soils toxicities of aluminum, iron and manganese, and deficiencies of phosphorus, calcium, magnesium, molybdenum, and zinc are possible. In alkaline soils deficiencies of iron, zinc, and manganese are common.

Regular incorporation of crop residues, collected animal manure and compost contributes considerably to a better nutrient supply for sorghum. Compost in particular will improve soil fertility in the long term and help ensure a balanced nutrient supply to the crop.

To achieve good yields under rain-fed and after-flood cropping conditions, it is estimated that sorghum requires about 35 kg/ha of N and 20 kg/ha of P₂O₅. The use of mineral nitrogen fertilizers is not permitted in certified organic production, and the application of phosphorus and potassium fertilizers is only allowed on the basis of soil analysis or deficiency symptoms. For better efficiency fertilizers should be spread close to the plants (e.g. along the rows or even into each planting hole).

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Nutrient supply

- Grows under low nutrient conditions.
- Responds well to improved nutrient supply.
- Yield is increased, if grown in rotation with leguminous (green manure) crops or intercropped with legumes due to better nitrogen supply.
- If fertilizers are used, they should be placed close to the plants.
- Deficiencies or oversupply of micronutrients are possible, depending on the soils.
- Growing a leguminous inter or cover crop helps to avoid poor yield in the crop that follows.

More attention to improved soil fertility will give higher yields!

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TRANSPARENCY 4.2 (6): NUTRITION OF SORGHUM

Discussion: Nutrient supply to sorghum

Inquire about the general problems and challenges related to crop nutrition in the area and nutrient supply to sorghum in particular. Questions you may ask include: Do crops grow well? Do some crops grow better than others? Are the soils considered fertile? Are there any obvious nutritional problems (symptoms)? What are the symptoms? Are any fertilizers used? How are they valued? For information on soils and soil fertility see the chapters 3.1 and 3.2 of the Basic Manual.

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Inoculation with *Azospirillum brasilense* can contribute to better nitrogen take-up even in combination with the application of farmyard manure. In Africa seeds are sometimes coated with cow urine, providing them with a direct supply of nutrients.

Rather than seeking to improve the soil through using inputs, crop nutrition may be more effectively improved by implementing good production practices that build up soil fertility through crop rotation with leguminous crops or green manures, soil protection measures, irrigation, etc.

You may also find it helpful to inquire about the participants' concept of plant nutrition. Possible questions are: Where do nutrients come from? What nutrient sources do you know of on the farm? How are nutrients made available to the plants? For further information on plant nutrition see chapter 4.1 of the Basic Manual.

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4.2.5 Pest and disease management

Cultivated sorghum is prone to attack from a wide range of pests and diseases. Some can cause considerable losses (also during storage). In the traditional farming context of the tropics direct control measures are rarely undertaken, as the crop is largely cultivated under low input conditions. Improved cultural practices (incorporation of infested residues after harvest), the use of tolerant or resistant cultivars and natural inputs can, however, reduce losses considerably. Organic farming always advocates preventive methods of crop protection. Curative or direct methods are recommended only as a last resort when preventive methods have proved ineffective.

Pests pose the major problem for sorghum cultivation in the arid and semi-arid areas. Nevertheless, diseases can also become a problem, especially if the rains continue through the period of grain maturity. Sorghum can act as a host for many fungi, bacteria, viruses and nematodes. Some diseases are very common. These include grain moulds and anthracnose on grains, foliar diseases such as anthracnose, leaf blight, leaf spot and tar spot, downy mildew and rusts. Other, less common, diseases include honeydew disease or ergot, as well as root and stalk rots.

Covered smut (*Sporisorium sorghi*): Sorghum can only be infested by covered smut when the seeds are infested by airborne spores at harvest. Infection of new plants occurs in the soil before the seedlings emerge (with the ideal conditions being soil temperatures of below 25°C and medium dry soil). Diseased plants show individual grains that are replaced by whitish to grey or brown smut sori. Heavily contaminated seed may turn greyish-black, especially in white-seeded sorghums. The fungus rarely survives in the soil between cropping seasons. Covered smut has almost been eliminated where hybrid seeds are used, as they are usually chemically treated. The disease can still be serious where no seed treatment is used. Infested seeds can be treated with hot water with great success. The susceptibility of sorghum cultivars to covered smut varies.

Downy mildew (*Peronosclerospora sorghi*): Sorghum downy mildew is an important disease of sorghum (and maize) in the tropics and subtropics, particularly in Africa, the Americas and India. The disease affects the plant at nearly all stages, resulting in vivid green and white stripes on the leaves and heads that are partially or completely sterile. The major sources for infection are spores that survive in the soil and airborne spores coming from infected plants. High plant density and rainfall after planting encourages development of the disease. The disease is not transmitted by seeds, provided that they are properly dried and stored. There

4.2. Sorghum		7
Major diseases of sorghum and their controls		
Diseases	Preventive control measures	Direct control measures
Covered smut (<i>Sporisorium sorghi</i>)	<ul style="list-style-type: none"> Use of tolerant/resistant cultivars 	<ul style="list-style-type: none"> Hot water treatment of seeds
Downy mildew (<i>Peronosclerospora sorghi</i>)	<ul style="list-style-type: none"> Dry seeds properly Deep plowing of infested residues Only grow sorghum (at most) every third year in the same field 	
Ergot (<i>Claviceps africana</i>)	<ul style="list-style-type: none"> Crop rotation Early sowing Removal of infested panicles Deep plowing of infested residues 	
Rough leaf spot (<i>Ascochyta sorghi</i>)	<ul style="list-style-type: none"> Crop rotation Use of resistant cultivars 	

TRANSPARENCY 4.2 (7): CONTROL OF MAJOR DISEASES IN SORGHUM

Sharing experiences: Pests and diseases in sorghum cultivation

If the participants have experience with growing sorghum, ask them whether pests or diseases can be a problem with this crop. Can they distinguish between serious and not-so-serious pests and diseases (i.e. those that lead to considerable losses and others that are of minor relevance)? Collect information on the main pests and diseases. Do they only attack sorghum, or other crops too? What are the symptoms? What is known about their biology? What is done to prevent problems from them, and how are cases of infestation dealt with?

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are some resistant cultivars. Effective control is also possible through deep ploughing of infested plant residues. Proper crop rotation is more effective. A break of at least 3 years between cultivating two sorghum or maize crops prevents new spores being added to the soil. Natural fungicide applied as seed treatment or foliar spray provides further effective control.

Ergot (*Claviceps africana*): This fungal disease of common sorghum occurs wherever sorghum is grown. It attacks the unfertilized ovaries and reduces them to a white fungal mass, which is visible between the glumes. Infected flowers exude a sweet, sticky honeydew that will drip onto the leaves and soil and under moist conditions will produce a white, powdery mass, on which secondary wind-borne spores develop. The fungus produces alkaloids that may have negative impacts on animals if fed to them. Cold nights 2-3 weeks before flowering and cool and wet weather during and in the days after flowering promote the disease. Ergot disease is mainly a problem that occurs when cultivating hybrid seeds. Cultural measures such as early sowing, removal of infected panicles at harvest, a 3-year crop rotation and deep ploughing of field residues will reduce the severity of infection, but these measures will have little impact if applied individually. The resistance of some cultivars is due largely to rapid pollination and fertilization. Chemical seed treatment with fungicides is effective, but is not allowed in organic farming.

Rough leaf spot (*Ascochyta sorghi*): A widespread fungal disease of sorghum species which generally leads to only minor crop losses and little economic damage. The disease is often more severe in fields where sorghum or Sudan grass are grown in succession. Infection most probably spreads by spores in wet weather or when there is a heavy dew. The fungus first makes small, reddish, discolored spots on the leaves, which become larger and in which yellow-brown centers emerge. In the later stages of development, the affected areas feel rough when rubbed between the fingertips. Entire leaves may turn brown and die. One control measure is to avoid repeated cropping of sorghum or Sudan grass in the same field. Some cultivars are highly resistant to rough leaf spot. Spraying of Bordeaux mixture (copper) reduces disease intensity, but can also lead to a toxic reaction of the plants.


Most insect species that infest sorghum occur widely and attack not only sorghum, but a range of other natural, and cultivated, plants. Most insects appear at a specific stage of the crop's development: many insect species feed on the leaves of seedlings; some bore into the stem giving a dead heart; many feed on the foliage during the vegetative stage; some suck

Compare the results of the discussion with information that is available to you, and clarify where necessary. Inform farmers about the possibilities of controlling pests and diseases through the use of cultural practices and selecting resistant varieties.

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the sap from leaves; some species damage the panicle at flowering; some feed on the grain developing within the glumes. In India, nearly 30 % of sorghum crops are lost to insect attack, but losses can reach up to 80 %. In general, one or two insect pests predominate in any given region. The most common insect pests of sorghum are shoot fly, stem borers, sorghum midge and head bugs. Cultural measures, such as the use of appropriate cultivars, seedbed preparation, and seed treatment are generally sufficient for managing these pests. The direct control of insect pests is rarely practiced. Application of non-specific insecticides has also been shown to kill natural enemies and to result in resurgence of the target or other pests. Sorghum is also susceptible to storage pests such as rice weevil (*Sitophilus oryzae*), flour beetle (*Tribolium castaneum*) and the grain moth (*Sitotroga cerealella*).

Shoot fly (*Atherigona soccata*): This insect is a significant pest of sorghum in the Middle East, South-East Asia, Africa and the Mediterranean, but does not occur in the Americas. The larvae destroy the growing points and stems of young sorghum plants, resulting in dead hearts. Shoot fly populations increase progressively during the rainy season under moderate temperatures and high humidity. Between seasons, the flies hide on the tillers of ratooned sorghum and alternative grass hosts. Infestations are normally high in post-rainy season crops of sorghum (with the exception of crops sown in India in late September), and especially when planting has been staggered. Simultaneous sowing at the onset of monsoon rains over large areas has proved very efficient against the pest (and against midge and head bugs). Ploughing after harvest and shortly before sowing, fallow periods and proper crop rotation reduce the carry-over from one season to the next. Crop residues should be collected and destroyed before the beginning of monsoon rains. The use of tolerant or resistant cultivars is recommended in areas that are regularly damaged by the shoot fly and in cases where planting has been delayed. Inoculating seeds with the bacteria *Azospirillum* and *Pseudomonas* considerably reduces shoot fly damage. High plant density, intercropping (with legumes or especially garlic), ensuring the availability of sufficient moisture and nutrients in the soil, delayed thinning and careful weeding all reduce the damage by shoot fly. Wild grass species can serve as trap crops. Fertilization with cattle manure may result in greater damage by shoot fly (and stem borer). Plants with shoot fly damage should be removed during thinning, and destroyed. In cases where plants are at risk of damage, it is possible to spray with *Bacillus thuringiensis* or Neem.

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Control of some major pests of sorghum		
Pests	Preventive control measures	Direct control measures
Shoot fly (<i>Atherigona soccata</i>)	<ul style="list-style-type: none"> Use of tolerant/resistant cultivars (for late planting mainly) Proper crop rotation with non-host plants (legumes) Plowing after harvest and before sowing Early and uniform sowing, high seeding rates Treat seeds with bacteria 	<ul style="list-style-type: none"> Spray <i>Bacillus thuringiensis</i> against larvae Spray Neem solution against larvae
Stem borer (<i>Busseola fusca</i> , <i>Chilo partellus</i> , etc.)	<ul style="list-style-type: none"> Early sowing Intercropping Promote natural enemies (e.g. the wasp <i>Cotesia flaviceps</i> Cameron) Simultaneous growing trap crops around the field and repelling plants within the sorghum crop Destroy stubbles after harvest 	<ul style="list-style-type: none"> Application of a Neem-sawdust/clay mixture into the funnel of young plants Spray Fish bean plant extract
Sorghum midge (<i>Stenodiplosis sorghicola</i>)	<ul style="list-style-type: none"> Early and uniform sowing Use resistant cultivars Crop rotation with non-host crops Intercropping Remove host weed species Destroy stubbles after harvest and plow before sowing 	<ul style="list-style-type: none"> Spray pyrethrum
		

TRANSPARENCY 4.2 (8): CONTROL OF MAJOR PESTS IN SORGHUM

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Stem borers (*Busceola fusca*, *Eldan saccharina*, *Sesamia sp*, *Acigona ignefusalis*, *Chilo partellus*): These insects prefer sorghum, but also attack other cereals and grasses such as sugarcane and maize. They can lead to major losses. The larvae feed on the growing points, leaves and stems of the plants at different growth stages. The symptoms are similar to those due to shoot fly, but occur later in crop development. Other symptoms are scarification of leaves in the vegetative stage (feeding in rolled leaves) and tunneled stems in later stages of crop growth. Late attack in the generative phase may result in chaffy heads and, in severe cases, the peduncles may snap. Stem borers pupate in the stems or between the stem and the leaf sheath. Depending on temperature, two or more generations develop per year. The insects survive from one season to the next as fully grown larvae in stems. Cultural practices to control stem borer populations include early sowing of sorghum, promotion of natural enemies, intercropping with millet (as adults do not lay eggs on millet stems) and destroying the residues after harvest to kill the caterpillars. Light-trapping of the adults, which are active at night may give early warning of a possible infestation. Spraying pesticides for stem borer control is usually ineffective, as these products do not reach the larval stages that live inside the stem. Repeated application of Neem kernel powder mixed with sawdust or clay and placed into the funnel of young plants can, however, be used to control stem borers where major damage is expected. In some areas, extracts of the leguminous Fish bean plant (*Tephrosia* spp.), a widely used fallow, green manure or cover crop, is used as a general insecticide.

Biological control of stem borers is possible with the wasp *Cotesia flaviceps* Cameron. This natural enemy of stem borers in India was successfully introduced to some African countries. A very promising method of controlling stem borers in sorghum is the 'push-pull' strategy that was originally developed for maize-based farming systems in Eastern and Southern Africa. The method is based on an age-old African practice of mixed cropping and consists of planting a carefully selected combination of companion crops around and within the crop. Some rows of Napier grass or Sudan grass are planted around the sorghum field. They act as trap crops, attracting and killing the stem borers. Additionally, repelling crops such as *Desmodium* spp. and *Melinis minutiflora* can be sown between the rows of sorghum. These companion crops all have the added advantage of being useful fodder plants and *Desmodium* also supplies nitrogen to the soil and suppresses the parasitic Striga weed.

Sorghum midge (*Contarinia sorghicola*): Potentially the most destructive pest of grain sorghum, this pest occurs wherever the crop is grown (with the possible exception of Southeast Asia). The adult is a tiny orange fly, which deposits small yellowish-white eggs in the spikelets of flowering heads a few hours after hatching from nearby spikelets in the

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Control of cereal stem borers with the "push-pull" method

Desmodium legume sown between the rows of sorghum (**push factor**): repels stem borer moths

2-3 rows of Napier grass (**pull factor**) around the sorghum field: attracts stem borer moths and kills their larvae

1 metre path row

Sorghum plot

- Plots should be at least 10 x 10m (50 x 50m maximum).
- Prepare soil to fine till to ensure good emergence of the small *Desmodium* seeds.
- Plant healthy Napier before the rain season at 75 cm between rows and 50 cm within a row.
- Sow *Desmodium* with the rains in rows between the rows of the cereal crop.
- After some weeks hand-weed the *Desmodium* to avoid competition.

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TRANSPARENCY 4.2 (9): THE PUSH-PULL METHOD TO CONTROL STEM BORERS.

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morning. The larvae feed on the developing seeds. Infested grains do not develop, and panicles appear blasted. Several generations can occur in one year. The midges are abundant during the rainy season when the crop flowers. High or very low temperatures and very dry conditions or high rainfall during flowering hinder the development of the insect. High infestations of sorghum midge occur among low density plant populations, or when there is a prolonged flowering period, due to staggered sowings and/or cultivation of cultivars with different maturities, and the presence of alternative (weed) hosts. Late-flowering crops are particularly susceptible to heavy losses, as the midge population builds up throughout the season. Natural enemies (parasitoids) do exist, but their populations only develop to significant numbers after the damage has been done.

If sorghum is sown early in the growing season, it usually escapes infestation. The use of (hybrid) resistant cultivars considerably reduces damage. Cultural practices such as appropriate rotation with non-host crops, and the intercropping of sorghum, help to reduce pest damage and to conserve natural enemies and environmental quality. To reduce the carryover of diapausing larvae (in suspended development) from one season to the next, crop residues should be destroyed (e.g. fed to cattle, incorporated into the soil or burnt) before the onset of monsoon rains. Ideally, fields should be ploughed after harvest and shortly before sowing. The timely removal of wild weed species of sorghum, which act as alternative hosts, in proximity to the crop, can help to reduce the size of the midge population. However, wild hosts also sustain natural enemies.

Spraying of insecticides is practiced in some countries, but it is costly, difficult to apply, must be well timed to coincide with the flight of the adults and is less effective than other measures. Insecticide applications are used in some areas, primarily to reduce losses in late plantings. The benefits of insecticide application are greater on midge-resistant cultivars than on susceptible cultivars. When farming organically, natural pyrethrum may be used.

Head bugs (*Calocoris angustatus* and other): Panicle-feeding bugs have become a major pest of sorghum. The head bugs feed on maturing grains, resulting in severe reductions of yield and quality. Improved varieties with compact panicles have been shown to be more susceptible to head bugs. When damaged by head bugs, the grains of early maturing cultivars are more likely to develop moulds, particularly those that mature under conditions of high humidity during the rainy season.

Birds: Losses due to bird attack during grain-filling are widespread. The cultivation of varieties with grains that have a purple seed undercoat containing tannin is an efficient control measure, as the birds ignore the bitter tasting seeds.

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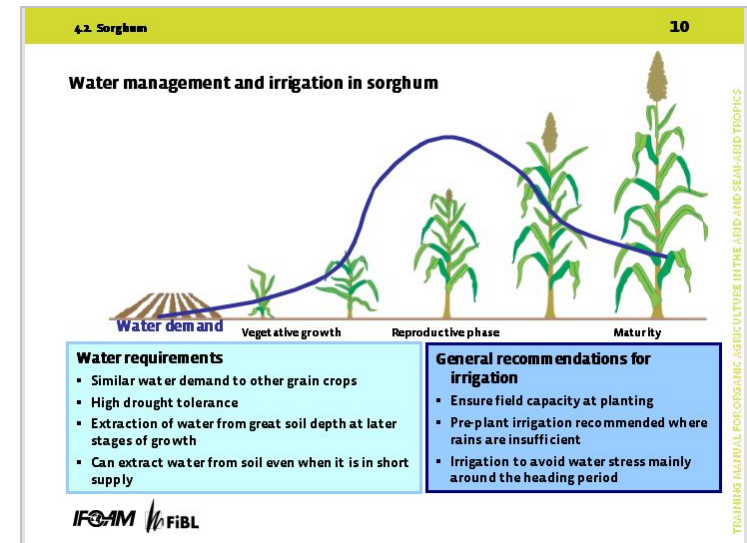
4.2.6 Water management and irrigation

Due to its drought tolerance, sorghum does not strictly depend on irrigation during the growing period. Irrigation does, however, increase the yield potential of the crop, as sorghum has similar water use rates to those of other cereal crops. Sorghum's ability to extract water from great depth and/or when it is in scarce supply make it better suited than most other cereal crops to growing in conditions where the water supply (ground water, or wells) is limited. Although sorghum tolerates drought stress, this does weaken the plants (as does over-irrigation) and increases the chances of attacks by bugs and mites. It also delays plant maturation.

The use of irrigation systems for sorghum cultivation is not uncommon in the tropics, but is practiced on a smaller scale, in areas under intensive management. After-flood cultivation is widespread in some areas, with flood waters acting as an alternative to irrigation. Need for irrigation water should take into account the depth of the moisture level in the soil at the time of planting, or water-holding capacity of the soil and the timing of the rains vis-à-vis the crop's development. For rain-fed cultivation of sorghum, sufficient moisture in the soil at planting and the water-holding capacity of the soil are the factors that influence water supply.

The water needs of sorghum are low during the early growth stages, thus irrigation prior to planting is generally not useful, especially if there has been sufficient rainfall during that time and irrigation is planned during the later stages of the crop's growth. Water supply should be increased in line with the development of the crop and reach a peak during the change from the vegetative to the reproductive phase. Adequate soil moisture during the peak period has the most positive effect on yields. For pre-plant irrigation, repeated flooding every alternate day for fifteen days before sowing has proven to be effective.

Irrigation during the growing period should aim at reducing water deficits to a minimum during the periods of crop establishment, flowering, and early yield formation. In cases where water supply is limited, irrigation should focus on avoiding water deficits between flowering through to early grain formation. Water is most efficiently used when applied in small doses over a long period of time. After pre-plant irrigation, in-crop irrigation may only need to be done once or twice, and may even be unnecessary in soils with good water-holding capacity.



TRANSPARENCY 4.2 (10): WATER NEEDS AND IRRIGATION IN SORGHUM

Discussion: Water issues

Clarify challenges in water management in the region together with the participants. Is water management an issue in irrigated systems only? Are there other cultural practices that reduce water losses, and improve the water-holding capacity of the soil and water supply of the crops? Are any crops in the region irrigated? What experiments with irrigation have been carried out? Where participants have experience with sorghum cultivation: How is sufficient water supply of sorghum ensured?

For further information see also chapter 3.5 of the Basic Manual.

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4.2.7 Other maintenance methods

The thinning out of crops, although traditionally seldom practiced, may be recommended in areas where there is a high risk of loss by seedling pests such as shoot fly, *Striga* infestation or by difficult growing conditions. If the intention is to thin out the crop, a high seeding rate must be used (e.g. sowing two seeds per planting hole). In the case of early thinning out (10 or 15 days after sowing), removed plants may be used to fill in gaps. Late thinning-out is practiced to reduce the seed bank of *Striga* where the weed is a problem (by "harvesting" early infested surplus sorghum plants).

4.2.8 Harvest and post-harvest handling

Harvest

Sorghum is harvested at the end of the rainy season (for rain-fed crops) or when the grains are colored and, begin to harden. Prompt harvest is important to avoid major losses by birds. For manual harvest the grains should have less than 20 % moisture. For combine harvesting, however, 13 % moisture is considered best (otherwise the grain needs to be dried).

The yield potential of sorghum under favorable conditions is about 7 tons per hectare. However, the average yield of grain sorghum under rain-fed conditions in the tropics is below 1 ton per hectare. Yields can range from between 2000 kg to as little as 200 kg per hectare. Irrigated sorghum may yield double or more.

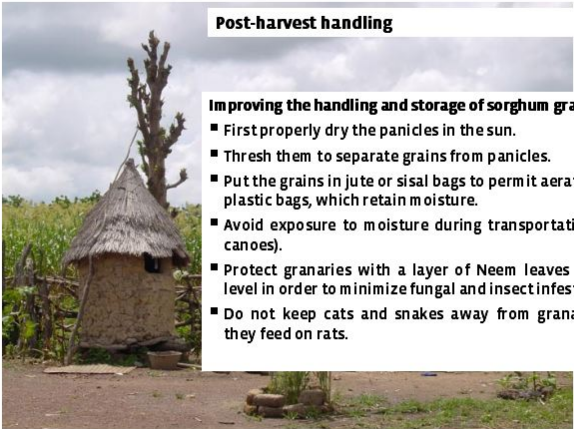
Most farmers in the tropics harvest sorghum by hand. The heads are either cut off, or the whole plant is removed and the head is cut off later on. Where short cultivars are grown, the plants are harvested with a combine.

Post-harvest

Sorghum grains are more difficult to store than other grains. Proper handling after harvest is of major importance, in order to avoid significant losses. Sorghum grains are very susceptible to storage pests and moist grains encourage the development of moulds. Unfortunately, many farmers negate the tremendous efforts they have made in producing the cereals by not complying with the basic rules of appropriate conditioning and storage.

Panicles must be dried properly, threshed to separate the grains from the panicles and placed in well-aerated bags for storage. The panicles are dried in the sun. Small amounts of sorghum grains are separated from panicles through pounding with a pestle after drying. As with wheat, the seeds separate easily from the floral brackets when threshed. After threshing, grains are generally winnowed.


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Post-harvest handling

Improving the handling and storage of sorghum grain

- First properly dry the panicles in the sun.
- Thresh them to separate grains from panicles.
- Put the grains in jute or sisal bags to permit aeration. Avoid plastic bags, which retain moisture.
- Avoid exposure to moisture during transportation (e.g. in canoes).
- Protect granaries with a layer of Neem leaves at ground level in order to minimize fungal and insect infestations.
- Do not keep cats and snakes away from granaries since they feed on rats.

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TRANSPARENCY 4.2 (11): POST-HARVEST HANDLING OF SORGHUM

Visit: Local storage facilities

Visit local storage facilities and discuss the difficulties with, and potential improvements in, post-harvest handling. Are the losses that occur during storage important? Why do they occur? How can they be avoided?

4 Management Guide for Crops

Panicles are usually stored in granaries. Plastic bags should not be used as they retain moisture and will promote the development of moulds. To reduce infestation by fungi and insects, a layer of Neem leaves can be laid out on the bottom of the granary. Cats and snakes can play a useful role in helping to control rats.

As a general rule, sorghum stalks and re-growth from the stubble should be worked into the soil carefully, or be grazed or destroyed soon after harvest to prevent further development of insect pests. Burning of the stubble is not recommended in organic farming, as valuable organic matter in the topsoil is destroyed and soil organisms are killed. Burning also causes soil erosion. Sorghum forage is often dried and stacked. It can also be made into silage. The drying and ensilage of sorghum forage is an effective way of avoiding poisoning from prussic acid. If the intention is to use the fied for grazing (pasture) after the harvest the sorghum will grow back better if 10 to 15 cm stubble is left. Forage sorghum is usually only cut once after flowering under rain-fed conditions. Where water and nutrients are adequate, forage sorghums can be harvested several times.


4.2.9 Economic and marketing aspects

Economic aspects

In many countries of the semi-arid and arid tropics sorghum is a traditional staple crop. It is mostly grown with none to little inputs, and use of improved varieties is very limited. Where farmers have adopted improved cultural practices, preference has been given to other grain crops such as wheat, maize or rice. The latter crops promise a better income, as they attract higher prices on the market. As a result, the cultivation of sorghum is increasingly being pushed into more marginal areas, due in part to its ability to grow under difficult agro-climatic conditions.

This explains how the increase of sorghum production in Africa in recent decades has been largely due to an increase in production area and not - or only partially - to increasing yields. In many cases a shortened fallow period has resulted in a decline of soil fertility, and thus productivity. In Asia however, where improved cultural practices have been more rapidly adopted (encouraged by higher population density and well-developed market infrastructure), sorghum yields have increased while the total area under cultivation has greatly declined due to substitution by cereal and other cash crops.

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The economics and marketing of sorghum

Economics

- Low productivity when grown on marginal lands
- Greatly increased productivity with improved cultural practices
- Under low input and dry conditions it provides higher and more stable yields than other cereal crops
- Lower yields than other cereal crops on fertile land

Marketing

- Low marketing potential where yields and yield stability are low and market infrastructure is lacking
- Consumption of sorghum is expected to grow
- Considerable potential for processing to high quality cereal food
- Marketing potential for certified organic sorghum will greatly depend on an integrated supply chain

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TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.2 (12): ECONOMIC AND MARKETING ASPECTS OF SORGHUM

Discussion: Is sorghum economically competitive?

After having given the participants some information on the economic aspects of sorghum cultivation, it may be interesting to discuss the competitiveness of sorghum compared to other cereals, and the role of the crop in the lives of farmer families. Some questions that you might ask: Have there been any noticeable changes in sorghum cultivation in the area in the last ten or twenty years? If yields have declined, what have been the reasons for this? Were they political, cultural, economic or agricultural? What constrains the adoption of improved cultural practices? Do you see any potential for changes? Discuss the possibilities for improving yield levels and reliability. What improvements are cost or labor intensive? What improvements imply only minor financial outlay or human effort?

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Thus for many farmers, sorghum has maintained its role as a low-input crop for marginal lands and subsistence. Financial and labor investments required for improved cultivation are usually considered not to be worthwhile.

Nevertheless, improved cultural practices (as recommended for organic farming) can play a major role in improving the productivity and yield stability of sorghum and the nutrition of farming families and rural communities.

Under favorable growing conditions, the yields of sorghum are generally much lower than those of other cereal crops. Under low input and dry conditions, however, sorghum has been proved to give better and more reliable yields. Yet, due to lower demand and government market policies, prices for sorghum are lower than prices for other cereals. In countries where yields are not consistent and adequate storage infrastructure is lacking prices for sorghum vary greatly between good and bad years, and over time.

Marketing potential

As yet, there is only very limited marketing of sorghum grains for human consumption at national or international levels. In most arid tropical countries, where sorghum is grown, grains are marketed at a local or regional level. In Africa low and unreliable yields that fall well below the crop's potential, mean that the crop is only widely marketed in years when there is a good surplus. The lack of marketing structures and long distances to markets are further contributory factors. By contrast, in India farmers have easier access to markets, but the demand is low.

Increasing urban demand for bread products in the arid tropics has resulted in significant imports of wheat into many countries. To improve the marketing potential of sorghum, efforts have begun to partially substitute wheat flour by sorghum flour in the production of breads and biscuits, and to completely replace maize with sorghum in traditional recipes. Sorghum improves the nutritional value of products (see information in the introduction) and makes the production of bakery goods and local recipes cheaper due to its lower price.

Based on the market trends of the last decades, global per capita sorghum consumption is expected to decline. However in Africa the demand is expected to grow, as a result of population growth. The possibility of making high quality cereal foods from sorghum has

Visit: Bakery products and traditional and new foods containing sorghum

If possible, visit an innovative processor with experience in mixing sorghum flour with other flours. Taste such products and share impressions. Discuss what could be done to further promote the processing of sorghum.

Group work: Sorghum marketing initiatives

Divide the participants into groups and ask them to analyze the possibilities of a local (organic) sorghum initiative. For the exercise, orient yourself with the following (for further information see the chapters on successful organic marketing initiatives):

- *Short description of the present circumstances*
- *Vision of the initiative*
- *Description of the planned initiative (project name, place, main idea, activity field, organization form, etc.)*
- *What is specific about the initiative?*
- *Milestones*
- *Potentials and risks, challenges and constraints*

Ask the groups to present their initiatives and discuss the lessons learned in plenary.

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been identified, and this may open new markets for sorghum grains on different economic levels, thereby increasing prices. This however, depends on whether policies seek to promote trade, and the processing of sorghum (in contrary to the strategies of some governments, that promote the cultivation and consumption of maize, wheat or rice).

Marketing trends for feed uses are different from those for human consumption. In Mexico and Argentina (two major sorghum producing countries) sorghum is grown solely for feed purposes. Production has decreased in the last decades due to the promotion and improved cultural practices of maize (more drought-tolerant varieties and no-tillage cultivation). Nevertheless, demand for sorghum as an animal feed is expected to grow in Asia and Latin America and, to a lesser degree in Africa.

The marketing potential for certified organic sorghum may be very limited and may depend on the development of integrated supply chains (organic farmers growing for a certified processor, who produces organic specialty dishes for urban and overseas populations).

The contribution that sorghum will make to human and animal nutrition in the future widely depends on productivity and yield reliability being raised, and production and marketing constraints being overcome.

Recommended readings:

- *The world of sorghum and millet economies*, FAO and ICRISAT, 1996.
- *International Sorghum and Millets Newsletter*. ISMN Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 92 pp. ISBN 1023-487X. Order code ISMN45.

Recommended websites:

- *International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India*, www.icrisat.org. Publications for download and order, newsletter (*International Sorghum and Millets Newsletter (ISMN)*), information on pests, diseases and crop production.
- *FAO Land and Water Division*: www.fao.org/ag/agl/aglw/cropwater/sorghum.stm. Information on water needs and irrigation of sorghum.
- *University of Hohenheim, Germany*, www.uni-hohenheim.de/~www380/parasite/ManSCPNR.htm. Training Manual on Striga control; additional control method against Striga under www.push-pull.net/striga.htm.
- *Push-pull strategy against stem borers*, www.push-pull.net.

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4.3 Wheat

Introduction

Wheat (*Triticum* spp.) is one of the world's most important staple foods, providing about one fifth of humanity's food energy. More than one third of the world's population relies on it as their main cereal. The two main cultivar groups are bread wheat (*Triticum aestivum*) and durum wheat (*Triticum durum*). Bread wheat covers about 90 % of the total area under wheat cultivation. The consumption of wheat is constantly increasing in many countries of the tropics. The comparably high price of imports is a considerable burden on these economies and provides an incentive for domestic wheat production.

Wheat is not a traditional crop of the tropics. Its cultivation began in the early stages of mankind in the Near East, in the upland regions of today's Iraq, a region that is commonly referred to as the cradle of civilization. From there, wheat cultivation spread to other regions of the world – mainly to temperate climates, but also to the semi-arid regions of the tropics. Today, the main areas of cultivation are North America, Russia, China and Argentina. In the subtropics and tropics, wheat is widely grown in India and Pakistan and to a lesser extent in most of the countries of South-East Asia, Africa and Central and South America. Being a crop suited to more temperate climates, wheat is most successfully grown in the upland regions of the tropics during the cool season, where temperatures do not exceed 25°C and humidity is low. Durum wheat is better adapted to hot and dry climates than bread wheat. Except for these highland areas, where winter wheat is grown, only spring wheat is cultivated in the tropics. Thanks to new photo-insensitive varieties, wheat cultivation has greatly expanded in the subtropics and tropics in recent years, leading to a kind of "Wheat Revolution" in these areas.

Wheat's popularity stems from its mild, even bland, taste and the ease with which it can be processed. Bread wheat has a high gluten content, a protein which makes the flour rise readily when baked together with water and yeast. By contrast durum wheat has a low gluten content and is mostly used to make pasta. Wheat grains can be stored for years and are easily shipped around the world. For white flour, only the inner part of the grain is used which is rich in starch and gluten. Milling of the whole grain gives darker but healthier flour, as it includes the germ (containing oil and vitamins) and the bran (the "shell" or sheath, containing minerals).

Lessons to be learned:

- *Wheat consumption is increasing worldwide.*
- *Wheat prefers moderate temperatures and a good water supply.*
- *Wheat does best in rotation with pulses (legumes).*
- *Market potentials and cultivation risks must be thoroughly evaluated before growing organic wheat in the tropics.*

Motivation: Can wheat be a valuable alternative?

To get an idea of the participants' knowledge on the cultivation of cereals in the tropics and to motivate them to learn more about wheat cultivation, you may start by comparing wheat with other cereals that are grown in the area. Prepare a big sheet of paper on an empty table and write the names of the cereal crops on the top and their characteristics on the left (use the table below as an example). Ask the participants to fill out the table in groups and to present their appraisal to the others. Draw general conclusions from the comparison, if appropriate. If the participants have no experience growing wheat, leave the wheat column empty and fill it out together later on.

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In general, wheat can be cultivated with few inputs and little mechanization. However, irregular and variable rainfall, a short growing season, periods of extreme heat, poor soils and aggressive pests and diseases can make it a challenge to grow this crop successfully.

	Wheat	Sorghum	Millet	Corn	Rice
Agro-ecol. requirements (water, nutrients)					
Average (local) yield					
Integration into local farming system and eating habits					
Market demand					
Production risks (pests, diseases, water, storage)					
Potential (agricultural, processing, market)					
Aptitude for organic cultivation					

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4.3.1 Agro-ecological requirements and site selection

Wheat is essentially a crop of the temperate to subtropical climates. The cool winters and moderate hot summers are conducive to a good wheat crop. Due to the wide adaptation of different cultivars of wheat to a variety of growing conditions, today it is grown from the moderate to cold climates of the far northern and southern latitudes all the way to the equator, and from sea level to altitudes of more than 4500 meters. Compared to other cereal crops, wheat's soil and water requirements are quite specific. Bread wheat and durum wheat have somewhat different ecological requirements.

Agro-ecological requirements

Temperature and light

Unlike winter wheat, which requires temperatures of 5 to 10 °C for three to six weeks during early growth in order to produce grain, spring wheat does not need chilling in order to head. The minimum temperature at which spring wheat will grow is about 5 °C. Ideal daytime temperatures for spring wheat are between 20 and 22 °C, while durum wheat grows best between 22 and 25 °C. Temperatures above 25 °C are not favorable for bread wheat; durum wheat, however, tolerates temperatures of up to 30 °C. Bread wheat prefers cool temperatures during early growth and flowering, but during ripening higher temperatures are possible. Durum wheat requires higher temperatures for germination and early growth.

Bread wheat needs long days to develop grains, in contrast to durum wheat, which requires short days.

Water/Humidity

As a member of the grass family, wheat depends on a regular supply of water throughout the growing period for appropriate vegetative growth and good yield development. A humid and well-aerated soil encourages deep and dense rooting and thus improves the water and nutrient uptake of the plants.

For rain-fed cultivation of bread wheat, 500 to 600 mm of rain is considered essential, whereas durum wheat needs less water in order to grow properly. Durum wheat is thus better adapted to dry conditions. Constant warm and humid conditions are disadvantageous for wheat cultivation, as they encourage disease.

4.3 Wheat
1

Agro-ecological requirements of wheat

Bread wheat

Temperature and light:


- Ideal between 20 to 22 °C
- Moderate temperatures during early growth and flowering
- Damage possible above 25 °C
- Long days required for grain production

Water/Humidity:

- High water demand
- 500 to 600 mm of evenly distributed rain is ideal
- No water stress at flowering
- Dry conditions for ripening

Soil:

- Deep soils
- Silty loams and clay soils
- Tolerates high ground water level
- No water logging
- pH 5.5 to 7.5



Durum wheat

Temperature and light:



- Ideal between 22 to 25 °C
- Hot days, cool nights
- Damage possible above 30 °C
- Short days required for grain production

Water/Humidity:

- Low water demand until tillering
- 180 mm rain between heading and flowering

Ideal sites:

Fertile, rather heavy soils during cool season with regular rains over a 100 day period

TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.3 (1): AGRO-ECOLOGICAL REQUIREMENTS OF WHEAT

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Sufficient water is especially important during early growth to encourage the development of healthy roots, and from the beginning of tillering until the green grains have developed. Wheat is most sensitive to water deficits during flowering. Heavy water stress during flowering seriously affects pollen formation, fertilization and grain development (which are also due to reduced root growth). Higher water supply in later growth cannot compensate for deficits during flowering. Dry conditions are required for grain ripening. Water deficits during yield formation can (especially in combination with hot and dry winds) lead to the grain shriveling.

Soil

Wheat grows best in deep soils even though its roots normally grow only about 1 meter deep. Wheat prefers well-drained and well-aerated sandy or silty loam and clayey loam soils with an organic matter content of at least 0.5 %. Light and shallow soils are not suitable as they have a low water-holding capacity. On light soils water deficiencies occur easily, especially if the wheat plants build many tillers.

Under temperate conditions and during initial growth, wheat will tolerate a groundwater table of as high as 0.8 m. It cannot however stand water logging for a long time.

The ideal pH of the soil is between 5.5 and 7.5. Wheat is sensitive to high soil salinity. Soils with a high sodium, magnesium or iron concentration should not be used for growing wheat.

Implications for site selection

Good yields of wheat require good water and nitrogen supplies during vegetative growth (both are often the limiting factors in wheat cultivation). Thus, wheat should only be planted on suitable soils with good water-holding capacities. To avoid soil erosion, the crop should not be cultivated on steep slopes.

Discussion: Do wheat's requirements match the local conditions?

While showing the transparency, discuss how well the listed requirements of wheat correspond to the local climate and soils. Are there any constraints or restrictions?

If the participants have experience growing wheat, compare their conclusions on the agro-ecological requirements of wheat based on their experience, with the information given on the transparency.

Does wheat have more specific requirements if it is grown organically? If possible, invite an experienced organic wheat grower to share his experiences.

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4.3.2 Diversification strategies and establishing the crop

Crop rotation and intercropping

Under temperate conditions, the repeated cultivation of wheat is quite common in conventional agriculture. Continuous cultivation of wheat, however, commonly results in elevated levels of weed competition and soil-borne diseases (i.e. foot and root rots) and leads to nutrient depletion and decreasing yields. A proper crop rotation therefore underpins successful wheat cultivation.

As a general rule, it is recommended that a cereal crop should not be grown on a plot of land more than twice in succession. Wheat, however, should not be grown more often than every third year. It should be grown in rotation with crops that do not act as hosts to the same pests and diseases and that suppress weeds well. The ideal partners of wheat (and of cereal crops in general) in crop rotations are pulses, or other legume crops. Legumes generally do not transmit diseases to wheat, cover the soil densely and supply nitrogen to the subsequent crops.


The best crops to precede wheat are legumes or tuber crops. Wheat responds well to the nitrogen supplied by the legume. Tuber crops leave a fine tilth, thus easing soil preparation before wheat. The cultivation of wheat as the second crop after a legume is also recommended. Growing wheat after another cereal crop increases the risk of pests and diseases.

In South Asia, wheat is commonly grown in rotation with cotton and legumes such as chickpea, mungbean, groundnut, short duration pigeon pea and soybean. In cooler climates wheat can be grown after soybean, which is sown as the first rainy-season crop.

Wheat can also be intercropped. Valuable intercropping partners are chickpea, barley, mustard, pea, long-duration pigeon pea, gram lentil or safflower. Wheat may also be intersown with a short-season crop (i.e. chickpea, lentil or grass pea) towards the end of the wheat's growing period, provided that there is enough moisture in the soil. Alternatively, a cover crop can be sown in after the second weeding of the crop, before the wheat plants head. Subsequent passages with a tine-weeder or a tine hoe or rake mixes the seeds with the topsoil and improves their germination.

4.3 Wheat
2

Crop rotations with wheat



Basic rules

- Not more than every second crop at the same site should be a cereal crop
- Not more than every third crop at the same site should be a wheat crop
- Wheat is ideally grown after a legume or tuber crop
- If other cereals are grown in the rotation, wheat should come first

Examples of practiced crop rotations:

Maize – Chickpea – Wheat – Groundnut – Oat – Safflower – Cotton


Sorghum – Chickpea – Sunflower – Groundnut – Wheat – Paddy

Intercropped in a ley cropping systems

Wheat – Chickpea – Safflower – Mustard, etc..

Tropical highlands

Soybean – Wheat – Green manure crop – Maize

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TRANSPARENCY 4.3 (2): POSSIBILITIES TO INTEGRATE WHEAT INTO CROP ROTATIONS

Group work: Which are the best rotations?

If the participants are not familiar with growing wheat, discuss the possibilities of introducing wheat into local rotations. What crops are actually grown? What place in the rotation cycle may be given to wheat? Compare different rotations and discuss their advantages and inconveniences. If wheat is grown in the area, discuss potential improvements to common crop rotations considering nutrient management, pests, disease and weed control. Do the practiced crop rotations correspond to organic standards and recommendations?

For general information on crop rotation see chapter 4.2 of the Basic Manual.

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Crop planning

Timing

In tropical lowland conditions wheat takes 4 to 5 months to reach maturity, while in highland climates it may take up to 8 months. Its cultivation should be timed so that hot temperatures are avoided between sowing and flowering, and sufficient soil moisture can be provided (if the crop is not irrigated) to satisfy wheat's high water requirements from sowing to the end of grain filling. Thus, rain-fed wheat is sown at the end of the rainy season or at the beginning of the dry season, when the moisture content of the soil is at its maximum. Irrigated wheat is usually sown later in the dry season. Wheat production should be timed to avoid heavy rains and problems with water logging. Sowing wheat in the hot season results in poor germination, poor tillering, increased root diseases and early flowering.

In the subtropics, rain-fed wheat is grown with winter rains, whereas in the tropics it is grown during the dry winter months with residual soil moisture. Irrigated wheat is grown during the winter months in the tropics, while in the subtropics it is grown with the summer rains. In areas with winter rains, wheat is also grown during the winter months with supplemental irrigation.

Variety selection

The wheat plant is largely self-pollinating. This is one of the reasons why hybrid varieties are uncommon. Most of the common varieties have, as a result of breeding, ears with awnless spikelets. Traditionally, tall varieties are preferred (which have the advantage of providing more straw) that are well adapted to low input conditions and local climate. Many of these cultivars are reported to have very good grain quality. During the Green Revolution, high yielding varieties were developed. Such varieties now account for more than half of the area of cultivated wheat in the tropics and subtropics. These are mostly very short-stawed varieties (that produce more grain weight per total biomass than other varieties) that depend on high nutrient inputs and sophisticated maintenance methods to develop to their potential. They are, also, reported to do quite well under low input conditions. Most of the high yielding wheat varieties bred in recent years have good agronomic qualities (e.g. resistances) and may thus be of interest to organic farmers. Mixed cropping of different selected cultivars reduces the risk of damage by diseases and pests (such mixtures must, of course, also correspond to market demands).

Sharing experiences: Wheat varieties

If wheat is grown in the area, ask the participants which varieties or cultivars are grown. What characteristics do the cultivars have? What characteristics are decisive? What characteristics are required for marketing?

If possible, visit field trials that show different cultivars under organic or low-input conditions and discuss the differences with an expert.

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When selecting wheat varieties for organic cultivation, special attention must be paid to the following characteristics: high disease (and pest) resistance, high nutrient efficiency, low tendency to lodging and good grain quality. For rain-fed cultivation, high drought tolerance is also of great importance. Lately, more attention has been paid to early maturing crops in order to reduce water needs and cultivation risks, and to gain time for other crops.

The quality criteria for bread wheat include high protein content, a balanced combination of amino acids and good milling and baking qualities. On national and especially international markets, only the best qualities are wanted. Cultivars that attain good yields through a high grain weight are preferred, instead of those whose yields come from making more tillers. Comparative field trials may be necessary to determine the varieties that do best under organic farming conditions.

Wheat seeds can be saved and used for subsequent cultivation. The seeds of modern varieties, however, should be replaced after 3 to 4 years.

Soil preparation

Wheat seeds require a rather fine but firm seedbed for good and uniform germination. For drilled seed, the lower seedbed should ideally be fine, and the covering layer should be composed of medium size particles. A tilth that is too fine results in a crusting of the soil surface. Durum wheat requires more careful seedbed preparation (more settled and with a finer tilth) than bread wheat.

The procedure for soil preparation depends on the previous crop as well as soil characteristics. Deep soil cultivation is recommended in silty and heavy soils to reduce soil compaction in the lower layers. Less soil preparation is required after tuber crops, as these leave a highly active soil and fine tilth. This will also avoid high nitrogen losses. A common procedure for soil preparation consists of early (and repeated) ploughing in the rainy season (depending on the mechanization) followed by (repeated) harrowing. Timely soil preparation aims at conserving as much moisture in the soil as possible. Irrigated wheat requires less soil preparation, but if the wheat is grown after rice, soil preparation is especially labor-intensive.

Shortly before sowing, the seedbed is prepared and ideally the topsoil is recompacted. In cases of high weed pressure, a weed cure that includes repeated superficial cultivation of the

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topsoil may be recommended (see chapter 4.3.3). Recompaction of the soil immediately after soil preparation reduces water losses by evaporation in arid climates. If the previous crop was not a legume, the application of compost or animal manure onto the soil surface is recommended to provide sufficient fertilization (see chapter 4.3.4 also).

Sowing

Wheat seeds are drilled mechanically, sown into furrows behind a plough or broadcast. Drilling eases later weeding (with the exception of a flexible harrow, which does not need the crops to be sown in rows).

Wheat seeds are commonly sown at a depth of between 2 to 4 cm. Under dry conditions a sowing depth of 5 to 8 cm may be necessary to reach the soil moisture and to prevent light rains from causing the seeds to germinate. Sowing too deep, however, results in poor stands and weak plants with few tillers.

Drilled wheat is sown in rows 15 to 22 cm apart. Under arid conditions a wider row distance of 27 to 35 cm is recommended. In more humid climates, or under irrigation, wider spacing between the rows allows for the sowing of a legume cover crop once the wheat plants are established. After harvesting the wheat the cover crop is either fed to farm animals or mulched. Wider distances between the rows are usually compensated for by increased tillering and do not result in lower wheat yields. Within the row a plant distance of 4 cm is common.

The best plant density for wheat stands is between 150 to 250 tillers per square meter. Depending on the weight of the individual grains 80 to 180 kg of seeds are required per hectare. In irrigated cultivation more than 200 kg of seeds can be sown per hectare. For broadcast wheat a higher seed rate is recommended compared to that of drilled wheat. Sowing at very low seed rates may lead to water stress under arid conditions, as the wheat plants will develop more tillers. In case of high weed pressure, an increased seed density may be advantageous to increase competition against the weeds.

Rain-fed wheat that is sown into furrows is left open, whereas irrigated wheat is covered with soil using a wooden plank or a roller to ensure good contact of the seeds with the soil and create an even soil surface for easier weed control.

Motivation: How are cereals sown?


Spread samples of cereal grains grown in the area on a table. Ask the participants how the soil is prepared for these crops. Are there any differences to how the soil is prepared for wheat? Are methods of minimal tillage practiced? If yes, under what circumstances?

4.3. Wheat **3**

Soil preparation and sowing of wheat

Soil preparation


- Finely prepared lower seedbed
- Rough top layer
- Less soil cultivation needed after tuber crops
- Weed cure when there is high weed pressure
- Minimal tillage possible on light soils with low weed pressure



Sowing

- Usual sowing depth 2 to 4 cm
- Deeper sowing in dry conditions
- Row distance 15 to 22 cm; wider row distance recommended under arid conditions
- Desired density of 150 to 250 tillers per m²
- Cross-drilling possible for more uniform emergence
- More seeds needed when broadcast

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TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.3 (3): SOIL PREPARATION AND SOWING OF WHEAT

4 Management Guide for Crops

4.3.3 Soil protection and weed management

Soil protection

The risk of soil erosion in wheat stands is greatest in early vegetative growth. After tillering the wheat plants cover the soil quite well and will have established a dense root system.

After harvest, the wheat straw should be left on the field to reduce wind and water erosion, water losses due to evaporation and to increase water percolation. Under arid conditions the straw may, however, attract termites.

Weed management

Wheat competes well with most weeds as it generally develops faster than they do. Nevertheless, competition from weeds can lead to losses in yield and quality. Yield losses due to weed competition mainly occur when the weeds compete with the crop for light, water and nutrients during the first 4 to 5 weeks, prior to completion of tillering. Tolerable weed density depends on the weed species and the climatic conditions, and can range from 3 individuals to up to 50 weeds per square meter. After tillering, weeds mainly hinder the ripening of the grains and harvest.

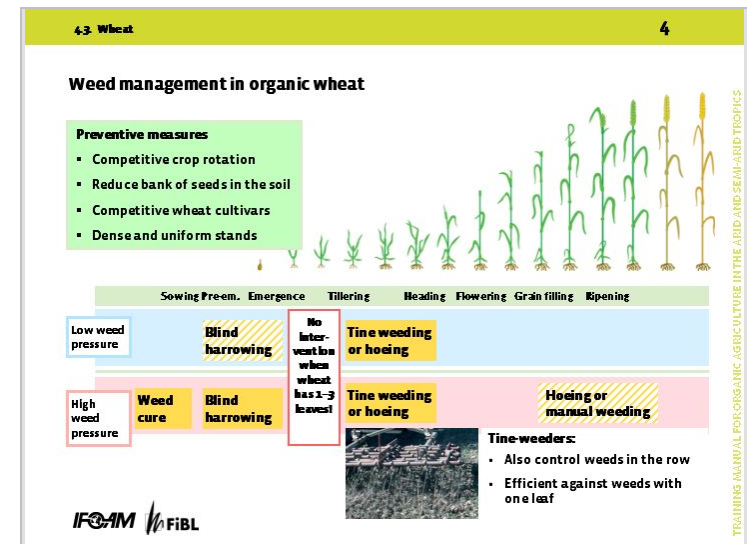
Preventive measures to reduce weed competition are: applying a proper crop rotation, variety selection, appropriate sowing density, use of well-decomposed farmyard manure. Rotation of crops with different growth habits (duration and extent of soil covering), growing periods, cultivation requirements and sowing dates are of major importance. Frequent problems with weeds generally indicate an unfavorable crop rotation. Variety characteristics, such as rapid early growth, strong tillering, tall plants and large leaf surfaces considerably increase wheat's competitiveness. A dense and uniform crop discourages weeds from growing. To some extent wheat plants can compensate for poor stands by building several tillers per plant, but tiller production depends on good growing conditions. Sowing half of the seeds at a right angle to the main sowing direction improves the uniformity of the stand. The use of well-decomposed farmyard manure prevents the spread of weed seeds.

Weeding wheat stands in the early stages can be difficult, as grass seedlings look similar to wheat plants and the wheat plants are closely spaced. Mechanical weeding is not recommended between the emergence of the wheat until the wheat plants have formed three leaves, as at this stage the wheat plants are sensitive to injuries and may be uprooted.

Motivation: Are weeds a problem?

To introduce weed management practices to organic wheat farming, enquire whether weeds create problems in local agriculture and find out what the common practices of weed control are. Is attention paid to crop rotation in this context?

For basic information on weed management in organic farming see chapter 5.4 of the Basic Manual.



TRANSPARENCY 4.3 (4): HOW WEEDS ARE CONTROLLED IN ORGANIC FARMING

4 Management Guide for Crops

The most common mechanical device for weed control in organic wheat is a tine-weeder (a harrow with spring steel tines). Tine weeding is very effective between sowing and plant emergence, as well as when the wheat plants have three to four leaves and the weeds are not taller than 1 cm, when they are easy to pull out. It is likely to be most efficient when the soil is neither too dry nor too moist.

To avoid uprooting the wheat seeds when harrowing, the crop must be sown sufficiently deeply and the tine-weeder must be pulled slowly and be well-adjusted to scratch only the soil surface. Tine weeding may not be very efficient against grass weeds. Flame weeders are usually not economic in wheat and inter-row weeders are not common in the tropics.

In cases of high weed pressure, special attention must be paid to obtaining a clean seedbed to avoid early weed competition. To reduce the weed stock in the topsoil, the seedbed is prepared early and the weeds are left to germinate. After approximately seven days the soil is cultivated superficially again to uproot the weeds and prepare the final seedbed. Irrigating the soil after soil cultivation can increase the effectiveness of such a false seedbed or weed cure.

Pre-emergence weeding is appropriate in cases of higher weed pressure. The efficiency of blind harrowing using a tine-weeder or a rotary hoe increases if the wheat is drilled a week after the final seedbed is prepared, instead of sowing being done shortly after seedbed preparation has been performed. The crop is then sown into the germinating weeds. The weeds are uprooted by superficial weeding (or killed by flame weeding) before the wheat plants emerge.

Harrowing is most effective when the wheat plants have three to four leaves. Harrowing or manual weeding at this stage can have a decisive effect on the further development of the wheat crop. Tine weeding can also be done at a right angle to the rows. Satisfying results with the tine-weeder can be obtained until the wheat plants have reached a size of 20 to 30 cm.

Provided that the wheat plants have been given the necessary attention in earlier stages, from heading onwards they usually compete well with weeds. In the later growth stages of wheat, weed management is aimed at eliminating problem weeds to avoid their dissemination and problems at harvest.

Demonstration: Using a tine-weeder

If possible organize a demonstration of a tine-weeder in a wheat crop at the recommended stages. If different mechanical devices are available, compare their effect on the weeds and the crop when applied at different speeds.

4 Management Guide for Crops

4.3.4 Supplying nutrients and organic fertilization

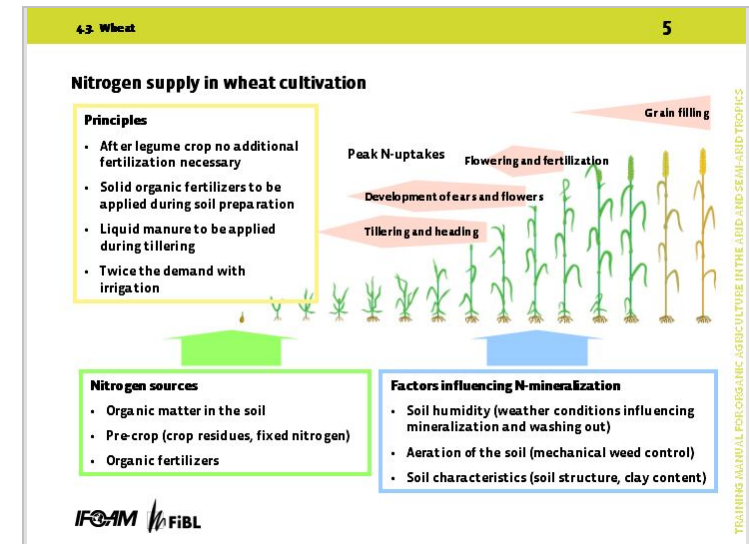
Wheat has an average nutrient demand. While modern wheat cultivars have a higher nutrient demand, other wheat cultivar groups can grow in very poor soils (e.g. spelt wheat, which is grown in small quantities in Europe, Africa and in the highlands of Iran). Nutrient demand is generally low until tillering. Between tillering and flowering, the demand is at its highest.

Nitrogen is the most needed nutrient and has an evident influence on both yield and quality. Sufficient supplies of phosphorus and potassium also improve yield and quality. Phosphorus is important for the production of starch and is found in important quantities in the grain. Potassium plays a role in resistance against aridity and diseases, and influences the storage capacity of the grains. At harvest it is mainly found in the straw. Although only needed in small quantities, magnesium is another important element as (together with nitrogen) it plays a role in building green leaves. Deficiencies can occur in light or acid soils, and on farms with no animals.

The availability of nitrogen, at different phases of wheat's life cycle (at tillering, heading, development of ears and flowers, flowering and fertilization, and the filling of the grains with starch and protein) has an important effect on final yield. The challenge for organic farmers is to correctly assess nitrogen availability via the mineralization of the residues of the previous crop and from the soil, and how much (if any) additional nitrogen is necessary. Irrigated wheat has about double the nitrogen demand of a rain fed crop.

If wheat follows a leguminous crop, additional fertilization is usually not necessary. After tuber crops, additional fertilization may be required. Solid farm manures and nitrogen rich organic fertilizers do well. They will not however be fully available to the wheat plants. Farm manure should be well decomposed or composted to avoid the transmission of plant diseases (depending on the plant material that has been mixed in with it). The appropriate application rates of farmyard manure are between 12 and 15 tons per hectare. Manure must be applied before sowing to be effective and should be incorporated into the soil surface. For sufficient mineralization, moist soil conditions are necessary.

If available, liquid farm manure is ideal and is best applied at the tillering stage. To avoid burning the leaves and nitrogen losses, it should be diluted with at least two parts of water. The dosage will depend on the manure's nitrogen content, the soil fertility and yield targets.



TRANSPARENCY 4.3 (5): NUTRIENT REQUIREMENTS OF ORGANICALLY GROWN WHEAT

4 Management Guide for Crops

An oversupply of nitrogen increases the risk of the tillers lodging. Lodged tillers do not produce grains, or the grains that they do produce are unable to ripen.

Micronutrient deficiencies are rare, although some area's soils are poor in zinc, which can lead to deficiencies that again result in low yields and low zinc content in the grains. This problem can be solved through the application of zinc. There are wheat varieties that do grow in soils low in zinc. If the plants fail to set grains, it may be due to boron deficiency, which can appear in some soils. If grains do not develop properly, it is a sign that the soil is deficient in copper. The spraying of copper oxychloride at 1.5 kg per ha resolves the lack of this nutrient. Magnesium deficiency can appear in soils with a low pH, if aridity hinders root uptake. Liming usually raises the pH, but may not be economic. In contrast, manganese deficiency can show up in soils with a pH that is above 7. The application of micronutrient fertilizers requires prior approval from the organic certification body.

If the wheat straw is incorporated into the soil after harvest, considerable amounts of organic material are added to it. The high C:N ratio of the straw may, however, reduce the availability of nitrogen to the following crop, creating a period of nitrogen deficiency. The application of a nitrogen rich source enhances the decomposition of the straw and prevents the immobilization of nitrogen (assuming the soil is moist; thus under dry conditions post-harvest irrigation may be required). Alternatively the crop residues may be composted together with other plant material or animal manure (e.g. vermi-composting; see chapter 4.4 of the Basic Manual).

About yield development in wheat

Wheat plants build three to four primary tillers and the same number of secondary tillers, of which only one or two normally form an ear.

Grain set is determined several weeks before the ears emerge. The carbohydrates for the grains come, to a large extent, from photosynthesis. The surface of green leaves after the emergence of the ear thus defines the degree of grain filling.

Sharing experiences: Fertilization strategies in cereals

Invite the participants to share their experiences about fertilization of wheat and other cereals. Ask the questions based on whether or not the participants have experience in growing wheat at all or with growing it organically. Possible questions include: What factors influence the development of wheat? What factors hinder good plant nutrition? How are they taken into account in practice? What strategies are used to fertilize wheat? Is there any potential for improvement?

As a second step, develop a fertilization strategy for wheat that is adapted to the local conditions.

Practical recommendation: No-fertilization "window"

A possible way to evaluate the effects of a specific fertilization measure is to exclude a square of about 10 by 10 meters of the wheat field from fertilization and to compare the impact of this on plant growth and yield.

4 Management Guide for Crops

4.3.5 Direct and indirect pest and disease management

Diseases and pests on average destroy 20% of the potential grain harvest, including losses during storage. In some cases, storage losses are the most significant. Losses due to diseases can be effectively controlled by: growing cultivars with corresponding tolerances or resistances, applying an appropriate crop rotation and ensuring good growing conditions. Pest management focuses predominantly on preventive measures, and great efforts are being made to breed varieties that are resistant to nematodes, the Sunn pest and Hessian fly. These pests can significantly damage wheat yields. In dry climates direct measures against diseases that rely on humid conditions for infection, are generally not necessary, although occasional treatments may be appropriate in humid climates which are more conducive to the spread of diseases. IFOAM standards allow the application of certain pesticides in cereals, whereas some organic certifiers do not allow any treatments in the crop at all.

Disease management

In warmer climates rust diseases among wheat are rife. The most widespread and dangerous rust forms are stem rust (*Puccinia graminis* f.sp.) and brown wheat rust. These only affect wheat. In cooler climates, stripe or yellow rust is also widespread. Rust diseases infect the leaves and sometimes the spikes and can reduce yield by up to half. Other important diseases are spot blotch, head scab, foot/root rot (*Fusarium* spp.) and Sclerotium foot rot (*Corticium rolfsii*). Other diseases such as tan spot (*Pyrenophora tritici-repentis*), powdery mildew, speckled leaf blotch (*Mycosphaerella graminicola*), glume blotch (*Phaeosphaeria nodorum*), Alternaria leaf blight (*Alternaria* spp.), loose smut (*Ustilago nuda* f.sp. *tritici*), Rhizoctonia root rot (*Rhizoctonia* spp.), bacterial leaf streak or black chaff (*Xanthomonas translucens* pv. *undulosa*) and barley yellow dwarf luteovirus can be regionally significant. The most common fungi in stored wheat are various species of *Aspergillus* and *Penicillium*. Fungal diseases such as *Fusarium* and *Penicillium* can produce mycotoxins that are harmful to both humans and animals.

In order to be effective, disease control measures must take into account how the diseases are transmitted. Foot and root diseases such as *Fusarium* spp., *Rhizoctonia* spp. and *Septoria* are soil borne. They develop in crop rotations that fail to interrupt their disease cycles, and are highly site specific. By contrast, powdery mildew (*Erysiphe graminis*) and rust diseases can be transmitted by wind over long distances. Thus the two groups of diseases require different control measures. Fungal diseases can also be spread through infected seed. Seed-borne diseases can be difficult to control. To prevent their transmission all seeds used

Motivation: Pest and disease problems in cereals?

Inquire about pest and disease problems in cereals in general and in wheat in particular. If any pests or diseases are predominant, ask the participants what preventative measures they use, and also what they do once they occur. Find out (i.e. by studying IFOAM or national organic standards), what direct measures are allowed.

4 Management Guide for Crops

should, wherever possible, be tested for seed-borne diseases and be certified disease free. Seed treatment may also be an economical option against seed-borne diseases. Some organic nutrients, such as milk powder, hocket, wheat flour or mustard flour, have proved to be effective against common bunt (*Tilletia tritici*), a major seed- and soil-borne disease in North Africa and West Asia. The most efficient measure against seed-borne diseases remains, of course, the use of certified seeds.

Leaf or brown rust (*Puccinia recondita* f.sp. *tritici*): This is the most harmful wheat disease of all. It spreads easily and occurs regularly from Argentina and North Africa to India. Brown rust can affect wheat at all stages, at temperatures between 2 and 32 °C, and does not necessarily rely on moisture. Losses occur as a result of a reduction of the green leaf surface. Infected plants normally make fewer tillers and fewer and smaller grains. The symptoms are red-brown pustules on the upper leaf and leaf sheath. On resistant cultivars the pustules stay small. At higher temperatures black spores develop. One direct treatment is to uproot and burn affected plants. The main measure, however, is to use resistant varieties of wheat in the first place. The cultivation of a mix of varieties may reduce the infection rate. Tobacco decoction spray is reputed to control rust diseases of wheat. During spraying, special attention is necessary to avoid ill effects on humans.

Stripe or yellow rust (*Puccinia striiformis*): In the tropics stripe rust is the main disease of wheat grown in the cool highland climates. Temperatures above 20 °C stop its growth. Losses occur due to a loss of active leaf surface, reduced root growth and increased water losses. Again, the use of resistant varieties is the main control measure, although resistance is regularly broken by new races of the fungus.

Spot blotch or brown foot rot (*Cochliobolus sativus*): Spot blotch is a soil-borne disease. It infects a great number of cereals, grasses and legumes and is distributed in soils throughout the world. The disease affects all parts of the plant, at all growth stages and can lead to serious damage, especially in arid regions and in drought-stressed plants. After infection in the soil, airborne dissemination causes severe foliar diseases and yield losses (at high humidity). Early infections result in the seedlings dying or in stunted plants, which show tiller abortion, while infections after heading cause premature ripening and small and shrunken seeds. After heading the lower leaves elongate and brown-black lesions that contrast sharply with the healthy leaf tissue are visible. The most visible symptom is a dark-brown colored sub-crown internode.

4.3 Wheat		6
Management of some major diseases in organic wheat		
Disease	Symptoms, influencing factors	Direct control measures
Leaf rust or brown rust	<ul style="list-style-type: none"> Most harmful disease to wheat Red-brown pustules on leaves and leaf sheaths Losses due to reduction of leaf surface, number of tillers plus number, and weight of, grains High daytime temperatures, humid nights and high nitrogen supply encourage disease 	<ul style="list-style-type: none"> Resistant varieties Mix varieties Moderate fertilization Uproot and burn infested plants
Stripe or yellow rust	<ul style="list-style-type: none"> Main disease in cool highland climates Grows below 20 °C Yellow-orange pustules on leaves and leaf sheaths in stripes Losses due to reduction of leaf surface, number of tillers plus number, and weight of, grains 	<ul style="list-style-type: none"> Resistant varieties Mixing varieties
Spot blotch	<ul style="list-style-type: none"> Soil-borne disease Dying seedlings Dark brown sub-crown internode Dark lesions on lower leaves after heading 	<ul style="list-style-type: none"> Avoid infested plots Proper crop rotation Resistant varieties Mixing varieties Preventive seed treatment
Powdery mildew	<ul style="list-style-type: none"> Each cereal is infested by a specific strain Affects all plant parts above the ground Small white cushions on upper leaf surface At later stages grey-brown patches 	<ul style="list-style-type: none"> Moderate fertilization Well-aerated stands Resistant varieties

TRANSPARENCY 4.3 (6): SYMPTOMS OF AND CONTROL MEASURES AGAINST SOME COMMON DISEASES IN WHEAT

4 Management Guide for Crops

The main control measure is a proper crop rotation (growing crops that will not be affected, such as lucerne, mung bean, snail medic, sorghum, safflower and white French millet). Other preventive measures are to avoid infested plots, to grow resistant cultivars, to mix resistant and susceptible cultivars and to treat the seeds with microorganisms or plant extracts (e.g. mustard which has a high glucosinolate level). The only effective direct measure is to burn the wheat residues after harvest to reduce the pathogen population in the soil (but this means that the organic matter of the topsoil will be burnt too).


Powdery mildew (*Erysiphe graminis*): The disease builds white to grey-brown fungal cushions with black dots on the leaves that lead to their death and to yield losses. Powdery mildew is only of major importance in highly susceptible cultivars. Its development is enhanced by dense stands with a close contact between the plants and, by high nitrogen supply. The main preventive measures are to use resistant varieties and variety mixtures, to avoid very dense stands and to avoid over-fertilization.

Pest management

Field pests include various aphids (which may also transmit viruses), termites, grass- and leafhoppers, bugs, thrips, beetles, grubs, worms, maggots, miners, midges, sawflies, nematodes (of the roots and the grain) and birds. In Africa in particular, but also in the Middle East and South-Central Asia, migratory locusts regularly destroy wheat crops. In India thrips, armyworms, borers and flies are reported to be common.

According to IFOAM standards, it is permissible to apply natural insecticides against pests. In most cases, however, this is not economical for the farmer. If an application of natural insecticides is being contemplated, its impact on the beneficial organisms within the crop must also be taken into consideration. Some certifiers restrict the use of natural insecticides in organic cereals. Potential agents against aphids, caterpillars or mites include pyrethrum, *Bacillus thuringiensis*, rotenone, soaps and the spraying of oils and Neem.

Aphids: Different aphids pierce and suck on different parts of plants. The most harmful is a mass-attack of aphids on the ears of the wheat, which results in smaller grains with less protein. Fortunately, heavy losses are rare. Aphids develop best in warm and dry climates, and natural enemies are important in controlling this pest. Cultural measures that encourage a high natural biological diversity and promote natural enemies consistently contribute to the control of aphids.

4.3. Wheat		7
Management of some major pests in organic wheat		
Pest	Preventive measures	Direct control measures
Aphids	<ul style="list-style-type: none"> Encourage natural enemies Moderate nitrogen supply Remove cereals and grasses that re-grow in seedbed Strip cropping of wheat with other crop 	<ul style="list-style-type: none"> Application of pyrethrum or rotenone
Sunn pest and wheat shield bugs	<ul style="list-style-type: none"> Avoid wheat cultivation in areas with high pest density (leguminous crops instead of wheat) Enhance parasite habitat by growing shelter belts of trees around wheat fields Plant early-maturing and resistant wheat varieties (if available) Avoid co-incidence of ripe grain and young Sunn pest adults by early harvesting Other cultural practices: crop rotation and mode of irrigation 	<ul style="list-style-type: none"> Mass release of egg parasites
Nematodes	<ul style="list-style-type: none"> Crop rotation (esp. against species with a narrow host range and a long life cycle; 3 year interval against root-knot nematodes, 5 years for cyst nematodes) with brassicas and legumes Resistant cultivars (if available) Mixed cropping Organic mulches at rates of 5 to 10 tonnes per hectare 	<ul style="list-style-type: none"> Incorporation of industry by-products (i.e. neem, mustard, castor bean, groundnut, coconut oil cakes) leads to a reduction when pressure is not too high Plant extracts from Tagetes, Rut a etc. (to be tested yet on larger scale)
Storage pests	<ul style="list-style-type: none"> Clean storage room Keep out rodents and insects Dry and cool storage 	<ul style="list-style-type: none"> Expose grains to sun/heat treatment Fumigation with CO₂ or N₂ gas Silicium stone powder
		

TRANSPARENCY 4.3 (7): SYMPTOMS OF AND CONTROL MEASURES AGAINST SOME COMMON PESTS IN WHEAT

4 Management Guide for Crops

Nematodes: Nematodes are aquatic animals that inhabit the films of water around soil particles. Their larvae attack the roots and stunt the plants. Some species are widespread, others occur locally, some affect many agricultural crops including vegetables, fruit and staple crops, and others only attack specific agricultural crops. Wheat is affected by root-knot nematodes (*Meloidogyne* spp.), cyst nematodes (*Globodera* spp., *Heterodera* spp.) and other species. Most plant-parasitic nematodes live in the topsoil. Some species can persist in the soil for several years (i.e. as cyst). Most plant-parasitic nematodes encourage fungal diseases. Nematode control focuses on the interruption of the nematode life cycle by crop rotation, the promotion of microbial activity and the use of resistant varieties. No biological means of control are yet known and experimental use of plant extracts and soil amendments has not been wholly successful. Other cultural measures such as soil solarization (the steaming or flooding of the soil), are quite effective but generally are difficult for farmers to apply themselves.

Sunn pest (*Eurygaster integriceps* Puton): Sunn pests and pointed wheat shield bugs are widespread throughout the rain-fed grain producing regions of northern Africa and southwestern and south-central Asia, but losses occur mainly in central and western Asia. The mature adults migrate to cereal fields where they begin to feed and later mate and lay eggs on weeds and wheat. The eggs hatch within a few days and the newly emerged nymphs begin to feed. The insects suck on leaves, stems and grains. Heavy attacks cause the stems to break, or lead to empty (white) grains. Even small attacks make wheat grains unsuitable for making bread, as the insects inject an enzyme. Two insects per square meter can be enough to damage a crop. To control this pest, cultural measures and natural predators are of major importance. A combination of the two approaches is being developed.

Storage pests: Storage pests include the rice weevil (*Sitophilus oryzae*), the lesser grain borer (*Rhyzopertha dominica*), the Angoumois grain moth (*Sitotroga cerealella*) and the khapra beetle (*Trogoderma granarium*). Rodents, predominantly the black rat (*Bandicota bengalensis*), also damage stored seeds. Agents to control storage pests in organic wheat are limited (see also 4.3.7 "Storage"). Thus, prevention and early detection are very important.

4 Management Guide for Crops

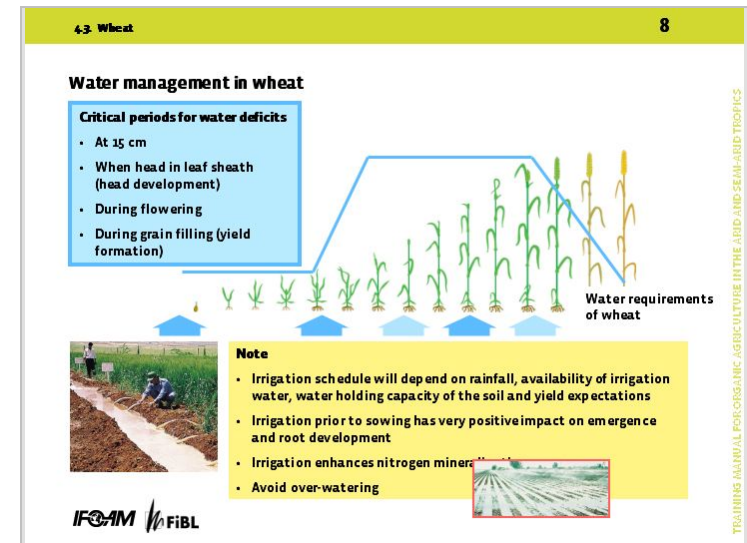
4.3.6 Water management and irrigation

Rain-fed wheat cultivation is practiced in many areas of the subtropics and tropics. However, the irregularity and variability of rainfall in many semi-arid regions, and wheat's high water requirements have encouraged irrigation of the crop. In dry climates irrigation can greatly increase wheat yields. Today, more than half of the surface area of the wheat grown in developing countries is irrigated. In some arid areas though, irrigation may not be possible or feasible.

Wheat responds well to appropriate water supply. If the soil is watered to field capacity prior to or soon after sowing, the wheat plants will develop better and produce more grains. Over-watering during the vegetative period of wheat growth should be avoided, as this produces excessive growth, which again can cause lodging. Irrigation and rainfall during late yield formation have little effect on the actual yield, provided that sufficient moisture is available in the soil. Extensive irrigation during late yield formation may cause lodging. Wheat is usually irrigated by flooding furrows, borders or basins. Sprinkler irrigation is especially appropriate when water is scarce or the topography or the soil is less suited to surface irrigation.

If irrigation water is scarce, irrigation should be prioritized for the periods of sowing, early vegetative growth and head emergence, and flowering. These are the critical stages of wheat's development when a water deficit will have a negative impact. Additional irrigation may be appropriate at the end of the vegetative growing period and during early grain formation (milk and dough stages). Thus, crops usually need to be irrigated 4 to 6 times. The first irrigation should be done about 20 to 25 days after sowing. Two or three additional irrigations may be done in areas where the soils are very light or sandy.

Pre-sowing irrigation, besides having a positive impact on crop development in dry conditions, also increases the efficiency of a weed cure. Irrigation enhances nitrogen mineralization from soil organic matter or organic fertilizers. Furthermore, soils with a silt loam and a clay loam texture are prone to surface crust formations which harden when dry. If kept moist and tilled the soils will maintain a good structure.



TRANSPARENCY 4.3 (8): WATER REQUIREMENTS OF WHEAT AND CRITERIA FOR IRRIGATION

Discussion: Is it worthwhile irrigating cereal crops?

Ask the participants about their opinions concerning the irrigation of cereal crops. Is it necessary to irrigate cereal crops? When is it worthwhile? At which stages is it most important to irrigate? Is it better to grow wheat during the dry season with irrigation or is it better to grow it in the rainy season? What irrigation method is best?

4 Management Guide for Crops

4.3.7 Harvest and post-harvest handling

Harvest

The time of harvesting depends on the sowing, the climate and the variety being grown. Irrigation delays harvest, whereas high temperatures speed up maturation.

Wheat grains are harvested when the plants turn yellow and the grains have become dry and hard inside and are of a golden color. Mature wheat grains naturally have a moisture content of 10 to 12 %.

Commercial farmers harvest the grain with mechanical combine harvesters, which cut the tillers and thresh and winnow the grains all at once. Most farmers in the tropics, however, harvest wheat with sickles. If wheat from small fields must be harvested before it is fully mature, it should be stacked in sheaves under shelter to dry.





Post-harvest handling


After harvest the grains must be threshed from the plant and then winnowed to separate the grain from the chaff, immature grains and impurities. Traditionally, threshing is done by beating the ears with sticks, by trampling or by driving a small tractor over the straw. Alternatively, a wheat sheaf may also be beaten against a low wall or a container, which makes it easier to collect the grains and reduces losses. In rice growing areas pedal or motor-driven paddy rice threshers are also used. Manual threshing methods generally result in higher grain losses than mechanical threshing.

One of wheat's characteristics is that the grain separates easily from the chaff. Winnowing by hand is common in the tropics, but is very laborious and does not achieve the same results as mechanical winnowing. Low-cost, hand-driven or motorized blowers are becoming popular for cleaning and additional drying.

4.3 Wheat 9

Harvest and post-harvest handling of wheat

Harvest	Threshing	Winnowing	Storage
			
<p>Separate the grains from the plants</p> <ul style="list-style-type: none"> ▪ When grains are dry and hard ▪ Golden colour inside ▪ No more than 10 to 12 % moisture 	<p>Separate the grains from the plants</p> <ul style="list-style-type: none"> ▪ Higher losses when done manually 	<p>Separate the grains from the chaffs</p> <ul style="list-style-type: none"> ▪ Grains separate easily ▪ Better results when done mechanically 	<p>Storage</p> <ul style="list-style-type: none"> ▪ Store clean grains with maximum 13% moisture ▪ Higher losses when stored on farm ▪ Clean and tight storage facilities

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TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.3 (9): HANDLING OF WHEAT FROM HARVEST TO STORAGE

Sharing experiences: Post-harvest handling

Ask the participants what experiments have been performed in terms of post-harvest handling and storage of cereal grains. Are any improvements possible or recommendable?

4 Management Guide for Crops

Storage

To ensure a good storage life and reduce losses, the wheat grains must be fully dried and cleaned of dirt, insects or bad grains. Moisture content below 13 % is considered safe for storage. Incorrect temperature and excessive humidity in the grain after harvest can destroy the baking quality and cause high levels of mycotoxins, which are harmful to humans.

The dried grains should be stored in such a way that air is able to circulate, thus preventing the development of moulds. High temperatures and moist conditions should be avoided as this may spoil the grains. Cool and dry storage will protect the grain from fungi and moulds. The storage area should also be secured against birds and rats, both of which also pose a storage problem. On farms, storage in metallic drums, earthen jars or polyethylene containers is common. For larger amounts of grain, bamboo and mud silos are also used. If the seeds are not stored in an airtight container, it may be necessary to re-dry them regularly.

Commercial storage facilities can be used as an alternative to drying and storing the grains on the farm where they are produced. If the grain is to be sold as a certified organic product the storage facilities must also be certified by an organic certification body.

The most common method of controlling insects in stored wheat grains is to lay them out in the sun. Most insects will leave the grain at temperatures of 40 to 44 °C. Insect control with natural insecticides or other treatment is permissible according to IFOAM standards, but may be restricted by some organic certifiers. Treatment of the grains in storage is rarely done in the tropics because it is too costly. Possible treatments include fumigation with CO₂ or N gas in closed containers or treatment with siliceous stone powder.

Processing

Consumers of organic cereals mostly prefer products that are made of the entire grain, as these contribute to a balanced diet and have a higher nutritional value. Brown flour made of whole grains has more than double the B vitamins of white flour, contains significantly more iron and calcium and tastes much better. Brown flour, however, needs more care than white flour to rise well when baked.

Wheat flour is not as nutritious as other flours such as bean, millet or soy, not to mention yam or cassava. For personal use it is therefore recommended that wheat flour be mixed with one third of one of the above flours.

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4.3.8 Economic and marketing aspects

Wheat yields can vary greatly, depending on growing conditions and the variety planted, commonly between 200 kg to 3 tons per hectare. Under ideal conditions (especially under irrigation) the yield may even be higher. By contrast, high temperatures, humidity and disease pressure, as well as poor soils and water scarcity can reduce yields considerably.

Due to its general acceptance among consumers and the worldwide growing influence of western consumer habits in the tropics, the demand for wheat is constantly growing. The demand for organic bread wheat and durum wheat has consistently developed in northern countries over the last ten years, the main markets for organic wheat being Western Europe, North America, Japan and Australia.

In many northern markets, local production cannot meet demand at the present time. Imports of organic cereals to Europe are actually satisfied by Canada and the USA. Competition from Eastern European countries may, however, soon develop. Organic wheat production is not yet significant in Asia and Africa (detailed information on organic wheat surface and production in the countries of the subtropics and the tropics is not currently available).

Before growing organic wheat, marketing opportunities must be carefully checked and certification requirements for the specific market clarified. In most developed countries, cereals are only grown on contract. Organic certification furthermore requires that a controllable supply chain, from production through processing and extending as far as marketing, exists.

Better prices are an incentive to convert to organic farming. For many organic farmers, price premiums are absolutely essential, as organically grown crops generally yield lower and demand more labor. There are premium prices available for quality organic wheat. Competition on the export markets is high though, and premium prices are only paid for wheat that has been grown on farms that have already accomplished full conversion.

In the tropics there are few regulated markets for certified organic wheat. Thus, a premium price for organic wheat is rarely realized. Organic manures, if available, are very costly. If the nutrients for the crop cannot be supplied by the farm's own sources or fertile soils, it may not be economical to grow organic wheat.

4.3 Wheat 10

Economics and marketing of organic wheat

Economics

- Better prices for certified organic wheat
- Yield reduction depending on cultivation intensity

Demand and marketing

- Still little production in the tropics
- Growing demand in the tropics
- Export potential to the North
- Highly competitive market

Before growing organic wheat

- Evaluate crop requirements
- Select marketing opportunities carefully
- Clarify certification requirements
- Clarify quality requirements

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TRANSPARENCY 4.3 (10): ECONOMICS AND MARKETING OF ORGANIC WHEAT

4 Management Guide for Crops

In face of the pressure to grow produce of high value and to avoid competition with production from moderate climates, preference, in the case of certified production, may go to a traditional tropical cash crop, such as cotton.

An important quality aspect for marketing bread wheat is the protein (or gluten) content of the grain (and its specific composition), as this defines the baking quality of the flour. Protein content is also highly relevant on international markets, although may be less important on local markets. Numerous factors influence the baking quality of wheat. The most important are the genetic definition, nitrogen uptake and the availability of water during growth, attack by weevils during grain filling or premature germination due to harvesting under humid conditions.

Wheat grains are a valuable source of calories, such as starch. Cracked or broken grains (e.g. bulgar) are used like rice or as porridges. The fermented and malted grain can be used for brewing beer and other beverages. In many countries in the tropics, wheat has been incorporated into the local cooking tradition and is mixed with other cereals such as rice, maize or cassava to improve the appearance, flavor and nutritional quality of foods.

Wheat straw is widely fed to ruminants or used for animal bedding, but can also be used as a substrate for mushroom production and to thatch roofs. By-products from the milling of white meal are the bran and the wheat germ. The bran, which is the outer husk of the grain, is rich in minerals and protein and can be fed to livestock, poultry or prawns. The wheat embryo is rich in protein and vitamins and is sold as a human food supplement (wheat germ).

Discussion: Is growing organic wheat worthwhile?

After having given some information on the economy and marketing of organic wheat, discuss the economic potential of wheat in the area. Is the demand for organic wheat consistent? Is it possible to realize a premium price for organic wheat? Are the risks bearable? Is it more appropriate to grow organic wheat intensively or at a low-input level?

If the participants have experience with growing wheat, discuss the potentials and constraints of organic cultivation of wheat compared to conventional cultivation. What major changes are necessary to convert to organic agriculture? Refer to the table made during the initial exercise. Draw final conclusions.

Recommended reading:

- J. Emmens, 2003. *Considerations for conversion to organic production for wheat based farming systems*. FAO.
- FAO, 2002. *Bread Wheat Improvement and Production*; FAO Plant Production and Protection Series – No. 30.
- Saunders DA, Hettel GP, 1994. *Wheat in heat-stressed environments: irrigated, dry areas and rice-wheat farming systems*. Mexico DF: International Maize and Wheat Improvement Center (CIMMYT).
- Wiese MV, 1987. *Compendium of wheat diseases*. 2nd edition. St. Paul, Minnesota, USA: APS Press.

Recommended websites:

- *Publications and activities of FAO's Crop and Grassland Service (AGPC):* www.fao.org/ag/agp/agpc/doc/crops/
- *Varieties, training and research activities:* www.icarda.org/
- *Wheat cultivation in India:* www.krishiworld.com
- *Irrigation of wheat:* www.vusat.org
- *Quality management along the supply chain:* www.organichaccp.org

4 Management Guide for Crops

4.4 Chickpea

Introduction

Chickpea (*Cicer arietinum*) is a pulse crop and a member of the Leguminosae family (*Fabaceae*). It is a quick-growing annual plant, which develops an upright shrub that grows about 60 cm high.

Peas have a higher percentage of protein than many other legume crops. The peas, the young shoots and the green pods are mostly used for human consumption, while the rest of the plant is used as animal fodder after threshing.

It is believed that chickpeas were first cultivated in Turkey about 7000 years ago. Today, they are the third most important food legume grown globally. The crop has adapted to tropical climates and is successfully cultivated in many tropical countries. Until recently, organic chickpeas were only produced in a few areas.

Chickpea capacity to fix nitrogen, the multiple uses of the different plant parts, their high nutritional value and their relative ease of cultivation, makes them an interesting crop for organic farmers.

Lessons to be learned:

- *Chickpea is a crop of high value and great potential.*
- *Successful cultivation depends largely on the quality of the seed, the correct timing of sowing and the cultivar's resistance to diseases and pests.*
- *Proper crop rotation is very important in order to avoid soil-borne diseases*
- *Irrigation can improve crop development significantly.*

Discussion:

Ask the participants which pulse crops are commonly grown in the area and what they are being used for. Ask them what the advantages and disadvantages of these crops are (if possible when grown organically). If no participant mentions chickpea, try to find out why. If participants have experience with growing chickpea, they will be a valuable source of information.

4 Management Guide for Crops

4.4.1 Agro-ecological requirements

Chickpea is predominantly grown as a post-rainy season rain-fed crop. In the subtropics of South Asia it is grown as a winter crop after the end of the monsoon rains, while in other areas it is also grown as a spring crop.

Temperature

Chickpea has adapted to a broad range of environments, extending from the tropics to the subtropics. It is heat tolerant and the optimum temperature for early vegetative growth ranges from 21 to 29 °C during the day, and 18 to 28 °C at night, depending on the cultivar. Low temperatures are ideal in order to induce flowering. Frost damages the green plant and harms both flowers and pods.

Rainfall

Chickpea grows well in soils with residual humidity. High soil humidity, however, can cause problems during seed germination. Once established, the deep and extensive root system allows chickpea to tolerate drought relatively well. Annual rainfall of 400 mm is sufficient to grow chickpeas. Good growth, though, strongly depends on soil moisture. Therefore drought stress may be greater in areas with a relatively high rainfall of 800 mm and high evaporation, than in areas with less rain but soil with good water retention.

Soil

Chickpea grows well in brown and dark brown soils (montmorillonite with good water-holding capacity). The crop prefers well-drained, deep tilled, aerated and rather heavy soils with a pH of 6 to 9. Very heavy soils cause problems during seedling emergence. Chickpea dislikes wet and water logged, tight, acidic and saline soils, which may also be slow to warm up in cooler climates.

4.4. Chickpea 1

Agro-ecological requirements of chickpea

Temperature


- Heat tolerant
- Optimum day temperature 21–29 °C
- Optimum night temperature 18–29 °C
- Sensitive to frost

Rainfall

- Post-rainy season crop (using residual water)
- 300–450 mm of water needed for growth
- Drought tolerance

Soil

- Brown to dark brown soils
- Heavy, but well-drained soils preferred
- pH 6–8, prefers deeply tilled soils
- No wet or waterlogged soils



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TRANSPARENCY 4.4 (1): AGRO-ECOLOGICAL REQUIREMENTS OF CHICKPEA

Sharing experiences: Requirements of chickpea

Ask the participants what criteria they apply for field selection of chickpea. Write their answers on a board. If helpful, compare with the results of the previous exercise.

4 Management Guide for Crops

4.4.2 Diversification strategies

Selection of suitable cultivars

There are two distinguishable types of chickpea: Kabuli and the Desi. Kabuli chickpeas, also known as garbanzo beans, have a larger, cream colored seed with a thin seed coat. Desi chickpeas have a smaller, dark colored seed with a thick seed coat. Depending on the variety, the growing period to physiological maturity can vary from approximately 100 to 150 days. Variations in size, shape and color of the peas can also be significant among the varieties.

The main variety selection criteria are flowering time, crop height, seed mass, seed size, yield, resistance to diseases and pests, and quality. Organic agriculture does not allow chemical seed treatment to prevent seed and seedling rots. For organic cultivation certified, disease-free seed (of organic origin if available) with a high germination rate of at least 85 % should be used. When farm-produced seeds are planted, only seeds from healthy crops should be used.

Rotational considerations

To prevent the transmission of *Ascochyta* blight, which is the major disease of chickpea, special attention must be paid to maintaining a break in cultivation (which also includes other legume crops) of three to four years on the same and nearby fields. *Ascochyta* infected chickpea residues should not be incorporated into the soil.

Traditionally, chickpea is grown in rotation with cereal crops such as sorghum, maize and paddy. The chickpea plants fix valuable nitrogen from the atmosphere, which becomes partially available to the (cereal) crops that follow and, due to their deep and extensive root system, allows them to be cultivated well into the dry season. Cereals interrupt the disease cycles of chickpeas and provide stubble to protect the soil from erosion. Chickpea may be cultivated in an alley cropping system with barley, lathyrus (grasspea), linseed, mustard, peas, corn, coffee, safflower, potato, sweet potato, sorghum or wheat to reduce pest and disease pressure.

Alley cropping or hedgerow intercropping is a practice in which different arable crops are grown simultaneously in the same field in strips.

Exercise: Collect information on diversification measures

If the participants are experienced with growing chickpea, find out about the major problems or challenges with the crop and collect information on approaches to solving these problems. Do these measures correspond to the aims of diversification such as ensuring the efficient use of nutrients, minimizing soil erosion, ensuring water supply, controlling weeds, etc.?

If the participants do not have any experience with growing chickpea, collect information on diversification practices in other legume crops (or crops in general) and the impact of these measures. If helpful, refer to the aims and approaches presented in chapter 4 of the Basic Manual.

4.4. Chickpea 2

Crop rotations with chickpea

Rotational criteria for chickpea:

- Not more than every 4 years
- Cereals before and after ideal
- Avoid other legume crops susceptible to *Ascochyta* blight
- Mixed cropping to reduce disease and pest pressure

Examples:

Sorghum – Chickpea – Safflower – Groundnut – Wheat – Paddy

Maize – Chickpea – Wheat – Groundnut – Oat – Safflower – Cotton

Intercropping in alley cropping systems:

Wheat – Chickpea – Safflower – Mustard, etc.

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TRANSPARENCY 4.4 (2): CROP ROTATION WITH CHICKPEA

4 Management Guide for Crops

Establishing the crop

The ideal time for sowing chickpea depends on the local climate, especially the time of the rainy season, as the crop is commonly sown at the end of the rainy season.

In the subtropics of South Asia, chickpeas are grown as a winter crop after the end of the monsoon rains, while in other areas they are grown as a spring crop after the winter rains. In Mexico for example, chickpeas are grown during wintertime, because the high summer temperatures reduce the yield. In highland climates early crops are susceptible to frost damage during flowering and pod set. Under favorable growing conditions, chickpea can show excessive vegetative growth, which predisposes the crop to lodging. Tall, rank crops are also more susceptible to foliar diseases such as grey mould, which can lead to significant flower abortion. Delayed sowing (as practiced by some farmers, who grow lentils in December and delay the sowing of chickpea to spring to avoid occasional infection with *Ascochyta*) may reduce yield significantly because flower and pod development coincide with unfavorable temperatures and water stress during the pod filling period.

Chickpea demands a healthy seedbed for good germination and fast development of the crop. To break soil compaction after a grain crop and permit chickpea roots to penetrate lower soil layers, it may be necessary to use a chisel plough. A deep cultivation should immediately, however, be followed by a superficial cultivation with a harrow 5 to 10 cm deep to close the soil's micro-pores and prevent water loss. Water evaporation is further reduced if the cultivation is carried out in the late afternoon or at night. In soils with low residual moisture, only a superficial soil preparation is recommended. Soil leveling with a wooden log attached to the harrow may be of advantage to avoid water flood and reduce root rot.

Chickpeas are commonly drilled at a distance of 30 to 60 cm between rows, but spacing of up to 1 meter is also practiced. In some areas the seed is also broadcast. The optimum sowing depth for chickpea is between 5 and 8 cm. Appropriate sowing depth improves the emergence of the crop, *rhizobium* nodulation, promotes lateral root development and eliminates a significant proportion of *Ascochyta* infected peas. Relatively superficial sowing is recommended where soils are prone to surface sealing or crusting.

4 Management Guide for Crops

4.4.3 Soil protection and weed management

Soil protection

A common practice is to burn the residues of the preceding crop. As burning is harmful to long-term soil fertility, the residues of the preceding crops should be incorporated into the soil instead of being burned (see also chapter 4.1 of the Basic Manual).

Weed management

Chickpea has a slow initial growth and takes time to cover the soil. The competitiveness of chickpea is therefore low and weeds can easily invade, leading to substantial yield losses. Many different weed species have been reported to infest chickpea fields (depending on the area and the crop rotation). Therefore special attention must be paid in order to ensure that there are few weeds in a field before chickpea is sown. Low weed pressure results from crop rotation with competitive crops, selecting fields with a low weed pressure (fields with a severe infestation of broad-leaved weeds should be avoided) and ensuring crop hygiene. Thus, weeds should not be allowed to spread and proliferate after the harvest of the crop preceding chickpea. As animal manure can be infested with weeds, manure from infested fields or of doubtful origin should first be composted.

If the chickpea seeds are broadcast, a slightly higher sowing rate is recommended in order to improve the crop's competitiveness with weeds. Chickpea's competitiveness can also be improved by using cultivars with better vigor and broad leaves.

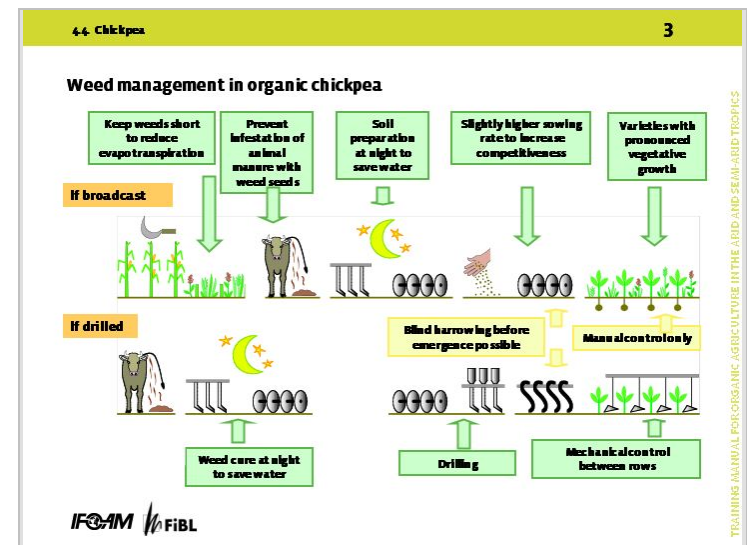
Direct control measures before and during crop growth are usually necessary. In cases where weed pressure is high, a pre-sowing weed cure is recommended: the seedbed is prepared early and is harrowed superficially when the weeds have developed 1 to 2 leaves. This is repeated several times if possible (for details see the Basic Manual).

After sowing and before emergence of the chickpeas, weeds can be disturbed once more with a curry-comb. The chickpea epicotyls must be at least 2.5 cm below the soil surface to avoid being harmed.

Mechanical regulation of the weeds after emergence is possible as long as the chickpea plants are smaller than 10 cm and are not too sensitive to damage.

Sharing experiences: Weed regulation in crops with low weed competitiveness

Ask the participants what experiences they have with weed control in chickpeas or other crops with low competitiveness. What preventive and what direct control methods are commonly used?



TRANSPARENCY 4.4 (3): WEED MANAGEMENT IN CHICKPEA

4 Management Guide for Crops

4.4.4 Supplying nutrients and organic fertilization

Like other leguminous crops, chickpea has the ability to fix nitrogen from the air in its root nodules. The amount of nitrogen that can be fixed by chickpeas can range from 10 to 140 kg N per ha depending on the cultivar used and the growing conditions. The total nutrient uptake for a yield of 1 ton of grain and 1.5 tons of straw per ha is approximately 48 kg N and 10 kg P₂O₅. However, the quantities of N, P and K accumulated in the chickpea crop are proportional to the total dry matter yield. On fertile soils, no additional fertilization with nitrogen rich sources is necessary. Phosphorus fertilization may be recommended if the soil is poor in phosphorus. Some certifiers may require a prior soil analysis. Ideally, phosphorus supply will be improved in the medium to long-term basis through the incorporation of organic manure into the soil (see chapter 4 of the Basic Manual). If available, the incorporation of 10 tons per hectare of animal manure during soil preparation stimulates the growth of the chickpea plants.

To maximize nitrogen fixation, seeds should be inoculated with the appropriate nitrogen fixing strain especially if the crop is to be sown in a new area or where the bacteria is missing from the soil.

How to inoculate enough seeds for one hectare:

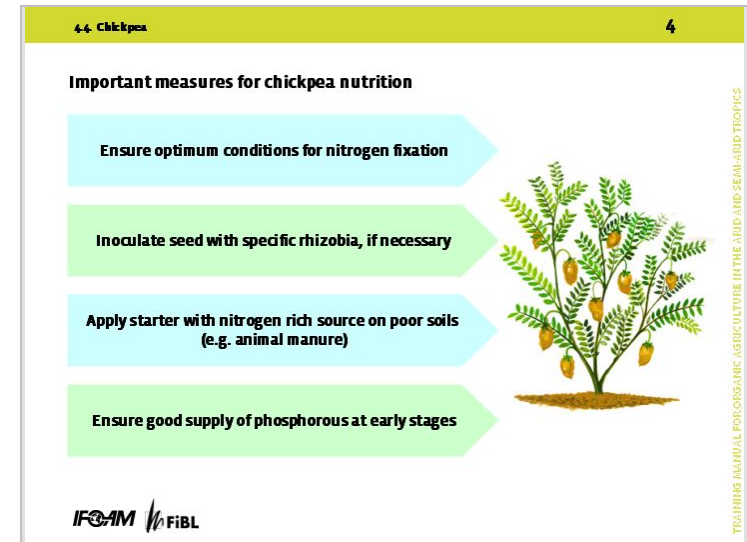
Dissolve 50 to 100 grams of sugar into 100 ml of 80 °C hot water and then add a further 400 ml cold water. Let the solution cool down for at least 3 hours so that the sugar dissolves. Add half a packet of inoculum (125 grams) to the 500 ml of adhesive solution. This quantity is sufficient to treat 50 kilograms of seed, sufficient for 1 hectare.

Just before sowing, slurry mix is applied to the seed. This is done in the shade, as exposure to high temperatures, direct sunlight and wind should be avoided. Inoculated seed should be sown immediately, and never later than 12 hours after treatment. Temperatures above 50 °C can kill the bacteria.

The following factors affect the nitrogen fixation of chickpea:

- Different cultivars fix different amounts of nitrogen.
- Excessive or deficient water in the soil can affect nodulation.
- Root temperatures above 30 °C reduce nitrogen fixation.
- The more nitrogen in the soil (e.g. as a result of nitrogen fertilizer applications), the less nodulation and nitrogen fixation takes place.

For further information see chapter 4.5.3 of the Basic Manual.



TRANSPARENCY 4.4 (4): MEASURES FOR CHICKPEA NUTRITION

Sharing experiences: Fertilization of legumes

Ask the participants how soil quality, nodulation, availability of water or soil moisture, starter fertilization, etc. influence the development of a legume crop.

4 Management Guide for Crops

4.4.5 Indirect and direct pest and disease management

The main pests of chickpea belong to one of the following groups (for control measures see transparency 4.4.5).

Leaf miner: The larvae of this fly cause a bow-shaped track under the leaf-surface. Infested plants turn yellow and show stunted growth. Spraying Neem seed extract is effective, but it does not last very long. Other botanical preparations can also be applied.

Armyworm: The caterpillars of various moths are commonly called armyworms. Most of them belong to the genera of *Spodoptera*. The moths are migratory and are well known for their sudden mass appearance. While the moths spread from one field to the next, the caterpillars defoliate the young plants in particular.

Heliothis: Heliothis species can cause severe damage to crops. Helicoverpa pod borers are the most devastating pest of chickpea in the tropics and subtropics. If present at flowering and early podding, the larvae feed on flowers and developing pods. The puncturing of young pods stops seed development and results in lower yields. If the larvae feed on the developing seeds during mid-to-late podding, the result is a reduction in yield as well as unmarketable seeds.

Mixed cropping of chickpea with wheat or mustard can help to reduce losses. Biological control of *H. armigera* can be carried out with sprays of nuclear polyhydrosis virus (NPV) or Bt.

Bruchids: Bruchids are a common pest in both the field and in storage. In the chickpea fields the bruchids lay their eggs onto the pod, whereas in storage they lay the eggs directly onto the grains.

The adult insect is a mottled brown beetle. The larva develops to a pupa inside the seed and emerges as an adult through a hole. One generation takes four weeks or more to grow. The new generation then easily infests nearby chickpea fields. The bruchids cause quantitative and qualitative damage through the perforation of grains, which leads to smaller grains and reduces both market value and the seed's ability to germinate.

Discussion: How are pests controlled?

Ask the participants which of the presented pests are familiar to them and how they have dealt with them in the past.. How satisfactory have the results been? How important have preventive measures been? Is there a potential to improve pest control measures?

If necessary or helpful, refer to chapter 5 of the Basic Manual to evaluate possible preventive and direct control measures.

4.4. Chickpea		5
Control of major pests in organic chickpea		
Pest	Preventive control measures	Direct control measures
Leaf miner <i>Liriomyza cicerina</i>	<ul style="list-style-type: none"> Avoid cultivation close to other chickpea fields Time the crop for when insect population is lower (e.g. winter) Practice appropriate crop rotation 	<ul style="list-style-type: none"> Use plant extracts (Neem kernel extracts, tobacco preparations, sweet basil (<i>Ocimum basilicum</i>, <i>Quassia amara</i>) Leaf miner fly traps Apply wood ash (talcum powder)
Armyworm <i>Spodoptera</i>	<ul style="list-style-type: none"> Regularly monitor for the pest (e.g. pheromone traps) Cooperation between farmers for successful control Encourage beneficial insects 	<ul style="list-style-type: none"> Light traps, armyworm traps Armyworm repellent (<i>Murraya paniculata</i>) Use plant extracts (garlic, Neem, <i>Pongamia pinnata</i>, <i>Chrysanthemum cinerariaefolium</i>, <i>Acorus calamus</i>, tobacco, <i>Curcuma domestica</i>)
Heliothis <i>Helicoverpa</i> spp.	<ul style="list-style-type: none"> Control broad-leaved weeds Sow trap crops (e.g. sunflower, okra) Encourage natural enemies 	<ul style="list-style-type: none"> Bt-spray, NVP-spray Pheromone traps, light traps Neem or other botanical preparations Trichogramma cards
Bruchids	<ul style="list-style-type: none"> At least 900 m distance between chickpea field and storage room Store in clean, beetle-proof containers Cool and dry storage 	<ul style="list-style-type: none"> Coat the seed with small quantities of vegetable oil (<i>Denetia</i> oil, Neem oil, coconut oil etc.) or mix leaves or powder of plants (Neem, <i>Cassia nigricans</i>, <i>Hyptis spicigera</i>, <i>Acorus calamus</i>) into the stored grain

TRANSPARENCY 4.4 (5): PEST CONTROL IN CHICKPEA

4 Management Guide for Crops

Common diseases in chickpea


More than 50 diseases can infest chickpea worldwide. However, only a few diseases, as described below, cause damage that is economically relevant.

Ascochyta blight: Ascochyta blight is a fungal disease which attacks both the roots and the above-ground parts of the host plant. It is one of the most widespread and destructive chickpea diseases, especially of susceptible varieties.

The fungus is transmitted on the surface of seeds and plant residues. Early infections usually originate from contaminated seed and can cause the damping-off of young seedlings. Taller plants show symptoms of pale fawn-brown colored lesions on stems, leaves and pods. Some defoliation also occurs. Under favorable conditions the fungus forms pycnidia spores on the lesions, which are spread by rain and wind.

Fusarium wilt: Fusarium wilt is a disease that is common in certain countries, for example India, Iran, Burma and Mexico. Wilt symptoms can appear on seedlings 25 days after sowing in the field, especially in susceptible varieties. Young affected plants have a pale color, drop their leaves, and the plants subsequently collapse and lie flat on the ground. The roots show no sign of external damage. Older plants, up to the podding stage, also show wilting.

The Fusarium fungus is transmitted through seeds and can survive on crop residues in the soil for more than six years. Due to this long survival period, preventive disease control through crop rotation has only limited effects. Seed treatments (natural substances, physical methods, etc.) must be tested in order to ascertain their effectiveness. However, many wilt resistant lines have been bred in Mexico, India and the USA and are currently available to farmers.

4.4 Chickpea		6
Control of major diseases in organic chickpea		
Disease	Symptoms	Direct control measures
Ascochyta blight (<i>Ascochyta rabiel</i>)	<ul style="list-style-type: none"> Pale brown-fawn colored lesions on stem, leaves and pods Dieback above stem lesions 	<ul style="list-style-type: none"> Healthy and high quality seeds, resistant varieties Crop rotation of at least 3-4 years Avoid humid growing conditions Keep a distance from last year's chickpea fields Plant spacing of 50 to 100 cm for good aeration Regular monitoring of the crop and early harvest Bury crop residues to a depth of 10 cm
Phytophthora root rot (<i>Phytophthora medicaginis</i>)	<ul style="list-style-type: none"> Lower leaves turn yellow and die off Tap root decayed and dark brown-black 	<ul style="list-style-type: none"> Avoid cool and wet conditions and waterlogged soils Use resistant varieties
Botrytis grey mould (<i>Botrytis cinerea</i>)	<ul style="list-style-type: none"> Flower abortion and failure to set pods Soft rot of affected areas covered with grey mould 	<ul style="list-style-type: none"> Avoid early planting and/or high plant densities and narrow row spacing Only use healthy seed of trusted origin (as it is a seed-borne disease)
Sclerotinia stem rot/ white mould (<i>Sclerotinia sclerotiorum</i>)	<ul style="list-style-type: none"> Light yellow or green discoloration of plant, lesion or rotting along the stem Plant bleached, infected area shreds apart 	<ul style="list-style-type: none"> Avoid moist conditions Avoid rotation with broad-leaved crops such as canola or peas since the disease can survive in the soil for 3-4 years
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TRANSPARENCY 4.4 (6): DISEASE CONTROL IN CHICKPEA

Discussion: How are diseases controlled?

Ask the participants which of the presented diseases are familiar to them and how they have dealt with them before. How satisfactory have the results been? How important are preventive measures? Is there potential to improve the control of the diseases?

If necessary or helpful, refer to chapter 5 of the Basic Manual to evaluate possible preventive and (in this case limited) direct control measures.

4 Management Guide for Crops

4.4.6 Water management and irrigation

Once established, the chickpea plant can adapt well to water scarcity as it generally meets its water requirements by using the residual moisture in deeper soil layers. However, the plants respond well to supplemental irrigation during early pod-filling, particularly if the water content in the soil is low. Yield losses due to drought can range from 20 to 50 % in semi-arid regions (generally due to the rapid depletion of soil moisture during the chickpea growing season). Lack of water during the early stages may affect the plant density (lower and non-uniform plant density), hinder growth (stunted plants), reduce the branching of the plant, and lighten the coloring of the lower leaves.

Well-timed crop irrigation is therefore critical, as it has great effects on both yields and seed quality. Irrigation, where it can be provided, should be timed to coincide with the following growth stages:

- Pre-sowing - In dry conditions irrigation before sowing leads to better germination of the seeds and thus to a better plant density.
- Post-emergence - Irrigation after emergence improves the establishment of the crop and enhances its competitiveness against weeds.
- Early/vegetative growth - Irrigation during vegetative growth enhances branching and improves nodulation and thus nitrogen fixation.
- Mid-flowering - Good water supply during flowering increases the number of pods.
- Pod development - Irrigation during pod development enhances yield.

Irrigation must not be heavy. Waterlogged conditions should be avoided especially after sowing, as excess humidity promotes the development of root and seedling diseases. Under very warm conditions and on soils with a low water-holding capacity, irrigation may need to be done more frequently. The most appropriate irrigation method will depend on topography. One method consists of watering every second row and alternating this pattern during the following irrigation.


Other water-saving measures to be considered include appropriate soil tillage, growing cultivars with a high water-use efficiency and short growing period, choosing appropriate seed rates and choosing soils with a good water-holding capacity. Timely sowing, sowing at soil depths where moisture is present and maintaining the weed population at a low level can be of major importance for sufficient water supply.

4.4. Chickpeas 7

Water management in chickpea

Cultivation measures to save water

- Soil preparation immediately after the previous crop
- Soil preparation during night
- If possible, flat soil preparation
- Cultivation in soils with good water-holding capacity
- Sow into slightly humid soil
- Select varieties with good water efficiency and short growing period



Irrigation

- Necessary in soils with low water-holding capacity
- Must be well-timed to the needs of the crop
- Avoid over-supply
- Alternate the irrigation of the rows

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TRANSPARENCY 4.4 (7): WATER MANAGEMENT IN CHICKPEA

Sharing experiences: Water management

Invite the participants to share their experiences with water management, asking them the following questions:

- What methods are used locally to store water in the soil?
- If it is a rain-fed crop (no irrigation possible), which experiments have been carried out in terms of the sowing date, plant densities, the selection of cultivars and cultural measures, in order to determine improved water supply to the crops?
- What priority is given to water management in irrigated crops?

Draft an irrigation schedule together with the participants, which considers the availability of water, water sources, irrigation methods and appropriate irrigation times.

Mention the consequences of improper irrigation.

4 Management Guide for Crops

4.4.7 Harvesting

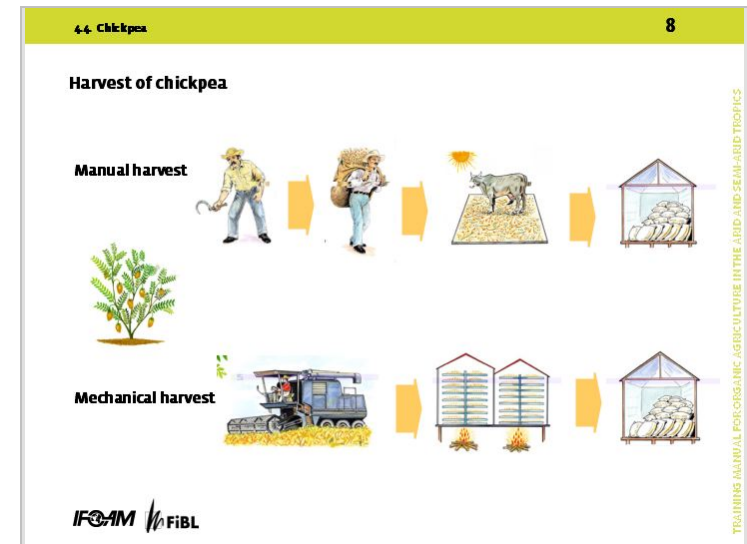
The timing of chickpea harvest depends on the moisture content of the apical pod and weather conditions. The acceptable moisture content for delivery or storage and the infrastructure available to the farmer are also relevant.

The crop is ready to be harvested when the stem and the pods are a light brown color and the seeds feel hard and rattle in the pods. A general rule is that harvest should be underway when the upper pods have a 15 % moisture level, if the target moisture level for delivered peas is 13 to 14 %. Harvested seeds with water content above 14 % should either be aerated or dried. Commercial desiccants, which are used to dry a standing crop uniformly, are forbidden in organic agriculture. A moisture content of below 13 % at harvest increases the susceptibility of the seeds to physical damage during and after harvest. Low moisture content also results in small and less uniform seeds and subsequently in economic losses.

Delaying harvest raises the risk of shattering the seeds before and during harvest, and reduces the quality and storability of the peas, especially under humid conditions. Exposure of the seeds to changing weather conditions reduces germination rate and plant vigor. Moulds and pests develop under humid conditions.

The longer the seeds remain in the field, the higher the risk that the seeds age and are damaged by weathering. Delaying harvest increases discoloration (green, brown) and the darkening of the seed coat, which reduces marketability. Darkening and loss of color are also accelerated by high temperatures and high humidity. Size and color of the peas are the most significant features in the market (e.g. buyers prefer a yellow-cream color for Kabuli chickpeas). Thus, to minimize damages, it is recommended that chickpea be harvested early.

Humid weather conditions before harvest result in significantly more cracked peas. Cracked seeds increase the possibility of the chickpeas breaking during post-harvest handling. Cracked peas reduce the processing efficiency and consequently the general quality of the product. Repeated drying and wetting of the mature pods also leads to yield losses due to pod drop and shattering, or to the opening of the pods and the expulsion of the seed.



TRANSPARENCY 4.4 (8): MANUAL AND MECHANICAL HARVEST OF CHICKPEA

Sharing experiences:

Invite the participants to describe their harvest methods, indicating their advantages and disadvantages. Then formulate harvest strategies that can be successfully adapted to the conditions of the region.

4 Management Guide for Crops

The crop is harvested by undercutting the plants slightly below the soil surface. This is done either manually with a sickle or mechanically by using a combine harvester. After manual harvesting the plants are carried to a suitable area to be dried in the sun for some days. Threshing is done either by beating the plants with sticks or trampling by animals (e.g. bullocks). Continuous mixing of the material is required for uniform threshing. In order to avoid damaging the seeds, they are removed from the threshing floor when 60 to 70 % have been separated from the straw. The seeds are then stored in a clean and dry place, protected from sun and rain.

For combine harvesting, headers are used. The header speed should not exceed about 8 km per hour to avoid damage or injury to the seeds, and the size of the sieve should be properly selected according to the size of the grains. The harvested seeds are then delivered for air-drying or storage.

Storage and handling

During storage the seeds progressively age. The rate of deterioration depends on seed condition at harvest, including the moisture content of the seeds, storage temperature and the duration of storage. Pests are another important factor.

The specific measures for handling and storage after harvest strongly depend on the infrastructure available on the farm or in the region. Chickpeas require special attention to avoid losses during post-harvest handling. The harvest of the chickpeas is just the start of the organic grain market chain. Nevertheless, the following should serve as general guidelines for storage.

To maintain their quality chickpea grains should be stored dry at cool temperatures in order to reduce the risk of pest and disease damage (e.g. moulds). Cool storage also reduces the darkening of the seed coat, and loss of color. Contamination with forbidden substances or GMO-residues (e.g. soy powder flour) must always be prevented.

How to control insects in small lots of up to 50 kilograms:

- **Insect-proof packing** - The best solution is to pack the grains in a gas-proof film. The bag may or may not then be flushed with an inert gas such as nitrogen, carbon dioxide or a mixture of both. The pack must be well-sealed, as insects are very good at laying eggs through even the smallest holes.

Discussion: Storing chickpeas

Ask the participants which storage options they have at their disposal and discuss measures of ensuring good storage conditions.

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- **Storage at low temperature** - Treatment at -18 °C (the temperature of a domestic freezer) will kill insects within approximately 24 hours. Additional time is necessary for the cold to penetrate to all parts of the bag as this happens very slowly.
- **High temperature** - Heating to 62 °C for a few seconds or to 55 °C for two hours has the same effect against insects as low temperature. Again, however, additional time must be allowed for the heat to reach the centre of the bag. If the grains are exposed to high temperatures, particular attention must be paid to ensuring that the product is unaffected by the heat and that all the pests are killed. Before treating bigger quantities of seeds, tests should be undertaken with small quantities. It is difficult to attain the correct temperature and therefore this method is rather risky.
- **Inert atmosphere** - Small lots of grain can be placed into gas-tight containers and then treated with carbon dioxide.

How to control insects in larger lots, such as small bins:

- **Inert atmosphere** - Carbon dioxide has been used to store bulk organic grain for many years. Such storage requires a well-sealed bin with the exterior painted white to reduce temperature-driven pressure changes. The bin should be pressure tested to meet the requirements of the storage time period.
- **Aeration** - With careful management it is possible to use controlled aeration in combination with surface application of certified diatomaceous dust to control pests.
- **Inert dust** - Certified diatomaceous earth dust can be added to dry grain to offer long-term protection against pests. However, such an application may not be accepted by some buyers, as it may change grain properties.

Before applying any treatment to the grains, the requirements of the buying agency, the market and both local and international organic standards should be considered.

Marketing

Key marketing standards are moisture content (14 %), purity (at least 97 %), defective grains (max. 6 %) and poor color (dark seeds up to 1 %). Specifications are very strict especially in the case of Kabuli, with unblemished grains capturing premium prices.

4 Management Guide for Crops

4.5 Pigeon Pea

Introduction

Pigeon pea (*Cajanus cajan*, *Leguminosae*) is one of the major grain legume crops of the tropics and subtropics. Pigeon pea has many names. Among other names it is commonly known as Red Gram, Congo pea, No-eye pea, Gungo bean and guandul. Pigeon pea is a perennial upright bush with a strong stem that reaches a size of 0.5 to 4 meters.

Although its origin is unknown, pigeon pea is believed to be native to India and to have emigrated from Asia to Africa about 3000 years ago. Today India accounts for almost 90 % of the world's production. Africa (mainly Kenya, Uganda and Malawi) produces 4 % of the world's pigeon peas, and the Caribbean and Central America 2 %. In other countries pigeon pea is grown on a small scale as a backyard crop.

Endowed with several unique characteristics, this crop plays an important role in traditional and organic farming systems. Although pigeon pea ranks only sixth in area and production compared to other grain legumes, it can be used in more diverse ways than other crops.

- The grains and pods are used predominantly for human consumption. The tasty seeds are eaten both as fresh shell beans and as dry beans.
- The crushed dry seeds are used for animal feed.
- Green leaves are used as fodder.
- The stalks serve as firewood and are used to make huts, baskets, etc.
- The crop is also grown as green manure to improve soil fertility.

The ability to fix nitrogen and to mobilize iron-bound phosphorous in the soil for the subsequent crops, as well as its good adaptation to dry climates and poor soil conditions, makes pigeon pea an interesting crop for the arid and semi-arid tropics. Furthermore, the peas have a high protein content, of 22 %.

As yet no information is available on the present importance of pigeon pea in organic markets. It is of importance in local markets and for self-sufficiency, but does not yet offer an organic premium.

Lessons to be learned:

- The multiple uses of the different plant parts and its unique growing characteristics make pigeon pea one of the most valuable legume plants.
- Thanks to its deep root system, pigeon pea extends active root space and withstands arid conditions well.
- Pigeon pea is easily incorporated into different crop rotations.

Group work: Compare locally grown grain legumes

Ask the participants to characterize the locally grown grain legumes. What are their uses and benefits? What are their agro-ecological requirements? Are there any local trends concerning the cultivation and use of legumes?

Write the answers on cards and stick them onto the pin board. If the participants do not know pigeon pea, add the information on this crop later on.

4.5 Pigeon Pea 1

Advantages of pigeon pea

Nitrogen fixation

Phosphorus mobilization

High protein content

Human consumption

Animal food

Fuel wood

Huts, baskets, etc.

Multiple benefits and multipurpose use of the plant parts

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TRANSPARENCY 4.5 (1): THE MULTIPLE QUALITIES OF PIGEON PEA

4 Management Guide for Crops

4.5.1 Agro-ecological requirements and site selection

Pigeon pea is a warm season plant. It is well adapted to the lower altitude regions of the tropics and subtropics and resists drought relatively well.

Soil

Pigeon pea tolerates a wide variety of soils, from sand to heavy clay loams. Well-drained medium heavy loams give the best yields.

Pigeon pea requires well-drained soils as it is sensitive to water logging. Short periods of waterlogging can kill young plants.

Pigeon pea builds an extensive root system, which allows it to tolerate low soil fertility and drought. Compacted, heavy and easily crusting soils should be avoided though as they restrict the development of taproots.

The most suitable pH range is between 5.0 and 7.0, although it is able to tolerate a wider range. Very high pH levels restrict nodulation and limit nitrogen supply. Pigeon pea does not grow well in saline soil, though some cultivars are relatively salt tolerant.

Rainfall

In the major areas where pigeon pea is cultivated annual rainfall ranges from 600 mm to 1400 mm, of which 80 to 90 % falls during the rainy season. Some cultivars withstand arid conditions with as little as 65 mm of rainfall. Although the plant can survive in very dry conditions, seed yield will be minimal under these conditions. Furthermore, extreme moisture stress will delay flowering.

Under humid conditions pigeon pea tends to produce luxuriant vegetative growth. Rain during the flowering period hinders pollination and results in low pod filling, also making attack by pod-caterpillars (*Helicoverpa armigera*) more likely.

Temperature

Pigeon pea is generally grown in a temperature range of 18 to 30 °C. Some cultivars will tolerate 10 °C under dry conditions and 35 °C under moist conditions. Pigeon pea plants tolerate heat stress quite well during vegetative growth. This crop does not, however, tolerate frost.

Discussion:

Discuss with the participants the agro-ecological requirements of pigeon pea. If pigeon pea is grown locally, do the participants agree with the characterization given in the manual? Can they add anything? If pigeon pea is not grown locally, what advantages or inconveniences may there be in growing pigeon pea in the area, compared to other grain legumes?

4.5 Pigeon Pea 2

Agro-ecological requirements of pigeon pea

Rainfall

- Resistant to drought
- Rain during flowering diminishes fertility

Soil

- Tolerates a wide range of soils
- Medium heavy loams are best
- Requires well-drained soils
- Grows well in pH 5 to 7
- Shows some tolerance to salt

Light

- Very sensitive to low radiation during pod development

Temperature

- Ideal growing temperature from 18 to 30 °C
- Withstands temperatures of 35 °C or more under moist soil conditions

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TRANSPARENCY 4.5 (2): AGRO-ECOLOGICAL REQUIREMENTS OF PIGEON PEA

4 Management Guide for Crops

Light

Pigeon pea dislikes shady conditions, showing thin and pale leaves and reduced pod production. Therefore flowering during the monsoon and cloudy weather leads to poor pod formation. Most varieties need short day conditions to flower.

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4.5.2 Diversification strategies

Although pigeon pea is a perennial plant, in India it is most often cultivated as an annual crop. In many parts of Africa and Central America, where pigeon pea is grown as a backyard crop, its perennial habit allows it to be harvested repeatedly. Repeated harvest, however, depends significantly on the availability of water (see chapter 4.5.6).

Traditional cultivars of pigeon pea are mostly intercropped. Due to their slow growth in early stages and their long growth duration, these cultivars make good intercropping or mixed cropping partners for cereals and other crops with shorter growing periods. Competition for water is widely avoided in this cultivation system, as the main growth of pigeon pea only begins after the companion crop has been harvested.

New early maturing pigeon pea varieties make it possible to insert the crop into new rotations. These varieties can be sown after sorghum in central India, after rice or wheat in the Indo-Gangetic Plain or after wheat, if irrigated, in most areas.

Hybrid pigeon pea varieties show greater vigor, increased stress resistance and greater resilience against a wide variety of adversities, such as drought, pests, diseases and weed competition. Yields are reported to be 20 to 30 % higher when these varieties are used.

Four types of pigeon pea are commonly distinguished due to their duration:

Duration	Approximate days to maturation
Extra-short	120–140
Short	140–170
Medium	160–190
Late	180–270

Besides being cultivated to maturity, pigeon pea can also be "harvested" early as a green manure.

Pigeon pea makes a deep and strong woody tap root and has well developed lateral roots in the superficial layers of the soil. With its deep root system it can loosen relatively impermeable soil layers at greater depth. This facilitates the downward percolation of moisture and makes new soil accessible for other crops.

Sharing experiences: Growing pigeon pea in rotation

Invite the participants to share their experiences with growing one or more types of pigeon pea. Try to characterize the potentials and limits of the different types from a farmer's point of view.

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Crop rotation

Pigeon pea does well in almost any rotation in the arid and semi-arid tropics due to its ability to fix nitrogen and mobilize phosphorus. Pigeon pea leaves up to 40 kg of nitrogen per hectare for the subsequent crop.

Due to its rather high drought tolerance, the crop provides an alternative to (bush-) fallow to the farmers for the dry season. This allows them to improve their incomes while reducing the depletion of soil fertility.

Sequential cropping of pigeon pea and wheat has spread widely in irrigated areas in northern and central India. A cereal or grass-type crop after pigeon pea minimizes the build-up of diseases and pests and makes best use of the nitrogen provided by the legume.

Pigeon pea is resistant to root lesion nematode and thus is a good rotation crop where this soil-borne pest is a problem.

Group work:

Divide the participants into groups and give them the following tasks.

Describe the rotations presently practiced. Discuss the advantages and inconveniences of these rotations. What roles do legumes have in the rotation? If pigeon pea is grown, compare with the rotations presented in this chapter and discuss possible alternatives to the present practice. Also discuss how pigeon pea can offer the greatest benefits: if grown for grains, as a green manure, as a crop with long duration or as a crop with short duration?

Collect the results from the groups and draw conclusions together.

4.5 Pigeon Pea							3
Examples of crop rotations with pigeon pea							
	1 st Crop	2 nd Crop	3 rd Crop	4 th Crop	5 th Crop	6 th Crop	
Example 1	Maize	Groundnut	Tobacco	Pigeon pea			
Example 2	Sorghum	Pigeon pea	Safflower	Groundnut	Wheat	Paddy	
Example 3	Maize	Pigeon pea	Wheat	Oat	Safflower	Cotton	
Example 4	Finger millet	Pigeon pea	Castor	Sorghum	Chillies		

TRANSPARENCY 4.5 (3): SOME EXAMPLES OF ROTATIONS WITH PIGEON PEAS

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Intercropping

Due to its deep root system, pigeon pea offers less underground competition to associated crops than some other legumes. As its initial growth is slow, intercropped pigeon pea makes less initial demands for light, water and nutrients than a short season cash crop. In traditional intercropping systems, pigeon pea is grown in association with a wide range of crops.

- Cereals: sorghum, maize, pearl millet, foxtail millet, finger millet, rain-fed rice and wheat
- Legumes: groundnut, cowpea, mung bean, black gram, soybean and phaseolus bean
- Long season annuals: castor, cotton

Most commonly pigeon pea is intercropped with cereals.

Pigeon pea is sown in rows at a wide row distance of 1.2 to 2.1 meters depending on the associated crop. About 3 to 4 seeds are planted per hill, later reduced to 2 plants per hill.

INTERCROPPING PARTNERS	SOWING PATTERN
Sorghum + Pigeon pea	Paired rows at 30:30:60 cm
Pearl millet + Pigeon pea	Paired rows at 30:30:60 cm
Maize + Pigeon pea	Paired rows at 40:40:80 cm or uniform rows at 60 cm
Pigeon pea + Upland rice	Uniform rows at 60-75 cm
Pigeon pea + Groundnut	Uniform rows at 75-90 cm
Pigeon pea + Soybean, Mung bean or Black gram	Uniform rows at 75 cm or uniform rows at 50 cm

In Kenya and Tanzania, one recommendation for intercropping involves planting paired rows of medium and long duration pigeon pea combined with three rows of maize. This system increases pigeon pea yields by 55 % with no accompanying decline in maize production and no increase in labor.

Currently, pigeon pea is gaining importance as a trap crop in cotton for the cotton bollworm. Ideally, intercropped crops yield higher due to a better use of the natural resources and less stress from climate and pests. Thus, economic revenue is both higher and safer.

Sharing experiences:


Ask the participants what the advantages of intercropping are. Compare their answers with the information found in chapter 4.2 of the Basic Manual. Is intercropping practiced in the region? What experiments have been carried out?

Discuss the transparency concerning intercropping pigeon pea. Is there any combination that may be appropriate in this region?


4.5. Pigeon Pea **4**

Common intercropping partners of pigeon pea

CEREALS	Sorghum	Maize	Rain-fed rice	Millet	Wheat
LEGUMES	Cowpea	Black gram	Groundnut	Beans	
LONG-SEASON ANNUALS	Castor	Cotton			



Pigeon pea intercropped with cotton



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TRANSPARENCY 4.5 (4): COMMON INTERCROPPING PARTNERS OF PIGEON PEA

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Green manure

In some areas of Africa and India, pigeon pea is cultivated as a green manure to supply organic matter to the soil and to control soil erosion. Its extensive root system makes the soil more friable, improves tilth and facilitates the infiltration of water. Nitrogen benefit from nodulation is highest if pigeon pea is cut at flowering.

Tall varieties of pigeon pea can be used as a semi-permanent, perennial component in alley cropping systems (e.g. gliricida + maize + pigeon pea). In this function, pigeon pea plants serve as a windbreak and hedge and are used for food and fodder. The foliage should be trimmed back to one meter and used as mulch at the beginning of the growing season or worked into the soil. Perennial pigeon pea varieties continue to grow and protect the soil even after the intercrops have been harvested.

Pigeon pea is commonly grown as a green manure with cotton or cereals such as sorghum, finger millet or maize.

Example: Pigeon pea green manure in maize-cassava intercropping

In cassava-maize intercropping, pigeon pea is a simultaneous fallow component, which helps sustain moderate yields of maize and cassava, provided that insects, nematodes and diseases do not lower its high biomass productivity where cropping continues for more than two years. When used as an annual alley hedge, cutting pigeon pea earlier and more frequently can increase both dry matter and nutrient yields without decreasing the grain and firewood yields later in the season. In the long term, though, continuous cropping of pigeon pea leads to increases in the populations of insects and nematodes, and diseases become more prevalent in the fields. This results in significant decreases in productivity and yields.

Motivation:

Divide the participants into groups and ask them to discuss the use of green manures in crop rotations. Compare their answers with the information given in chapter 4.5.2 of the Basic Manual.

Compare the benefits of pigeon pea as a green manure with those of other species used in local farming. Define the criteria that are relevant for choosing a green manure. Draw a table on the board as shown below and fill it out together.

	Pigeon pea	?	?
Nitrogen fixation			
Weed suppression			
Rooting			
Biomass production			
Robustness			
Uses			
Etc.			

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Crop planning and sowing

Under rain-fed conditions pigeon pea is usually sown at the beginning of the rainy season to ensure sufficient vegetative growth before flowering and to avoid early drought stress.

The soil is prepared by plowing during the dry season, followed by two to three passages with the harrow. In dry regions or in periods of water shortage, it is recommended that tilling takes place at night to conserve soil moisture. Where there is any risk of waterlogging, furrows are recommended.

If available, animal manure can be spread two to four weeks before sowing and worked into the soil superficially.

Pigeon pea is sown at a depth of 2.5 to 5 cm. Deep sowing is recommended in dry conditions. The sowing rate depends on the desired plant density and the cultivars used (short, medium or long cultivation period), the cropping system (rotation or intercropped) and the germination rate of the seeds. The longer the cultivation period is, the lower the ideal plant density. For extra-short cultivars a density of 300,000 plants per hectare is recommended; for cultivars with a short and medium cultivation period 80,000 to 100,000 plants should be used; for those with a long cultivation period, the target should be around 50,000 to 60,000 plants per hectare.

Pigeon pea seedlings emerge two to three weeks after sowing. Vegetative growth begins slowly but accelerates at two to three months. Growth is stronger under long day conditions, but short day conditions induce flowering. Flowering usually starts 60 to 200 days after sowing. Under many conditions plants continue to flower while the pods ripen. New varieties are less sensitive to day length.

Discussion:

Which type of duration of pigeon pea (long season, medium or short) and which time of sowing are best?

Discuss the advantages and disadvantages of different times of sowing (these may also be related to different types of pigeon pea).

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4.5.3 Soil protection and weed management

Weed management

Pigeon pea competes poorly with weeds until it is well established. Due to its slow early growth, it commonly takes 45 to 50 days to cover the soil. The low competitiveness can greatly affect crop yields where there is a lot of pressure from weeds.

Preventive weed management measures must therefore be taken into account. In cases of high weed pressure, a weed cure is recommended prior to sowing. A possible weed cure is to prepare the seedbed early and harrow it superficially when the weeds have developed one to two leaves. This measure should be repeated several times if possible.

After sowing and before emergence of the plants, weeds can be disturbed once more with a curry-comb. The pigeon pea plants must be at least 2.5 cm below the soil surface to avoid being harmed.

Once the pigeon pea plants have emerged, they can be weeded mechanically. Special attention should be given to conserving moisture and avoiding damage to the pigeon pea plants.

A common method of weed control in traditional pigeon pea cultivation is to make two passages through the crops, pulling out the weeds by hand. The first weeding should be done 25 to 30 days after sowing and the second at 45 to 50 days. Mechanical post-emergence regulation of the weeds is possible as long as the pigeon pea plants are smaller than 10 cm.

Sharing experiences: Weed management

Depending on whether the participants have experience with the cultivation of pigeon pea, invite them to share experiences with weed management in general (not using chemicals) or with regard to the control of weeds in pigeon pea specifically.

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4.5.4 Supplying nutrient and organic fertilization

Pigeon pea plants develop an extensive root system, which allows them to access nutrients from deep layers of the soil. In traditional farming systems no fertilizers are applied to pigeon pea. Depending on the status of the crop and the intensity of the organic farming system, application of organic fertilizers may be appropriate.

Like other legumes, pigeon pea has the ability to fix nitrogen from the atmosphere in its root nodules. Therefore, the crop is not very dependent on the amount of nitrogen in the soil or on the application of fertilizers to satisfy its nitrogen requirements.

In their early stages, pigeon pea seedlings depend on some soil nitrogen. Thus, in poor soils it is recommended that a starter dose of organic fertilizer be given (e.g. 10 tons of animal manure per hectare). The manure may be placed in the bottom of the planting furrow or applied along the rows. A banded application of the manure provides maximum nutritional benefits.

Inoculating the seeds with an effective nitrogen-fixing bacterium improves nitrogen fixation in the roots and may raise grain yield by 20 to 70 %. Like cowpea, pigeon pea is also nodulated by *Rhizobia*.

At later stages of plant development, most of the required nitrogen is derived from fixation in the nodules. The quantity of nitrogen supplied in this way can vary from a few to 40 kilograms, depending on the variety. In northern India a type of pigeon pea is reported to grow which can fix up to 200 kilograms of nitrogen per hectare over a period of 40 weeks.

Phosphorus is theoretically the limiting nutrient in pigeon pea cultivation. Trials have shown that pigeon pea responds well to small quantities of phosphorus fertilizer. Pigeon pea seems, however, to have a special mechanism to extract phosphorus from the soil. Some research in India has shown that the plant's roots release piscidic acid, which reacts with ironbound phosphate in the soil, making it plant soluble. This mechanism increases not only the availability of soluble phosphorus for the pigeon pea plants themselves, but also for subsequent crops in the rotation cycle. Pigeon pea also hosts mycorrhiza fungi in its roots, which allows it to access phosphorus and zinc more easily. The application of some farmyard manure or commercial phosphorus fertilizer is recommended, especially if the plants show deficiency symptoms (stunted growth and dark green leaves).

Deficiencies of potassium, zinc and other micronutrients have been recorded in most soils. Generally, small amounts of animal manure applied to the soil during field preparation helps to satisfy these needs. If soil analysis shows low reserves of potassium, the certification bodies generally allow the use of potassium magnesia (potassium sulfate).

Discussion: Animal manure - yes or no?


Get the participants to discuss which fertilization strategy proves best under local conditions to ensure a sufficient nutrient supply for pigeon pea or other legume crops.

Discuss the advantages and disadvantages of using animal manure to fertilize pigeon pea. If helpful, write the answers on cards and pin them onto a board (as shown below).

Compare with the transparency below.

Application of animal manure:

Advantages	Disadvantages
?	?

4.5. Pigeon Pea		5
Advantages and disadvantages of applying animal manure to pigeon pea		
Advantages	Disadvantages	
Serves as starter dose to encourage nitrogen fixation	Proper composting necessary to avoid spreading weed seeds	
Provides small amounts of micronutrients (Zn, K, ...)	Not available for other crops	
Feeds the soil organisms		
Increases soil organic matter		
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TRANSPARENCY 4.5 (5): ARGUMENTS FOR AND AGAINST AN APPLICATION OF ANIMAL MANURE

4 Management Guide for Crops

4.5.5 Pest and disease management

Legumes are generally damaged more by insects than cereal crops are. Pigeon pea can also be attacked by many pathogens including fungi, bacteria, viruses, nematodes, mycoplasma organisms and pests. The traditional varieties with medium to long duration are known to be particularly susceptible. Pests in particular can devastate a crop completely. In general, however, only a few of them cause economic losses and their distribution is in many cases geographically restricted.

Pest management

Several insects attack pigeon pea. In India, over 200 species have been recorded feeding on the crop, most of them after flowering only. The most important pests are the pod borer, the pod fly, scale insects and the blue butterfly.

In organic farming, pest management aims to reduce the risk of an attack by limiting the population of potentially harmful insects and avoiding the coincidence of pests with the crop at critical stages (for influencing factors see chapter 5.2.1 of the Basic Manual). Encouraging natural enemies such as wasps and birds can decisively reduce the pressure of pests. New varieties with a short duration have proved to be less affected by pests, as their exposure is reduced. Direct control is possible by using repellents such as Neem seed kernel, chili or garlic extract, or by spraying natural toxic substances. Some farmers shake the plants and collect the pest larvae on plastic sheets dragged between the rows. The larvae are then fed to chickens or killed.

Pod borer (*Helicoverpa armigera*) destroys the buds, flowers and pods of the pigeon pea; in the absence of flowers or pods they will feed on the leaves. In some areas the pest can devastate the crop. Preventive measures focus on the use of tolerant or resistant varieties, avoiding coincidence with the pest, intercropping, checking broad-leaved weeds, growing trap crops such as sunflower and okra, spraying repellent preparations (such as Neem seed kernel, *Tephrosia*, tobacco, *Pongamia*, chili-garlic, and botanical preparations) and encouraging natural enemies (such as *Trichogramma*). The efficiency of preventive measures has so far, however, been rather low against this pest.

In organic farming direct control is possible by spraying *Bacillus thuringiensis* or NVP. Pheromone and light traps are also used. Cards with larvae of *Trichogramma* can be hung out (see transparency 5.2.3 of the Basic Manual) to parasitize the pest. The application of pesticides is generally not economic in extensive cultivation and is difficult in tall crops. Because of its long flowering period, pigeon pea may partially compensate for attack by pests such as *Heliothis* borers and *Agromyza* fruit flies by renewed flowering.

Sharing experiences:

Discuss which pests are known to attack pigeon pea locally and what preventive and direct methods are used to control the pest.

4.5 Pigeon Pea		6
Major pests and their control in organic pigeon pea		
Pest	Preventive measures	Direct control measures
Pod borer (<i>Helicoverpa armigera</i>)	<ul style="list-style-type: none"> Use tolerant/resistant varieties Regular monitoring especially from flowering onwards Cultivate trap crops: sunflower, okra Encourage natural enemies 	<ul style="list-style-type: none"> Bt-spray, NVP spray Pheromone traps, light traps Neem seed kernel, tephrosia, tobacco, pongamia, chili-garlic, botanical preparations Trichogramma cards
Pod fly (<i>Melanagromyza obtusa</i>)	<ul style="list-style-type: none"> Use tolerant/resistant varieties Appropriate timing of crop 	
Blue butterfly (<i>Lampides boeticus</i> ; <i>Catochrysops strabo</i>)	<ul style="list-style-type: none"> Encourage natural enemies Use tolerant/resistant varieties 	<ul style="list-style-type: none"> Pheromone traps, light traps Botanical preparations (Neem, tobacco, pongamia...)
Scale insects (<i>Ceroplastodes cajani</i> ; <i>Icerya purchasi</i>)	<ul style="list-style-type: none"> Encourage natural enemies by destroying ant colonies 	

TRANSPARENCY 4.5 (6): CONTROL MEASURES AGAINST THE MOST COMMON PESTS IN PIGEON PEA

4 Management Guide for Crops

Pod fly (*Melanagromyza obtusa*) infested pods do not show external evidence of damage until the fully grown larvae chew exit holes through the walls. Damaged seeds are unfit for human consumption and are not viable for germination. The complete destruction of crops as a result of pod fly infestation has been reported. Control measures in organic farming focus predominantly on the development of resistant varieties. Planting time can also influence the level of attack.

Scale insects (*Ceroplastodes cajani*, *Icerya purchasi*) feed on the plant sap, mainly on the stem and occasionally on the leaves. They prefer to attack perennial pigeon pea crops.

Blue butterfly (*Lampides boeticus*; *Catochrysops strabo*) larvae of both species feed on the leaves, buds, flowers and pods during the vegetative stage. Effective preventive measures include encouraging natural enemies and using tolerant or resistant varieties. Possible direct control methods include pheromone traps, light traps and botanical preparations such as Neem, tobacco or *Pongamia*.

Disease management

There are several diseases that can be economically relevant in pigeon pea cultivation.

Sterility mosaic virus is transmitted by mites and attacks the whole plant. The first symptoms appear as the clearing up of the veins on young leaves, but it spreads, producing a mosaic pattern that covers the entire plant.

Fusarium wilt (*Fusarium udum*) is the most destructive fungal disease of pigeon pea. It attacks the whole plant, starting from the root and leading to the wilting of seedlings and bigger plants. The disease is both seed and soil-borne. Crop rotation (especially with tobacco, sorghum or castor) is advisable against this disease. Solarization of the field in the summer reduces inoculums of the pathogen.

Dry root rot (*Macrophomina phaseolina*) affects the finer roots, in particular in the reproductive stage, when the plants are more susceptible. Infected plants suddenly wilt and die.

Rust (*Uredo cajani*) fungus attacks the leaves, causing them to dry out and eventually to drop off. Severe infections can lead to extensive defoliation.

Working group:

Divide the participants into groups and ask them to define the main diseases in pigeon pea in their region. Have any preventive and direct methods proved to be effective? Invite them to present their answers to the others. Draw conclusions together for disease control in pigeon pea. Does the transparency offer any additional information?

4.5 Pigeon Pea		7
Diseases and their control in organic pigeon pea		
Disease	Preventive measures	Direct control measures
Sterility mosaic (<i>Sterility mosaic virus</i>)	<ul style="list-style-type: none"> Use resistant varieties Adequate soil bed preparation exposing the remaining pupae to the sun Adequate crop rotation 	<ul style="list-style-type: none"> Destroy sources of sterility mosaic inoculum on perennial or ratooned pigeon pea Uproot infected plants at an early stage of diseased development and destroy them Broadcast leftover cooled rice in the field to attract predatory birds Physical shaking of plants to dislodge the larvae
Fusarium wilt (<i>Fusarium udum</i>)	<ul style="list-style-type: none"> Select fields with no previous record of wilt in at least the last 3 years Rotate with tobacco, sorghum or castor Intercrop with sorghum Use resistant varieties 	<ul style="list-style-type: none"> Uproot wilted plants and use them for fuel wood Collect and burn plant residues after harvesting Soil application of 5 kg of Trichoderma formulation per hectare Seed treatment with chitinolytic <i>Alcaligenes xylosoxydans</i>
Dry root rot (<i>Macrophomina phaseolina</i>)	<ul style="list-style-type: none"> Use resistant varieties Select fields with no previous record of dry root rot Avoid water stress at flowering and podding 	<ul style="list-style-type: none"> Seed treatment with <i>Trichoderma viridae</i> Soil treatment with fluorescent <i>Pseudomonas</i>
Phytophthora blight (<i>Phytophthora drechsleri</i>)	<ul style="list-style-type: none"> Avoid fields with patches that are prone to waterlogging Select fields with no previous record of blight Use of raised seed beds with good drainage 	<ul style="list-style-type: none"> Soil treatment with <i>Trichoderma harzianum</i> Seed treatment with <i>Trichoderma viride</i>

TRANSPARENCY 4.5 (7): METHODS TO CONTROL THE MAJOR DISEASES IN ORGANIC PIGEON PEA

4 Management Guide for Crops

Phytophthora blight (*Phytophthora drechsleri*) is a devastating disease which attacks the above-ground parts of young plants and leads in many cases to the rapid death of the whole plant. Infected plants that survive the disease often produce large galls on their stems, especially at the edges of the lesions.

Alternaria leaf blight (*Alternaria tenuissima*, *A. alternata*) affects the leaves and causes severe defoliation and the drying up of infected branches.

4.5.6 Water management and irrigation

Pigeon pea needs about 200 to 240 mm of water to produce about 1 ton of grain per hectare under traditional and organic production systems.

Water management in organic pigeon pea cultivation aims at providing sufficient soil moisture at the sowing stage and at preserving soil moisture during growth (see chapter 3.5 of the Basic Manual).

As pigeon pea is usually sown during the rainy season, and in the case of traditional types with a long duration, grown to maturity during the subsequent dry season using residual water, irrigation is in general not necessary.

Sufficient water from flowering to pod filling does increase grain yield, since these stages are sensitive to water stress. Excessive moisture promotes vegetative growth and enhances the incidence of *Phytophthora* and *Alternaria* blight.

Typical water stress symptoms of pigeon pea are leaves which point toward the sun at noon. Irrigation before plants show drought symptoms is wasteful and can cause waterlogging, which is detrimental to appropriate development of pigeon pea.

Because of its susceptibility to waterlogging, furrow irrigation during growth is not recommended, except in very well-drained soils. In intensive cropping of short-duration cultivars, irrigation may be required.

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4.5.7 Harvesting and post-harvest handling

Harvesting

The time for harvesting pigeon pea depends mainly on intended use, but also on the greenness of the pods and the variety cultivated. For long-duration types, the first harvest for human consumption is expected to be four to six months after sowing late in the dry season, when only a few other legumes are available. If used for forage, pigeon peas are cut before flowering or when first pods ripen.

Pigeon pea leaves, unlike other crops, remain green even when the pods are ready for harvest. This makes the decision to harvest difficult. A general rule is that harvest should be underway when 75 to 80% of the pods are well-filled and begin to lose their bright green color, or when pods turn brown and are dry.

The yield of dry seeds ranges from below 1 to 5 tons per hectare, depending on the growing conditions and the cultivation system.

Methods of harvesting

Traditionally pigeon peas are harvested by cutting the stem at the base with an axe or sickle. The harvested plants are bundled and transported to a threshing floor, where they are placed upright to dry. Alternatively, the harvested plants can be left to dry in the field.

Another way to harvest pigeon peas is to pick the pods by hand. This method is commonly used when the green pods are to be used as a vegetable; it is also recommended when the intention is to harvest more than once. The crop will flower again and build new pods, though yield generally declines after the first harvest.

When it is not feasible to handpick the pods, the upper branches, which carry the mature pods, are cut. When using this method, special attention must be paid to leave as many leaves as possible on the plant to allow it to grow again. This method, however, delays the second harvest and usually results in lower yields than handpicking. The green pods should not be exposed to the sun as they heat up and get sun-burned.

Mechanical harvest is possible using a combine-harvester, but is restricted to cultivars which mature uniformly and carry the pods at the same level above the ground.

Discussion: How to harvest pigeon peas?

Discuss how the participants harvest organic pigeon pea. If necessary, develop new strategies together to harvest and thresh this crop.



TRANSPARENCY 4.5 (8): METHODS OF HARVESTING PIGEON PEA

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Post-harvesting

After harvest the pods must be left to dry to a moisture content of 10 % in order to avoid mold during storage. Once dried, the pods must be beaten in cloth sacks, or spread on the threshing floor and beaten with sticks to separate the seeds from the pods. They can also be threshed using wooden flails or trampling. Pods that remain unbroken must be opened by hand. The grains are cleaned by winnowing.

Ratoon cropping – an alternative?

Ratoon cropping refers to a multiple harvest system, in which the regenerated stubble of the established crop in the field is managed for subsequent production. The ratoon crop usually produces 50 to 65 % of the sown crop yield. This method is not advised if rotation is possible. To increase the yield from the ratoon crop, irrigation is recommended after the main harvest. In a ratoon cropping system, pigeon pea should be cut back after the onset of the first rains to reduce mortality. The best ratooning height is 30 to 45 cm above ground.

Ratoon cropping bears considerable risks. It can provide good development conditions for soil-borne diseases, such as the sterility mosaic disease wilt (*Fusarium udum*) and can encourage dry root rot (*Macrophomina phaseolina*).

The advantages of this system are that it minimizes cultivation costs, avoids the risks associated with sowing a second crop under rain-fed conditions and provides additional returns. It is not, however, recommended that pigeon pea be grown for longer than two consecutive years, as the risk of pest and diseases increases rapidly.

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4.5.8 Economic and marketing aspects of pigeon pea production

Pigeon pea is a multipurpose plant. The crop provides food, fuel, forage and even serves as a building material. Although most pigeon pea production occurs in India (90 %), the crop is grown all over the world and serves as an important source of protein for over a billion people.

Food

Pigeon pea is mainly used as a food. Most people de-husk and split the cotyledons to make foods such as dhal. The dry seeds contain about 22 % protein, as well as carbohydrates, fiber, minerals and fat, and are an important protein food in many tropical areas. Green peas and pods are consumed as a fresh vegetable. The peas are also used to make a great variety of snacks, including spicy crisps, grains and noodles.

Fodder

The young leaves and shoots of pigeon pea make excellent fodder. Crude protein values of fresh forage range from 15 to 24 %. The plant's exceptional nutritional value and high productivity can make it an interesting crop for livestock farmers. As well as the green plant parts, crushed dry seeds can be fed to animals.

Wood

Pigeon pea stalks are an important household fuel in many areas. While the thicker main stem is used as firewood, the thin straight branches are used to thatch roofs or to make baskets.

Other uses

Pigeon pea also serves as a host for the scale insect *Kerria lacca* (family of the *Coccoidea*), which secretes a resinous substance that is used as a natural varnish. Brood varnish insects are bound onto the stem of one-year-old pigeon pea plants just below the first branch. The larvae colonize the branches and secrete the gummy substance. The coated branches are harvested twice a year. The substance finds use in industrial applications for surface coatings, textiles, wood treatment, printing, pharmaceutical remedies, adhesives and in the electrical industry.

Pigeon pea is also believed to have medicinal properties. The salted leaf juice is taken for jaundice in some countries. Floral decoctions are used for bronchitis, coughs and pneumonia. The dried roots are also used as alexeritics, anthelmintics and expectorants.

Discussion: Drawing conclusions on pigeon pea and defining its potentials

After having presented the different aspects of organic cultivation of pigeon pea and the uses of the crop, draw conclusions by going over all the notes on the pin board, the transparencies or the notes of the participants.

- *Why is pigeon pea valuable?*
- *Does pigeon pea offer advantages compared to other legumes?*
- *What relevance does the crop have in terms of self-sufficiency?*
- *How do we estimate the market potential for organically grown pigeon peas?*
- *What impressions have participants formed about the cultivation or marketing of pigeon pea?*
- *What may be the next necessary steps?*

If helpful, note the conclusions and add them to the course documentation.

Recommended websites:

- www.icrisat.org - general information on the crop and additional information on pests and diseases
- www.vusat.org - general crop management; examples of cropping systems
- www.odi.org.uk - findings from research on improving market access of smallholders for pigeon pea
- www.vusat.org/learning/agri/Pigeonpea_hm/Index.htm - diseases and pests

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4.6 Dates

Introduction

The date palm (*Phoenix dactylifera* L.) is the oldest tree known to have been cultivated by man. The tree is supposed to have its origins in Northern Africa or Western Asia. Date palms are trees of the arid tropics and are mostly found between the latitudes 10 to 35 ° North of the equator. Today, the main production areas are still in the countries of its origin (i.e. Iran, Egypt, Saudi Arabia, Iraq). Dates are, however, also grown in other areas with dry and warm climates, such as Pakistan, Western India, the southern states of the USA, Mexico, Brazil, Argentina, Southern Africa and Australia. Organic cultivation of date palms is currently concentrated in Egypt, Tunisia, Morocco, Israel and the United States. In 2003, 1200 hectares of date palm were certified organic in Tunisia.

Date palms can easily be grown under harsh conditions, and yield great amounts of fruit with a high nutritional value. The date palm, which can yield for more than 100 years, plays a central role in the traditional farming system of the oasis gardens, where it provides shade, maintains moisture levels and protects the soil (see chapter 2.2).

In the arid regions of North Africa, dates are one of the basic staple foods, due to their high sugar content of 50 % and high level of dry matter. Dates are a good source of fiber, potassium (2.5 times more than bananas), calcium, phosphorus, iron, vitamins A, B1, B2 and niacin.

A date palm may produce from five to more than ten bunches which flower and ripen in succession. Each bunch bears 5 to 15 kg of dates. This results in a yield of 25 to 150 kg of dates per tree. Although other palm species with edible berries exist, the date palm is the only species of economic importance.

Most dates are cultivated for subsistence or sold on local markets, whereas nearly all the certified organic dates which are grown in Northern Africa, are shipped to Europe. Good market opportunities account for the wide interest from growers in organic cultivation. Organic cultivation of dates provides them with a good way to improve their incomes. In order to comply with international quality requirements, organic farmers entering the export market need to acquaint themselves with the specialized farms, packing sheds and warehouses that are required. Furthermore they need to be aware that the market is largely built around a few newly developed high-yielding varieties of date palms.

Lessons to be learned:

- *The date palm is a typical crop of the arid regions and can contribute to sustainable agriculture.*
- *The date palm does not have specific soil requirements.*
- *Availability of water is the essential criterion in site selection.*
- *Diversity and improvement of soil fertility are essential for sustainability.*
- *Soil cover improves the ecological equilibrium in the plantation, protects the soil and, in the long term, improves soil fertility.*
- *Most pests and diseases are easily managed in organic date palm cultivation, thus conversion to organic production is easy provided that prevention measures are applied properly.*
- *Proper handling during harvesting and in the post-harvest process is of major importance to ensure good quality.*

Motivation:

Ask the participants what crops or other trees they know of that contribute to sustainability and equilibrium in arid climates.

Ask them to characterize date palms (strengths and weaknesses) in comparison with the other cited crops.

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4.6.1 Agro-ecological requirements and site selection

Temperature: Palm trees require high temperatures to grow. For flowering, temperatures in the shade must be at least 18 °C, and for fruit setting at least 25 °C. At 9 °C and below, the terminal bud stops growing. Winter temperatures below -8 °C are harmful to the tree. On the other hand, the date palm can tolerate temperatures of up to 50 °C. Date palms also need the cool nights that are typical of the arid tropics. Date palms thus grow well in climates with a mild winter and a long hot summer. For fruit development, a mean temperature of 21 to 30 °C is required for at least one month.

Water and humidity: The date palm is well adapted to dry and semi-dry climates. Nevertheless, the availability of water is beneficial to the tree and to fruit development. With a daily uptake of 150 to 200 liters of water for a single tree, rain-fed date palm cultivation is not possible. A regular supply of water is necessary to ensure that the fruits develop properly. However, rain and excessive relative humidity of the air during flowering inhibit pollination (at 40 to 50 % this becomes critical) and lead to fungal diseases during fruit development. Rainfall during the final maturation of the fruits generally results in great damage due to fruit rot. The ideal situation is to have an annual rainfall of 230 mm with no rain whatsoever during the flowering months.

Wind: Strong roots and a flexible trunk make the date palm quite resistant to winds. The fruit bunches, however, may need some protection from wind to avoid losses.

Soil: Date palms can be grown in a wide variety of soils. However, the trees prefer deep soils with a good texture that allows aeration, soil drainage, easy root development and good water retention. Best yields are obtained on sandy loams. Date palms tolerate an alkaline pH of up to 8. Their salt tolerance is considered to be the highest of all fruit crops, higher than for other salt tolerant crops, such as, pomegranates, figs, olives and grapes that have a medium salt tolerance. Other fruit crops commonly grown together with date palms generally have a low salt tolerance.

Site selection: The main criteria for site selection for date palm cultivation are climate and the availability of water for irrigation. For irrigation, a light slope is preferred and good drainage is advised. It is preferable to have a site that is easily accessible without the risk of water logging or invasion of desert sand. The various varieties have similar soil requirements and all grow easily on the sandy oasis soils.

Motivation: What are the requirements of date palms?

Note the keywords that characterize the requirements of the date palm ("temperature", etc.) and invite the participants to characterize the crop based on their knowledge. Additionally, the requirements of other crops can be examined. After that, present the first transparency and discuss the differences, if there are any.

TRANSPARENCY 4.6 (1): AGRO-ECOLOGICAL REQUIREMENTS OF DATE PALMS AND CRITERIA FOR SITE SELECTION

Discussion: How relevant are the requirements?

Define the ideal cultivation area in the country based on the requirements described. Discuss which agro-ecological requirements of date palm are decisive for quality production. Is it worthwhile to cultivate date palms for commercial use on sites that are not ideal?

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4.6.2 Designing the plantation and establishing the crop

Variety selection

The main criteria for variety selection are the intended consumption, the quality of the fruits and specific agro-ecological requirements (see transparency). In date breeding programs, the main traits that breeders look for are high fruit quality, resistance to cold, rain, specific pests and diseases, tolerance of extreme drought, heavy soil, high pH and salt, and the specific timing of maturity. Varieties harvested at the Khalal stage (half ripe) for local fresh consumption have the advantage that the whole bunch is harvested at the same time, infestation of fruit is low and yields and consequently revenues are therefore high. On international markets, the Medjool, Deglet Nour and Barhi varieties are the most sought after.

From an agronomic perspective, growing many varieties is important for sustainability as it reduces the risk of diseases and improves diversity for marketing (for basic aspects of diversity see chapters 2.1.1, 4.2.1 and 5.1.2 of the Basic Manual). Some high yielding date varieties may therefore be grown for export and other varieties for domestic consumption and local markets.

Propagation of date palms

Date palms are either male or female. It is only possible to make this distinction after three to five years when they flower. Growing trees from seeds gives 50 % male plants, which do not bear fruit. Thus, date palms are usually propagated by cutting off suckers (or offshoots), which the palms produce while they are young.

When cutting off young shoots special attention must be paid to choose only healthy plants from proven female cultivars. Fungal diseases such as *Fusarium* can be transmitted through suckers. In order to avoid the propagation of diseases and pests, seedlings should only be taken from healthy tissue culture.

To obtain strong new trees only specific offshoots should be used. These should grow from the base of the mother tree, have a weight of 15 to 30 kg, be between 1.5 and 2 meters, have thorns and their own roots. The roots are then trimmed back to approximately 5 cm and the leaves are cut off. The offshoots are planted immediately in the place where it is intended that they should grow. The newly planted trees should be irrigated and supervised regularly. It takes about 8 years for an offshoot to give yields of economic value.

Motivation: Is diversity relevant?

Ask the participants what they see as the relevance of diversity in date palm cultivation. How is diversity established in date palm plantations?

4.6. Dates			
Characteristics of some common date varieties			2
Variety	Destination	Characteristics of the fruit	Agroonomic characters
Barhi	Fresh consumption	Round, sweet, juicy, dark yellow, do not store well	Medium to late variety, highly sensitive to frost and, when fruits are ripe, to rain
Hayani	Fresh consumption	Black, shiny, long fruit, not too sweet	Tolerates cold better than other varieties
Medjool	Dried consumption	Light to dark brown, large fruit, soft and very sweet, loose skin, sugar crystallising	Early variety, highly sensitive to rain, fruits highly sensitive to extreme temperatures and humidity
Amari	Dried consumption	Soft, sweet, medium sized	
Deglet Nour	Dried consumption	Semi-soft, medium sweet, renowned flavor, light to dark brown, stores well	Drought and rain sensitive, highly sensitive to Bayoud
Hadrawi	Dried consumption	Sweet, fleshy, dark brown	
Zahidi	Dried consumption	Golden, round, medium sized, not too sweet	More resistant to cold
Mesalber		Great size	

TRANSPARENCY 4.6 (2): SOME VARIETIES AND THEIR CHARACTERISTICS

Exercise: Characterization of the varieties grown

Characterize the varieties that are grown by the participants. Use the transparency above, if helpful. What characteristics are essential? Are there any major differences? Are the criteria in variety selection the same for organic as for conventional cultivation? Are the varieties most in demand on the international markets also the best varieties for organic cultivation? Is there any necessity to introduce new varieties?

Demonstration: Propagation

If possible, demonstrate to the participants how to choose the right offshoots and how to plant them correctly.

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Intercropping

In many regions date palms are traditionally intercropped with other fruit trees such as citrus, pomegranates, apricots, figs, olives, grapes or guava and with arable crops such as barley, wheat, alfalfa or vegetables such as beans.

Diversification of crops offers many advantages compared to monoculture and corresponds to the principles of organic farming (see transparency). The market potential and the need for fodder for livestock production will largely determine which crops are best cultivated alongside date palms on a given farm. Intercropping of date palms with alfalfa and other legumes provides the soil with nitrogen. Green fences of Tamarisk (*Tamarix aphylla*) and Ironwood (*Casuarina equisetifolia*) or strips of Spanish Reed (*Arundo donax*) offer shelter, especially to young trees, thus intercrops have many uses.

Planting

Tree density of the plantation can vary from 100 to 200 trees per hectare (which corresponds to a planting distance of 7 to 10 meters within and between the rows), depending on the cropping system and climate. Wider planting of the trees gives better aeration of the date palms and allows more sunlight to the crops in the middle and the bottom level of the plantation. On the other hand, narrow planting, as practiced in traditional oasis farming, creates a favorable microclimate, through creating a dense canopy.


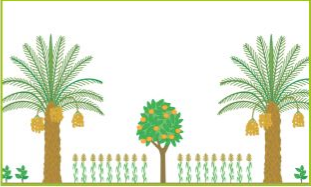
For every 50 to 100 female trees, one male must be planted in order to provide enough pollen for artificial pollination. For natural pollination, three male trees are necessary for every 100 palms.

Date palms can be planted throughout the year, providing that they are watered sufficiently. For planting, a hole one meter wide and one meter deep is prepared. The bottom half of the planting hole is filled with a mixture of compost or manure from organic or extensive livestock husbandry and soil. Ideally, the holes are prepared two to three months before planting to allow the organic material to decompose and settle. The planting holes are then filled with soil. The offshoots are buried firmly up to their maximum diameter, taking care that the crown remains 10–15 cm above the soil so that irrigation water does not touch it. The freshly planted palms are then watered daily for one or two weeks, and fenced in to protect them from livestock and protected with palm leaves to minimize water loss.

In their early stages, the palms may be intercropped with low crops like barley, pulses, and wheat. When the palms are taller, apricots, figs, grapes, oranges, peaches, pomegranates, etc. are intercropped instead.

4.6. Dates 3

Comparison of plantation designs

Traditional high density plantation (oasis)	"New" low density plantation
	
Advantages <ul style="list-style-type: none">• Favorable temperate microclimate• Shade for secondary crops	Advantages <ul style="list-style-type: none">• Lower disease pressure• More space for secondary crops• Mechanization possible
Disadvantages <ul style="list-style-type: none">• Less space for secondary crops• Mechanization difficult• Higher disease pressure	Disadvantages <ul style="list-style-type: none">• Higher solar radiation

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TRANSPARENCY 4.6 (3): COMPARISON OF PLANTATION DESIGNS

Discussion and exercise: Design an organic date palm plantation

Based on the transparency, discuss the potential of low density date palm plantation and subsequently design a diverse cropping system which enhances soil fertility and has economic potential when cultivated organically.

If appropriate, discuss the necessity of transforming a traditional date palm plantation to a low density cropping system.

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4.6.3 Soil protection and weed management

Soil protection

In arid and hot climates, wind erosion and high radiation are the main factors that reduce soil fertility. Wind carries away the highly fertile fine clay and humus fractions of the soil, while high radiation reduces plant and root growth and endangers soil life. Soil protection measures in date palm plantations are therefore needed to protect the soil against these two threats.

Date palms reduce wind speed but, in open spaces, they may not be sufficient to control wind erosion. A multilayer farming system and living hedges (narrow bands of closely planted woody species) of well adapted multipurpose trees like Polynesian Ironwood (*Casuarina* spp.), strips of Spanish Reed (*Arundo donax*), or stone walls significantly reduce the effect of strong winds.

Permanent soil cover may be needed to reduce the negative impacts of solar radiation. Mulches are being tested as an alternative to green soil covers. If no crops are cultivated under the palm trees weeds can, to some extent, help reduce erosion.

Beside their primary advantages green soil covers (and to a lesser extent mulches and weeds) have a number of secondary advantages, which improve the ecological equilibrium in the plantation as well as long term soil fertility:

- They reduce the temperature at the soil surface, and thus water evaporation.
- They increase root growth and thus improve drainage in heavy soils.
- They reduce water erosion.
- They encourage beneficial insect populations to build up and control pests.
- When incorporated into the soil they add organic material, and enhance soil fertility.

Group work: Soil protection measures




Invite the participants to assess the soil protection measures that are practiced in date palm plantations in the region. Ask them the following questions:



- What soil erosion problems are occurring?
- What are the reasons for these problems?
- What attempts have been made to solve these problems?
- What were the successes and failures of these attempts?
- What recommendations for improvements can be made for organic cultivation of the plantation?

Ask the participants to present their results to the others and, if helpful, conclude with information from the Basic Manual.

4.6. Dates
4

Soil protection in date palm cultivation

Reduce wind speed by:	Reduce water erosion by:	Reduce solar radiation by:
 <ul style="list-style-type: none"> ▪ Hedges ▪ Multilayer cultivation 	 <ul style="list-style-type: none"> ▪ Using dams to guide the flow of water ▪ (Permanent) soil cover or mulches ▪ Improving soil structure (through the build up of organic matter) 	 <ul style="list-style-type: none"> ▪ Multilayer cultivation ▪ (Permanent) soil cover

TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.6 (4): AIMS OF AND MEASURES FOR SOIL PROTECTION IN DATE PALM CULTIVATION

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Weed management

Direct competition by weeds is, if at all, only of importance for newly planted date palms. Weed control measures thus primarily depend on the competitiveness of the crops that are grown beneath the trees. If weed sensitive crops such as vegetables, grapes, fig trees or pomegranates are grown between the date palms, special attention must be paid to weed control.

Measures to prevent weed infestation include:

- Rotation including weed competitive crops (i.e. alfalfa)
- Cultivation of dense green manure crops
- Filtration of irrigation water to prevent dispersion of seeds
- Proper composting of plant residues to kill the weed seeds

To avoid dispersion of weeds that are propagated by seeds, weeds should be hoed after flowering and left as mulch on the soil surface, incorporated superficially into the soil, or collected and composted.

In traditional date palm plantations, couch grass is the predominant weed. The best strategy to fight couch grass is to plough the soil several times a year with appropriate equipment.

4.6.4 Supplying nutrients and organic fertilization

Research has shown that the supply of nitrogen strongly influences the yield and quality of the dates, whereas the influence of phosphorus and potassium has not been proven. Although, some experts say that potassium supply does also affect fruit size and fruit quality. Conventional agriculturalists have reported that the application of excessive quantities of mineral nitrogen fertilizer reduces fruit quality and shelf life.

Nutrient deficiencies in date palms result in reduced length and number of leaves, making the date palm more sensitive to diseases, insect attacks and physiological disorders.

Traditionally, fertilization of the date palms relies on the application of pure animal manure collected from goats, sheep or camels and dug into the soil around the trees. Application of four wheelbarrows to each tree, every two to three years is a common practice. In older plantations, sand from dunes is sometimes brought in to loosen compacted soils. Similar results can be obtained by growing crops which build a deep and intensive root system.

Sharing experiences: Weeds

Ask the participants the following questions: Are there any specific weeds, which can become a problem in date palm plantations in the region? If yes, which? Which non-chemical measures have been applied and proved to bring good results, especially in the long term?

Discussion: Compare different approaches to plant fertilization

Together with the participants, assess approaches and methods of fertilization of the date palms in both traditional and "conventional" intensive cultivation systems. Describe a fertilization concept based on organic principles. Try to find answers to the following questions: What criteria are of special relevance? What practical consequences result from this? Are commercial fertilizers really necessary?

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Organic farming, similarly to traditional farming, uses farmyard animal manures and grows legumes to supply the trees with nutrients. Organic farming, however, puts more emphasis on the production of compost from manure produced on the farm. The reason for this is that a regular supply of compost is the best way to improve the organic matter content of the soil and to ensure balanced plant nutrition. Increased organic matter content also improves the water holding capacity of the soil and consequently the efficiency of irrigation. Thus, from an organic perspective, animal manure is best composted together with plant residues. Compost should be applied at least every four years, after harvesting and pruning (during wintertime), around the base of the palms.

If compost is applied regularly, the application of commercial fertilizers is generally not necessary. Specific mineral fertilizers may, however, be needed if soil analysis shows very low levels of a main nutrient, or if plants show deficiency symptoms such as manganese deficiency. Natural phosphate, calcium carbonate, etc. may be directly applied to the soil when there is a deficiency of these elements. Natural phosphate can also be added to the compost (at a rate of approximately 15 kg per ton of compost) to encourage the composting process. Liquid fertilizer products, authorized by organic standards are mainly used when the organic matter content of the soil is lower than 1% and when annual crops are grown.

Mineral nitrogen fertilizers and highly soluble phosphorus and potassium fertilizers are not allowed in organic farming.

The cultivation of the soil has an indirect impact on plant fertilization as it enhances aeration and thus biological activity of the soil, the motor for mineralization of nutrients.

Sharing experiences: Making compost

Invite the participants to share experiences of making compost with plant residues and animal manures. The following questions may be used to guide the process: What farmyard and external primary materials are available? What qualities do they have for making compost? What observations have been made when making compost? Is farm-produced compost economically viable? Can buying compost be an alternative? In cases where compost has already been applied over several years, have any impacts been observed in terms of yield, water retention and plant health?

For additional information on compost production see chapter 4.4.3 of the Basic Manual.

4.6. Dates 5

Ensuring nutrient supply in organic date palms



Challenges in nutrient supply:

- Can we fertilize the crops from farm sources?
- Can we give up commercial mineral fertilizers?
- How do we get enough organic material?

Fertilization strategy

1. Grow leguminous intercrops and green manure crops to improve nitrogen supply
2. Produce compost to build up soil fertility
3. Where necessary, use accepted commercial fertilizers, to satisfy specific needs of the crops, but only on the basis of soil analysis



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TRANSPARENCY 4.6 (5): MAJOR QUESTIONS AND BASIC STRATEGY FOR NUTRIENT SUPPLY OF ORGANIC DATE PALMS

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4.6.5 Pest and disease management

Although the date palm is considered to be relatively free of diseases due to the hot and dry climate, it does suffer from attack by some pests. The main pathogen affecting the date palm is *Fusarium oxysporum f.sp. albedinis* or Bayoud, which is responsible for the death of many trees. Other fungi that cause leaf spots or root and fruit rot also affect date palms. They are also affected by palm lethal yellowing phytoplasma (the main host is the coconut palm), a very serious disease that is transmitted by *Myndus* spp., a plant hopper.

The date worm (*Ectomyelois ceratonia* Zeller) and the red palm weevil (*Rhynchophorus ferrugineus*) are the two most common pests. Bugs, mites, scales and nematodes can also damage date palms.

In storage, dates may be affected by insects (the most common being the fig moth and the dried fruit beetle) or microbial infestation. Microbial infestation is more common in soft dates because of the higher moisture content, and is due mainly to yeasts that cause fermentation of sugars, and molds that grow on the surface.

Many of the general preventive measures listed in chapter 5.1.2 of the Basic Manual are highly relevant to pest and disease control in organic date palm cultivation. Most of the problems due to a major infestation by diseases and pests have one of the following causes:

- Monoculture cultivation and use of non-resistant and/or few varieties of date palm.
- Small planting distances and thus insufficient aeration within the plantation.
- Cultivation in unfavorable soils.
- Unsuitable site conditions due to a deep water table, insufficient water for regular irrigation, unfavorable climate, etc.
- Insufficient hygiene and crop maintenance (i.e. use of infested planting material or infested leaves and fruits not being removed).

Although all these points are recognized as being of major relevance for disease and pest prevention when properly applied, their impact on the development and the dissemination of a specific pest or disease varies, and may by themselves be insufficient to control some pests.

As in other organic crops, the possibilities for direct disease and pest control are limited in date palm cultivation and success demands good observation of the trees and proper and timely application of preventive strategies. A range of selectively acting, approved products

Group work : Pest and disease control

Ask the participants the problems that they experience with pests and diseases in date palm cultivation within the region. Ask each group to draw the life cycle of one pest or disease on a big piece of paper and to note which preventive and direct measures of control are commonly applied. If needed, participants may be given a list of preventive measures from chapter 5.1.2 of the Basic Manual.

Secondly, give participants a list with the authorized methods and active agents from the organic certifying agency, in order to screen the direct control measures for organic date palm cultivation and check that these are acceptable. Invite the groups to present the results of the exercise and discuss their examples in plenary.

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can be used for pest and disease control. Care should be taken to check with the certifier and to apply them only at the most effective times.

To enhance natural pest control, organic farmers put special emphasis on attracting natural predators by creating a diverse biotope, ideally with, a continuous supply of flowers.

Inflorescence rot or Bayoud (*Fusarium oxysporum*): This is the most important disease in non-suppressive soils in date palm plantations. All plant parts at all stages can be affected. So far, the disease has only spread in North Africa (Morocco, and Western Algeria). Infested trees have a white chlorotic color and leaves fade and wither. Infestation can lead to the death of the tree. The fungus is soil-borne. Its development is encouraged by intensive cultivation of intercropped lucerne, clovers and Egyptian privet. Some varieties (i.e. Takerboucht, Bou Jigou, Taadmant, Bou Stammi) are reported to be resistant to the disease. Most resistant varieties, however, do not produce good quality fruit. Strict use of healthy planting material and a biologically active and aerated soil are important in order to prevent infestation. As some soils are known to suppress the disease, the ability to suppress the disease may theoretically be added to soils where there are infested trees. So far, however, no direct measures against the disease have been found. Thus, infested trees must be destroyed and incinerated, including the roots.

Date worm (*Ectomyelois ceratoniae* Zeller): The date worm is widespread and responsible for about 10-20 % of date losses. It infests both the unripe and ripe fruits of the date palm, and also grows on figs and pomegranates. Primary hosts are pigeon pea and Indian tamarind. The pest has several natural enemies such as parasitoids, predators and a pathogen (*Bacillus thuringiensis kurstaki*).

The life cycle of the date worm starts with the small, white butterfly, which lays eggs into the ripening fruit. Most infested fruits fall to the ground before harvest. Webs spun by the moth sometimes prevent infested fruit from falling to the ground. Diseased fruits should not be left uncollected on the ground, as they can give rise to further infestations in the same year. Control of this pest thus focuses on collecting the fruits infested with the worms at least every four days from September or October (depending on the climate) until harvest. The collected fruits must either be fed immediately to the animals or must be buried at least 30 cm deep. Collection of the infested dates on the ground and of mummified fruits on the tree reduces late infection and the inoculum for the next year's crop. Alternatively, in older plantations sheep can be temporarily grazed in the plantation if no other crops are grown

4.6. Dates				6
Date palm diseases and pests & their possible control measures				
Disease	Important to know	Preventive control measures	Direct control measures	
Bayoud or Inflorescence rot (<i>Fusarium oxysporum</i>)	<ul style="list-style-type: none"> Most important disease in soils that do not suppress this disease Soil-borne fungus Encouraged by intensive cultivation of intercropped lucerne and vegetables Can kill the tree 	<ul style="list-style-type: none"> Only use healthy planting material Use resistant varieties Encourage biological activity and aeration of the soil 	<ul style="list-style-type: none"> Eliminate and burn infested trees, including roots No replanting for at least 5 to 8 years 	
Pest	Important to know	Preventive control measures	Direct control measures	
Date worm	<ul style="list-style-type: none"> Infests both unripe and ripe fruits Infested fruits fall to the ground prematurely or are spun together on the tree 	<ul style="list-style-type: none"> Collect infested fruits every four days at least Grazing of sheep 	<ul style="list-style-type: none"> Spray <i>Bacillus thuringiensis</i> (Bt) Release <i>Trichogramma cacaeciae</i> Use insect-proof nets on fruits Heat treatment or freezing of fruits before storage 	

TRANSPARENCY 4.6 (6): THE MOST COMMON DISEASES AND PESTS, AND POSSIBLE CONTROL MEASURES IN ORGANIC FARMING

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that may have to be protected. Additional manual collection, though, is still necessary. A common protective measure is to wrap the bunches of ripening fruits in insect-proof nets. Direct control is possible by spraying a solution with *Bacillus thuringiensis* (Bt) when the worm is in its larval stage or by releasing Trichogramma wasps (*Trichogramma cacacaea*) (at a rate of 2000–3000 per tree) in September or October. It is also possible to control the date worm before storage by heat treatment of the fruits (two hours, 60 °C) or by very low temperature (-9°C for three hours).

Red palm weevil (*Rhynchophorus ferrugineus*): This pest is widespread and affects the stems and growing points of different palm species. It is known to cause serious damage to date palms in Middle Eastern countries. The female weevil lays its eggs in wounds along the trunk or in petioles. The larvae feed towards the interior of the palm, where they pupate. The adult weevils are active during both day and night. Generally, the pest is detected only after the palm has been severely damaged. The beetle has several natural enemies. Cultural and sanitary methods include preventive treatment of cut wounds with repellents and prompt destruction of infested plant material. Successful methods of biological control have not yet been developed. Laboratory tests in India have shown that oil derived from garlic is toxic to the weevil, and this finding may lead to the development of new control measures.

Date palm scale (*Parlatoria blanchardi*): The scale is a serious pest in several countries. The species mainly sucks at the base of the leaves and at the crown. As a result, leaves wither and eventually die. Heavy infestations affect plant vigor and often result in reduced yields. They often also result in an unsightly appearance, making the crop unsellable. The scale develops in plantations with a high humidity and poor air circulation. To control it, foliar applications of oil-based compounds have proved effective against the immature stages of the pest. Providing undergrowth to protect the predators of this pest effectively reduces infestation levels and keeps those that have already occurred below the economic damage level. Outbreaks can also be restricted by inspecting transplant shoots before moving them to new areas. Some plant varieties are tolerant to infestations of this pest. Releasing natural predators (bugs of the species *Pharascymnus*, *Cybocephalus*, *Chilocorus bipustulatus*) is usually successful.

Mites or Bryobia (*Oligonychus afrasiaticus* and *Paratetranychus simplex*): Mites are widespread (*O. afrasiaticus* in Northern Africa and *P. simplex* in the Western Hemisphere). They can occur solely on date palm (O.a.) or in a range of different crops (P.s.: wheat,

4.6. Dates		7	
Major pests of date palms and possible control measures (2)			
Pest	Symptoms / Important to know	Preventive measures	Direct measures
Red palm weevil	<ul style="list-style-type: none"> Holes in the crown or trunk from which chewed-up fibres are ejected Crunching noise produced by feeding grubs Withered bud/crown 	<ul style="list-style-type: none"> Treat wounds 	<ul style="list-style-type: none"> Destroy infested plant material
Date palm scale	<ul style="list-style-type: none"> Widespread Develops in side the plantation Early death of the leaves 	<ul style="list-style-type: none"> Propagate natural predators with undergrowth Use pest-free shoots 	<ul style="list-style-type: none"> Foliar application of oil-based compounds against immature stages Release predators
Mites or Bryobia	<ul style="list-style-type: none"> Widespread On leaves and unripe fruits Needs dry and windy conditions Encouraged by Spanish reed 	<ul style="list-style-type: none"> Remove infested crop residues (dates, leaves, etc.) 	<ul style="list-style-type: none"> Treatment with sulfur in winter
Bugs	<ul style="list-style-type: none"> Eat tissue of young leaves and destroy areas of vegetation 	<ul style="list-style-type: none"> Removal of breeding sites Trap in artificial hotbeds 	<ul style="list-style-type: none"> Fungus <i>Metarrhizium anisopliae</i> Virus <i>Rhabdovirus oryctes</i>
Rodents	<ul style="list-style-type: none"> Causes damage on trunk and fruits 	<ul style="list-style-type: none"> Encourage predators, like owls 	<ul style="list-style-type: none"> Mechanical devices around the stem

TRANSPARENCY 4.6 (7): FURTHER COMMON PESTS AND POSSIBILITIES FOR THEIR CONTROL WHEN CULTIVATED ORGANICALLY

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sorghum, maize, *Allium* species, etc.). They attack both the leaves and the unripe fruits of the date palm. Large scale mite infestations need dry and windy conditions. Spanish reed encourages their spreading. It is essential to remove infested dates and leaves in order to interrupt the life cycle of this pest and to control it. Winter treatment with sulfur is another possibility.

Bugs (*Oryctes* spp.): Bugs can eat the tissue of young leaves and destroy the growing point. For preventive control, breeding sites, like rotting plant material, must be removed and green manure crops worked into the soil when it is cut back. A fast-growing ground cover hampers the movement of the adult beetle looking for suitable breeding sites. In addition, "artificial" hotbeds or breeding sites may be created to attract the bugs, after which they are collected and destroyed. Direct control is possible by spraying the *Metarrhizium anisopliae* fungus or the *Rhabdionvirus oryctes* virus.

Rodents can also cause damage to the trunks and fruits. To prevent such damage, mechanical devices can be mounted around the stems. Owls are also efficient predators of rodents.

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4.6.6 Water management and irrigation

Water is considered to be the critical factor in date palm cultivation. The date palm prefers to have its "head in the sun and roots in the water" (although it dislikes waterlogged conditions). Irrigation is generally imperative. Water supply is frequently the main challenge in many date palm plantations, especially if intercropped.

In terms of water management, priority should be given to the date palms rather than to annual crops and hedges. The water needs and the irrigation patterns depend on many parameters, including soil texture, climate, associated crops, grown varieties, etc. In the Djerid region in the Southwest of Tunisia, the variety "Deglet Nour" needs between 20,000 and 24,000 m³ of water per year and hectare. The period when irrigation is required depends on the climatic conditions and the physiological state of the tree. During the cold and wet season the quantity of water, and frequency of irrigation, can be reduced from what is required in the hot and dry season.

The majority of plantations are irrigated by flooding bunds, which encircle the stem of the tree. Surface irrigation is also used to water the intercrops. As date palms are sensitive to waterlogging, the establishment of a proper drainage system is essential. Due to drainage and the mostly sandy soils, excessive salinity of soils is not generally a problem in date palm plantations.

Increasing the organic matter content of the soil considerably improves the water retention capacity of sandy soils, with 1 gram of compost being able to hold about 2 grams of water.

Motivation: Water management

To introduce the subject, ask the participants where they see challenges in water management in date palm cultivation. What would the approaches of a sustainable farming method such as organic farming be to water management? Of what relevance is sustainable water management in the long term?

4.6. Dates 8

Water management and irrigation



- Minimize water demand**
 - Water entrapment
 - Ensure good infiltration
 - Improve water retention of the soil
 - Reduce evaporation
 - Store rain water
 - Avoid excessive and improper use of water
 - Adjust water supply to growth stage
 - Avoid water logging
- Management measures**
 - Improve content of organic matter in the soil
 - Avoid soil compaction
 - Mulch the soil
 - Create a temperate microclimate through multilayer cropping
 - Install water storage infrastructure if possible
 - Apply an appropriate irrigation schedule
 - Drain away excess water

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TRANSPARENCY 4.6 (8): PRINCIPLES AND PRACTICAL MEASURES FOR SUSTAINABLE WATER MANAGEMENT IN DATE PALMS

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4.6.7 Crop maintenance

Pollination

Natural pollination by wind and insects is possible within plantations if male trees make up 3 to 4 % of the trees within the plantation. Artificial pollination is more common though, as it leads to better results. There are no differences between the methods of pollination practiced by organic farmers and by conventional agriculturalists.

The female flowers are pollinated when they open (from February to April). The application is done manually: either one spike of pollen is attached to each female bunch or the pollen is spread directly onto the female flowers. If there is enough pollen, it can be used as a pure pollen; otherwise the pollen can be mixed with a carrier such as flour or talc.

As the female flowers of each tree open progressively over a period of one month, pollination is repeated three to four times.

To ensure that the pollen used is of high quality it should be applied not more than seven to ten days after collection (if it has not been stored in a cool place). If stored at 4 °C or lower, the pollen can be kept for up to one year.

Manual pollination requires a person with a head for heights to climb to the top of the tall date palms. In some date plantations cranes are used to lift the workers to the crown of the tree.

To improve fruit quality and size it is recommended that the female inflorescences be trimmed.

Pruning and bunch management

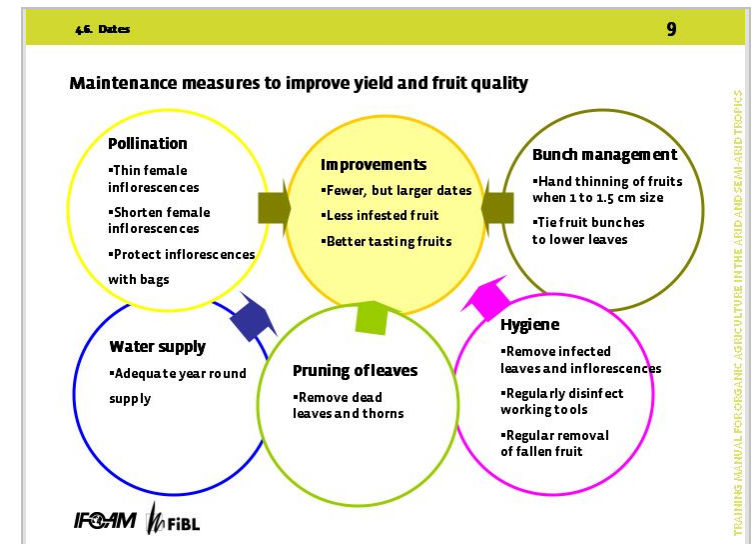
Dried, infested and damaged leaves must be removed regularly. Pruning is needed in order to establish equilibrium between the root system and the green part of the plant, to reduce disease and pest pressure through better ventilation of the tree, and to reduce the propagation of pests and diseases by eliminating infested leaves. A general rule recommends leaving ten green leaves per tree. The main pruning is generally done in winter after harvest. Healthy palm leaves can be used to shelter new plantations. Infested leaves are composted.

To improve the quality of the fruits, it is advised that the number of fruits per bunch be limited in March or April by removing some of the twigs. Approximately one third of the twigs are usually removed. The remaining twigs are cut back by approximately one third of their length.

Date palms can grow to up to 30 meters or more. But after 60 to 80 years yields decline and the tree becomes too tall, which makes crop maintenance difficult. Thus they are usually cut down at this age.

Discussion: Pruning

Discuss with the participants the relevance of pruning.



TRANSPARENCY 4.6 (9): MAINTENANCE MEASURES TO IMPROVE YIELD AND FRUIT QUALITY

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4.6.8 Harvest and post-harvest handling

Harvesting

Fruit development takes about 200 days and should be completed by the time that the stalks are cut.

Four stages of maturation can be distinguished, according to moisture, sugar and tannin content: kimri (first 17 weeks, dates are green, hard and bitter), khalal (the following six weeks, in which the dates reach full size, harden and become yellow to red), rutab (following four weeks, dates are half-brown and become soft and sweet) and tamr (two weeks later, this is the final stage of maturation when dates become softer and sweeter). Depending on the variety and the destination of the fruits, they are harvested during one of these stages. Dates which are to be stored for long periods (such as dried dates) are left on the tree to complete ripening. Dates that will be eaten fresh, boiled or cooked with honey, are picked when green and allowed to ripen in an incubator.

Flowers of the female tree bloom at different times. Consequently, the fruits on a particular stalk will ripen in succession. The right moment for harvest is defined by the color of the fruit and the designated use, which also depends on the variety. The time of harvest also can depend on the climate in the area. For example, fruits of the same variety ("Deglet Nour") of date are harvested 15 to 20 days in the Dgerid region of Tunisia than they are in the Nefzaoua region.

Fruits are harvested by hand by climbing up the palm trees to reach the fruit bunches. In some plantations cranes are used to lift up the workers. During harvest, special care must be taken not to damage the fruit or the palm. Damaged and fallen dates are separated from healthy fruits. After harvesting, the dates are cleaned with water and dried in the sun.

Post-harvest handling

The only difference in post-harvest handling of organic dates, compared to conventional fruits, is that no applications of pesticides are allowed on the stored fruits. For drying, only air drying is permissible.

In the post-harvesting process, hygienic conditions in the packing and storage rooms are key factors in satisfying quality standards. The rooms must be cleaned properly before harvest begins and sprayed in the evening with a natural pesticide (e.g. pyrethrum) to kill any remaining moths. The next day the working tables must be properly cleaned with soap water to avoid traces of the pesticide coming into contact with the fruits. Windows and doors must be protected with mosquito nets to prevent pests from coming in from the outside. During post-harvest handling the rooms are swept daily to remove infested fruits and pathogens.

Visit: Storage rooms on an organic farm

If possible, visit a storage room on an organic farm and discuss with the owners / managers what measures are necessary to avoid post-harvest infestation of fruits and ensure good fruit quality.

4.6. Dates		10
Quality management in post-harvest handling		
Harvesting	Appropriate handling to prevent ...
↓	Clean storage rooms from pests before harvest	New infestation of the fruits by pests
Sorting	Wash fruits with drinking water	Growth of molds and yeasts
↓	Dry the fruits to below 20 % moisture content (26-30 % is acceptable)	Further development of eggs of pests in the fruit
Washing	Freeze the packed fruits (-40 °C for 2 days)	Taking up the aroma of produce such as garlic, onions, herbs or spices
↓	Separate dates from other produce	Further damages by insects and increased browning of the fruits
Drying	Ensure optimum storage temperature (below 13 or 5 °C for a short time; 0 °C for 6 to 12 months; -18 °C for >12 months)	Growth of micro-organisms due to moisture condensation on the dates
↓	Avoid temperature fluctuations during storage	
Sorting	Disinfect with carbon dioxide (100 % for 2 days; necessary for export). Treatment with methyl bromide and radiation not allowed	
↓		
Packing		
↓		
Storage		

TRANSPARENCY 4.6 (10): WHAT MUST BE DONE TO AVOID LOSSES IN QUALITY DURING POST-HARVEST HANDLING?

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Air-drying should give a moisture content of 20 % or below in order to prevent moulds and yeasts. The optimum storage temperature is 0° C, which allows for a storage period of between 6 and 12 months. For longer storage durations it is possible to freeze the dates (18°C).

For short time storage, temperatures should be below 13 °C in order to prevent insects causing feeding damage or reproducing, and below 5 °C to avoid new insect infestation. Below 4 °C no insect activity takes place, but at these levels the insects will not necessarily be destroyed.

The general quality standards for export are defined by the Codex alimentarius. Organic standards do not yet define any specific quality criteria for dates.

Organic dates must be packed with cardboard material and labeled as organic. Organic dates must be separated from conventional fruits at all stages of post-harvest handling.

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4.6.9 Economic and marketing aspects

Dates remain the most important crop in the oasis, whereas the harvested intercrops are mostly used for family consumption.

Organically cultivated dates generally give similar or even higher yields than conventionally grown dates. In Tunisia, conventional farmers harvest about 8 tons of dates per hectare, whereas organic farmers harvest about 10 tons per hectare. The main reason for this is that most traditional oasis farmers do not supply enough organic matter to the plantation, whereas organic date farmers are more aware of the relevance of soil fertility for yield.



In general, dates coming from organic farms are easily sold on local markets or for export at a higher price than conventional produce. The price of organic dates is generally 10 to 20 % above that of their conventional counterparts. This is because many consumers prefer dates without chemical residues.

Many organic farmers say that the organic cultivation of dates has raised their revenues. Farmers' incomes have improved by an average of 1000 to 2000 dollars per hectare due to organic farming.

The market for organic dates, both for local consumption and for export, has been growing strongly in recent years. The greater part of organic date production is sold domestically as fresh fruit.

Exercise: Is organic date cultivation economically competitive in your context?

Add together the costs for conventional and for organic date cultivation and handling, and compare them with the yields and revenues. Are there any differences? Are there possibilities to (further) improve the results of organic cultivation? Do any of these farming systems promise to be more sustainable?

4.6. Dates		11	
Revenue from conventional and organic dates in Tunisia			
		Conventional dates	Organic dates
Yield (tons per hectare)		8	10
Price (Euro per kg)		0.75 (1.2 Tunisian Dinars)	0.875 (1.4 Tunisian Dinars)
Revenue		6,000 (9,600 Tunisian Dinars)	8,750 (14,000 Tunisian Dinars)
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TRANSPARENCY 4.6 (11): YIELDS, PRICES AND REVENUE FROM CONVENTIONAL AND ORGANIC DATES IN TUNISIA IN 2004

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4.7 Olives

Introduction

The olive tree (*Olea europaea* L.) is one of the major crops of the Mediterranean region. First cultivated in Syria, Palestine and Crete, olives are today commercially grown between 30 and 45 ° North and South in several countries throughout the world including, Australia, Chile, China, Mexico, New Zealand, South Africa and the southwestern areas of the USA. However, the countries with by far the most significant production are all situated in the Mediterranean basin.

Olives are grown predominantly for oil. Only a small proportion of the harvested fruit is eaten as table olives. Olives and olive oil are an integral part of Mediterranean cuisine, and most olive oil is consumed within Mediterranean countries, leaving less than 20 % of production to enter world trade. As Mediterranean gastronomy has spread throughout the world, the consumption of olives and olive oil has increased in most countries in recent decades (such as preserved olives on pizzas). To a large extent, olive oil does not compete with other vegetable oils, but occupies a niche market.

Olive fruits contain 15 to 35 % oil, depending on the cultivar, and are thus high in energy. They are a good source of protein and b-carotene and contain other useful nutrients such as sugars, vitamins (B, C and E) as well as minerals such as iron, calcium and potassium. The high nutritional value and characteristic taste of the olive make the fruit and the oil highly valued agricultural products.

The olive tree itself is an evergreen tree, which can reach a height of 3.5 to 15 meters and which can live for a very long time. Olive trees take 25 to 50 years to mature. However, they begin to carry fruits four to eight years after planting. It is not uncommon for olive trees in traditional groves to be more than 200 years old and they can get much older. The leaves are replaced every two or three years with leaf fall usually occurring and new growth beginning in spring.

Olive tree orchards have long-since contributed to the characteristic landscapes and quasi-natural environments of arid and semi-arid climates. However, their management has changed a lot in recent decades. Intensive plantations have started to replace extensively cultivated olive groves, cultural practices have been improved and mechanical harvesting has been introduced. Organic growers aim at combining the ecological value of the olive orchards with a high economic potential to produce a healthy and socially viable product. High prices and relatively good market opportunities provide a strong incentive for many farmers to grow organic olives and continue in agriculture.

Lessons to be learned:

- *Appropriate management of natural resources minimizes environmental degradation, reductions the use of external inputs and improves the system's sustainability, thus helping reduce pest problems.*
- *When establishing new olive groves, careful selection of the site and cultivars and careful evaluation of the planting density are of great importance. In organic olive orchards minimum tillage and a (green) soil cover are applied, where possible, to conserve soil and encourage beneficial insects. Appropriate cultural practices and intensive observation of the crop contribute considerably to consistent yields and good quality produce.*
- *Higher prices for organic fruit and oil are an incentive to convert to certified organic cultivation. Major efforts are necessary, however, to keep costs low, add value to the produce and find marketing opportunities in order to make organic cultivation economical.*

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4.7.1 Agro-ecological requirements

Temperature

Because of its Mediterranean origin, the olive tree is adapted to a mild climate and tolerates extreme climatic conditions ranging from heat and drought in the summer to the cold of the Mediterranean winter.

A cold period is necessary in order to induce flowering and good fruiting. However, the temperature should not drop below -10°C , as this may injure the tree. Olive trees are sensitive to late spring frosts, which kill the blossoms. To ensure full ripening of the fruits, olive trees require a long, warm, growing season. The optimum growing temperature is between 12 and 22°C . At temperatures below 7 to 9°C the tree's growth stops. After a cold period, regrowth only starts at a temperature of 12 to 13°C .

High temperatures above 30°C inhibit growth if the soil moisture is very low. Growth stops completely at over 35°C , even if there is sufficient moisture. Dry winds and temperatures that are too low or too high are detrimental for flowering and fruit setting.

Water

One characteristic of the Mediterranean climate is the dry periods that occur during the warm season. Olive trees are drought tolerant and grow well under such conditions. For rain-fed olive cultivation at least 500 mm annual rainfall is required in order to obtain good crops. Water requirements are highest during the flowering and fruit setting periods in late spring and when the fruit size is increasing. Rain, however, is detrimental to a good fruit set.

Rainfall in excess of 1000 mm of annual rainfall is unfavorable, as the olive tree is susceptible to a number of diseases when the atmospheric humidity is high. High rainfall levels also adversely affect oil quality by decreasing oil proportion in the fruits, as a result of osmotic exchange.

Soil

Olive trees grow on a wide range of soils. Due to their relatively shallow root system they also grow on poor soils and rocky hillsides. They do not tolerate waterlogged soils or soils with a very shallow water table (these conditions also favor *Verticillium* wilt). For adequate yields, well-drained and well-aerated deep soils with a sufficient level of soil organic matter are necessary. Increasing the level of organic matter in the soil improves its structure and

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Agro-ecological requirements of olive trees

Temperature

- Moderate temperatures of 12 to 22°C ideal
- Cold period (but not below -10°C)

Water

- Low water requirements
- At least 500 mm for rain-fed cultivation
- Low atmospheric humidity

Soil

- Tolerates a wide range
- Prefers well-drained, deep, fertile soils
- No waterlogging
- Tolerates a pH of up to 8.5
- ± tolerance for salt

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TRANSPARENCY 4.7 (1): AGRO-ECOLOGICAL REQUIREMENTS OF THE OLIVE TREE

Discussion: Evaluation of the growing conditions

Ask the participants to characterize the growing conditions in the area. Note and discuss the answers. Are there any factors evident that might influence the successful cultivation of olives or that demand special attention?

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thus drainage, water holding capacity and aeration. This has a positive effect on root development and the biological activity of the soil, and thus on overall plant nutrition. Olive trees can tolerate alkaline soils with a pH of up to 8.5. However, the ideal is a pH of 5.5 to 7.5. Soils with frost pockets and poor drainage should be avoided, as should salty soils.

Site selection

Even if olive trees are relatively more tolerant of harsh ecological conditions and lower soil fertility than most other horticultural crops, the potential of a site for olive cultivation must be carefully assessed to achieve good yields. Olive cultivation on poor soils (especially if not irrigated and cultivated with little manure) will result in lower productivity. This is manifested by crops bearing first a high fruit set with small fruits (or fruit drop) for one year, followed by two years of low fruit set. The characteristics of the microclimate such as humidity, aeration and shading should be carefully considered as they affect the physiological conditions of the trees and the degree of pest and disease infestations.

When planning a new olive grove, the soil quality should be analyzed to determine whether there are any site-specific problems regarding nutrient content, pH and organic matter level. The existence of hard pans, Verticillium wilt, and signs of soil erosion such as rills or gullies should also be assessed. Soil structure and soil biological activity should be examined at least visually, for example by assessing the existence and number of earthworms.

In colder areas in the northern hemisphere, it is recommended that the trees be planted with a south or southwest aspect to reduce the risk of frost, ensure plenty of sunshine and avoid conditions that favor leaf spot (on susceptible cultivars); in the southern hemisphere, a northern aspect is best.

As olive trees dislike windy conditions, windbreaks may be necessary on windy sites, particularly to protect young trees. On slopes special measures like permanent soil cover may be necessary to prevent soil erosion.

Generally access to irrigation water is preferable, but this depends on the objectives of the grower and his or her yield expectations. Water is, however, also greatly appreciated by olive flies, which can negatively affect yields.

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4.7.2 Diversification strategies

In many traditional farming systems of the Mediterranean area, olive trees are intercropped with wine plants, almond and other fruit trees, arable crops or grazing land. Such diversification also makes sense in an organic farming system, as it creates a more diverse ecosystem and promotes natural regulating mechanisms.

When designing an organic olive production system, major attention should be paid to establishing a diverse and sustainable farming system. Diversification in organic olive cultivation promotes a model of olive production that respects the environment and sustains the multiple functions of agriculture - including its social, cultural and recreational aspects. Of course, beyond the conservation of the olive grove environment, with its habitats and wildlife, (and protecting it from detrimental alterations and pollution), organic production must also focus on yield and market requirements.

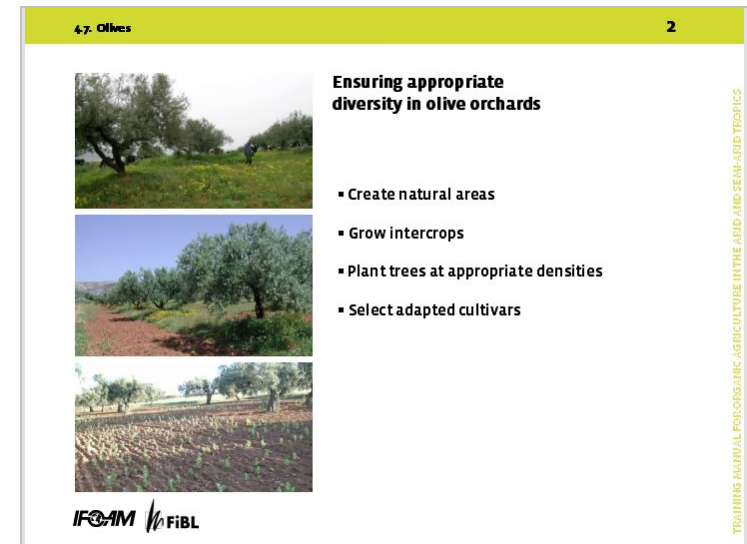
The principle of diversification is valid in any climate, but can be a major challenge under arid conditions.

A) Establishing a new olive orchard

Design of the olive orchard

When planning a new olive orchard, many aspects must be considered to ensure that an appropriate, diverse and eventually sustainable orchard is created. Among these aspects are the following:

- Create natural areas for higher diversity and as habitats for natural enemies.
- Grow intercrops to enhance beneficial biota in the soil such as mycorrhiza, rhizobia, and free-living nitrogen fixers. Intercrops also confuse pests and improve soil fertility.
- Ensure that tree density will provide aeration and light conditions in the orchard that are adapted to the productive potential of the site (especially in cases where there is no irrigation).
- Select cultivars adapted to the site, and meet desired agronomic and fruit quality criteria. It is preferable to select cultivars that contribute to the conservation of genetic resources (e.g. local varieties that are better suited to the area).



TRANSPARENCY 4.7 (2): HOW TO ENSURE DIVERSITY IN OLIVE ORCHARDS

Farm visit:

If possible, visit a nearby, organically managed, newly planted (or older) olive grove and discuss with the farmer(s) the importance of diversification within their farming system, what measures have been undertaken to increase diversity, why certain possibilities may have been left out and what their experiences are with their farming system.

Ask questions such as: How are natural enemies promoted? How is soil fertility improved? Is there any diversity in cultivars and crops? Has the farming system been designed for specific site conditions?

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Suitable cultivars

A great number of olive cultivars exist, with a wide variety of agronomic and commercial characteristics. In cultivar selection several factors must be considered, such as: the intended consumption of the fruit (e.g. pickling/preserving or oil production), specific phytosanitary requirements (e.g. resistance to olive leaf spot or Verticillium wilt) or climatic conditions in the area (such as drought and frost), and whether the trees are self-pollinating or need pollinators. Further factors include the alternate bearing behavior of olive trees, tree shape and size, the uniformity of fruit ripening, fat content and oil characteristics, and also the soil type and yield expectations. Thus, olive cultivars should not only be selected for maximum yield. A general distinction is made between cultivars for oil, for table consumption or those with a dual purpose.

Most olive cultivars will set some fruit in an orchard with only one cultivar. However, the trees benefit greatly from cross-pollination. It is strongly recommended to use more than one variety in larger orchards. Pollinators should have the same blossoming period as the main cultivated crop. Choosing two early cultivars, a mid-season and a late season cultivar, for example, will spread the harvest over a longer period of time and reduce the risks of losses due to unsuitable weather conditions as well as narrow the fluctuation in harvest from year to year.

Olives are primarily propagated by rooting semi-hardwood cuttings, which are normally taken from one year-old branches near the bottom of selected, superior, trees. This method is the most efficient and economical, and is more effective than propagation from seedlings in reducing heterogeneity within an olive grove. Another propagation method that is practiced is the budding of seedling rootstocks.

The nursery stages of organic olive production are the same as for conventional olives, as no legislation for organic plant production exists yet. However, only natural compounds may be used for plant protection. In some cultivars, Rhizogenesis may be difficult to control without the use of synthetic hormones.

Site preparation and planting

Soil analysis is recommended prior to planting. This should include texture, pH, CaCO₃, organic matter, macronutrients (at least P, K and Mg) and micronutrients (e.g. boron). The content of organic matter in the soil should be higher than 1 % if no irrigation is planned and higher than 2 % if irrigation is planned. Olive trees tolerate saline or alkaline soils and a high calcium content to some extent (see also chapter 4.7.1).

Depending on the participants' knowledge of olive cultivation, show some olive cultivars recommended for organic cultivation, or discuss the characteristics of cultivars grown in the area.

What relevance does cultivar selection have for production reliability and quality, compared to environmental factors and their variability? Which variety characteristics are the most important?

Discussion: Criteria for cultivar selection

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A soil profile (for details see chapter 4.2.1 of the Basic Manual) shows what specific measures (if any) need to be taken to improve the soil conditions prior to planting (e.g. drainage). Olive trees will grow on poor soils and rocky hillsides, but deep soils produce the best quality fruit. Soils with previous crop infestations of *Verticillium dahliae* (a disease that is generally restricted to perennial crops) should be avoided.

Before planting a new orchard, the soil must be well prepared. If the soil has been compacted, deep ploughing is necessary. A deep rooting green manure crop, such as sunflower or alfalfa, which will loosen the soil and increase soil organic matter, should ideally be planted first. Basic fertilization with organic and/or mineral components (see chapter 4.3 of the Basic Manual for allowed fertilizers) is recommended when the soils have a low nutrient content.

The planting density of an olive crop must be carefully evaluated. The appropriate density depends mainly on the availability of water and the size and growth habit of the cultivar. Tree densities can vary from 17 olive trees per hectare (grown under drought conditions in Sfax, Tunisia), to more than 400 trees per hectare in irrigated orchards with unlimited water and nutrient supplies and trees that grow upright and are of a moderate size. (This kind of orchard may, however, be less environmentally friendly, and more exposed to pathogens). In traditional farming systems, densities of between 70 and 150 trees per hectare are common. Plant densities of more than 300 trees per hectare are not recommended in organic cultivation as they lead to shading and poor air circulation. Planting patterns with wider inter-tree spaces also allow for easier crop management (e.g. use of machinery for soil management) and higher diversity (intercrops, flower strips, etc.).

The plant material used should come from a known and trusted origin and be guaranteed to be free of diseases such as *Verticillium*, *Armillaria*, *Rosellinia*, olive knot or *Agrobacterium tumefaciens*.

To prevent soil erosion in a plantation on a slope, the rows of olive trees should be intercropped with permanent grassland.

Training systems

The chosen training system (depending on labor resources) should ensure optimal sunshine and aeration inside the canopy, avoid conditions that favor the development of insect pests and diseases (a strong biannual cutting may, for example, increase black scale by stimulating

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vigorous shoots), and should be adapted to the chosen harvesting method. Furthermore, it should ensure the longevity of the trees.

Regular removal of lateral shoots is important so that a single trunk is left. This facilitates the use of shaking machines. Traditionally, a free vase-shaped canopy is favored, as this form is better for handpicking. Modern mono-cone shaped canopies are more suited to mechanical harvesting.

B) Conversion of an existing olive orchard

Before converting an existing olive orchard to organic cultivation, the site conditions, planting density, soil quality and varieties should be examined carefully in order to assess risks and potential improvements. A detailed conversion plan will facilitate the process by providing farmers with a step-by-step plan, which will help them achieve ideal growing conditions.

Decreasing the amount of chemical fertilization some years before transition will help in obtaining balanced trees that are less attractive to pests or diseases. Sometimes it is desirable to change the variety of mature olive trees (e.g. in cases of high pest susceptibility). This can be done by grafting scions of the desired cultivar onto the primary branches of the tree.

Besides the purely productive aspects, ecological aspects must also be considered at the earliest as possible stage before transition. The basic structure of the landscape, such as grassland, hedges, old trees or old stone walls should not be destroyed by earthworks. Draining of wildlife habitats should be avoided, as they are species-rich and contribute to functional biodiversity. Furthermore, potentially stony, poor sites should be preserved as they are habitats for specific species. Natural pest control may be further enhanced by planting or sowing hedges or floral strips of specific plant species that attract pest controlling insects. These could include *Inula viscosa*, *Capparis spinosa*, *Lycium subglobosum*, *Zizyphus vulgaris*, *Ficus*, *Pinus* spp., acacias, oaks, *Tribulus terrestris*, etc.

Farm visit and group work:

If possible, visit a nearby conventionally managed olive orchard (ideally one that is about to be converted to organic cultivation) and in groups, discuss the following issues:

- *What conditions of the olive orchard are favorable to organic cultivation? Are there any constraints regarding conversion to organic cultivation?*
- *What measures should be undertaken before, during and after conversion?*
- *Design a conversion plan that shows the necessary changes.*

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4.7.3 Soil protection and weed management

In olive orchards, alleyways with cover plants are highly recommended to help avoid soil erosion, reduce soil compaction, and maintain and enhance the diversity of plant species. This also increases ecological stability (for criteria and measures to control soil erosion see chapter 3.4 of the Basic Manual and the introduction to this manual). Green alleyways can generally be grown without providing competition to the olives, or impacting on yield and quality. Cover plant species should be chosen according to water availability and by observing which species spontaneously grow in the surrounding areas. Best results will be obtained from locally harvested seeds, but marketed seeds of cover crops adapted to local pedo-climatic conditions can also be useful.

In organic olive groves soil management is largely achieved through the use of cover crops. Depending on climatic conditions and the priorities of the farmer, cover crops are either chopped periodically, and worked into the soil as green manures, mulched and left on the soil surface, or grown as permanent crops for grazing. Mulching significantly reduces water losses during the dry period. These fields are, however, sensitive to fire in dry periods.

Cover crops can be annual or perennial. A permanent soil cover has the advantage of leaving the soil untouched. It may, though, compete with the olive trees for water and nutrients if it grows too close to the tree and is active during the hot season. In olive orchards with a permanent soil cover, however, biodiversity increases and beneficial organisms are promoted by virtue of food and shelter being available all year round (e.g. *Inula viscosa* growing in orchards will attract an insect attacked by *Eupelmus urozonus*, that parasitizes *Bactrocera oleae*). The economic benefits that result from reduced intervention and the additional gain in terms of animal feed should not be underestimated. Thus, in areas with sufficient rainfall and adequate soils, maintenance of a permanent or temporary green soil cover during the growing season is highly recommended.


As an alternative to cover crops, mulching is an appropriate measure for avoiding erosion during heavy rainfalls, hindering the growth of weeds around the trees and reducing water evaporation (see also chapter 4.7.6 water management and irrigation). This measure also contributes, to some extent, to the maintenance of the organic matter content in the soil. Litter from the olive grove (branches, leaves etc.) or straw from cut grass or shrubs can be used for mulching. The ideal time for laying out the mulch is March-April or May-June, after the vegetation in the grove has been cut. The mulch should be placed around the trunk of the olive trees (the bigger the diameter of mulch plants the better).

Motivation: The function of cover crops



Discuss the requirements of cover crops for soil protection in organic olive orchards, and the criteria for the selection of cover crop plant species.

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Criteria for appropriate cover crop selection in olive orchards



- Nutrient and water requirements
- Length of biological cycle
- Temperature and light requirements
- Rooting pattern (requirements for soil improvement and soil conservation)
- Susceptibility to pests and diseases
- Feasibility of cultural practices (e.g. harvesting with nets)
- Vulnerability to fire, especially in dry, windy areas
- Feeding qualities (where using grazing animals)
- Feasibility of using machinery (for cover crop management)
- Cost of seeds

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TRANSPARENCY 4.7 (3): CRITERIA TO BE CONSIDERED IN SPECIES SELECTION OF A COVER CROP

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Legume species can contribute large amounts of nitrogen to the soil. The residues of legumes decompose more rapidly than grasses (grasses such as vetch or barley provide large amounts of organic material but have a rather slow decomposition rate). Their tasseled roots make them useful in improving soil structure, preventing erosion, improving water penetration and reducing nutrient losses and depletion. Mixtures of grasses, legumes and other species are commonly used for cover cropping, as they complement each other's properties.

In Australia, geese have proved to be excellent at controlling problematic grass weeds in established olive orchards. Sheep are widely kept too, but may demand special attention in order to ensure that they do not cause damage to the trees and soil. Wind erosion can be greatly reduced by substituting deep tillage with superficial tillage (at 10 to 15 cm depth). Tillage should only be done if it is strictly necessary.

4.7.4 Supplying nutrients and organic fertilization

Appropriate fertilization is of major importance in olive cultivation in order to prevent premature fruit drop and alternate bearing (as explained above), and thus to ensure good yields and high quality. Olive flowers are unusual in that they develop at the extremity of the shoots the year before they flower. A balanced and appropriate nutrition of the trees will result in shoots that are vigorous and flower well. Furthermore, a balanced and moderate nutrition level helps to avoid plant protection problems and improves the drought and frost tolerance of the olive trees. Corresponding to the approach of organic plant production in general, fertilization in organic olive orchards aims at maintaining or improving the fertility of the soil, largely through the appropriate management of soil organic matter. Thus the primary aim is not to supply specific amounts of plant macronutrients, but to "feed" the soil (and subsequently the tree) by incorporating compost or farm manure and the cultivation of cover crops and green manures, in as much as the climatic conditions allow.

In both traditional and conventional farming, organic fertilization of olive trees is often neglected as the small amount of organic fertilizer available is preferentially given to more intensive crops such as vegetables or citrus trees. When converting to organic olive cultivation (or farming in general), a basic shift in fertilization strategy is needed; from a mostly mineral based approach that relies on through-flows, to a more closed approach to nutrient recycling within the farm, with a strong emphasis on organic fertilization. One method that encapsulates this closed nutrient concept is composting crop residues,

Motivation: Brainstorming actual fertilization practices and the challenges in olive tree nutrition

Invite the participants to draft a program for fertilization - including potential sources - and to define major challenges in olive tree nutrition (or plant nutrition in general). How might possible problems be overcome?

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Fertilization of organically managed olive trees

Common nutritional problems in olive orchards:

- Low soil organic matter level
- Nutrient deficiencies
- Imbalanced nutrient supply

The approaches of organic farming:

- Use of compost
- Green manuring
- Use of additional fertilizers where required

Intercropped green manure

Compost production

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TRANSPARENCY 4.7 (4): COMMON NUTRITIONAL PROBLEMS AND APPROACHES TO FERTILIZATION OF ORGANICALLY MANAGED OLIVE TREES

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farmyard manure and the residues from olive processing. The regular application of farm compost contributes to a balanced and somewhat continuous supply of nutrients to the olive trees. Grazing livestock in the olive orchard can also make a welcome addition to the application of compost.

The primary materials for compost production are residues from olive processing (such as pomace), chopped leaves and branches from olive trees and hedges, and other collected plant material and animal manure.

Compost and animal manure are best spread in early autumn (in the northern hemisphere), before sowing a temporary green manure crop. The autumn rains will assist the microbial decomposition of the compost and make nutrients more readily available.

Compost and additional necessary fertilizers are mainly applied to the olive trees (depending on the amounts of fertilizers available, tree density and the cultivated intercrops) by even distribution in, and slightly beyond, the rooting zone (generally the diameter of the rooting zone is about twice as large as the canopy).

Green manuring not only supplies the soil with organic material and nutrients, but also improves the soil structure and the absorption of rain water, helps to control weeds and offers shelter and food to beneficial insects.

Green manure plants are sown after the first autumn rain, when the soil is ready for cultivation. The ideal moment depends on local climate and weather, field conditions and the species sown.

The recommended quantity of organic materials to be applied to the olive trees depends on the fertility of the soil (see also laboratory soil analysis), the nutritional condition of the trees (which can be examined by leaf analysis), their yield, the green manure species and organic materials used and the fertilization program of the grove. It may be appropriate to feed each mature tree with about 50 kg of compost or cow or sheep manure every two to three years, 2 to 3 tons of chicken manure per hectare has been proven to complement fertilization with other animal manure due to its high nitrogen and phosphorus content.

The fertilization program should be carefully observed and monitored carefully to ensure that it is appropriate. Aspects to observe include: soil fertility (soil structure, presence of earthworms, water-holding capacity, etc.) and its development over the years, and the productivity of the olive trees (level of production, percentage of fruiting, viability of

Group work:

Following the presentation, and based on their experience, ask the participants to work in groups to develop a checklist for the nutrition of olive trees. The checklist must include aspects such as nutrient recycling, composting, green manuring, appropriate fertilization etc.

If possible, test the checklist on nearby olive farms or simply have the results presented to the other groups. Discuss the contents of the checklists.

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vegetation, leaf color, etc.). Abnormal symptoms in foliage or growth may be signs of nutrient deficits. Additional periodic soil and plant analyses are helpful though, in determining the nutritional status of the soil and possible deficits. Temporary deficits may occur after a long period of rainfall or unbalanced fertilization.

In order to satisfy the specific nutritional needs of the olive trees, micronutrients or natural mineral substances (that meet organic standards) can also be applied. Such applications must first be justified by analysis (soil analysis in case of mineral fertilizers, leaf analysis in case of micronutrients – in the northern hemisphere this is best done in July). The use of such products and their inclusion in the fertilization program should be done in cooperation with the farm advisor and the farm inspector.

If required, phosphate and potassium can be applied to rain-fed orchards in autumn at rates of 0.3 to 0.5 kg phosphorus and 0.8 to 1 kg potassium per tree. The correction of a low soil pH is important to ensure good solubility of these nutrients.

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4.7.5 Pest and disease management

As seen earlier, organic growers aim to establish an agro-ecological balance in the orchard, which prevents major problems with pests and diseases. The idea is to keep pests and diseases below the economic threshold level by encouraging natural control mechanisms. This can be accomplished (at least partially) by ensuring a balanced growth of the trees through appropriate pruning, fertilization and irrigation, and by promoting beneficial predators and parasites (see chapter 5.2 of the Basic Manual for additional information). Resistant and tolerant cultivars, healthy planting material and an appropriate system of training the trees, also play an important role in preventing groves from becoming infested with specific pathogens. Extra attention needs to be given to preventive plant protection measures during the transition to organic agriculture, when an ecological balance has not yet been established.

A (permanent) green soil cover, (where possible border planting, hedges, uncultivated patches of vegetation and stone walls should contribute to this) enhances biodiversity (of both flora and fauna) within the olive grove and enhances and protects natural enemies.

Direct plant protection measures may be employed, although priority must be given to natural, cultural, biological and highly specific methods. Plant protection products may only be used when absolutely justified. Biological agents (e.g. *Bacillus thuringiensis*) or pesticides (of mineral or plant origin) may be used, if they are truly necessary and are applied in accordance with organic standards. The application of plant protection products should be based on economic thresholds, risk assessment and the prognoses provided by forecasting services such as the International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC), if available. The approximate level of infestation or the risk of damage must be monitored and recorded regularly in the case of all major pests and diseases.

Some pests and diseases can pose serious problems for olive production when their populations or activity exceed certain levels. The severity of attacks will depend partly on local conditions, such as climate. The most harmful pest to the olive tree is the olive fly *Bactrocera oleae*. The olive fly is widespread, especially in the Mediterranean area. Its larvae cause considerable damage to the fruit and greatly reduce both the quality (by increasing acidity of oil) and quantity. Other important pests of olives are olive moth *Prays oleae*, the black scale *Saissetia oleae* and the olive scale. In certain regions other pests can also cause severe problems.

Motivation: Brainstorming on pests and diseases in olives

Ask the participants to name the pests and diseases that are known to infest olive trees in the area. What are the critical factors that encourage their outbreak? How are they controlled?

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The most harmful disease in olives is Olive Leaf Spot. This disease develops in humid conditions and can result in extensive defoliation of the trees. Verticillium Wilt, which is caused by a soil-borne fungus, occurs mainly in newly planted crops and can lead to serious losses. A number of other diseases can also sometimes cause severe damage.

Several naturally occurring parasitoids and predators are known to attack the pests of olives. Encouraging these naturally occurring beneficial insects is highly recommended; releasing marketed beneficial insects may even be appropriate in specific cases, but is usually quite expensive and must be done every year.

Some farmers find chickens to be invaluable in controlling insect pests such as olive fly, which live in the soil (during winter) during one stage of their life cycle.

In the Mediterranean area it is sometimes necessary to spray natural insecticides in order to control the olive fly (and occasionally black scale) and to prevent fungal diseases (copper spray being most commonly used in the later instance). The use of broad spectrum insecticides, also kills natural enemies and unbalances the population dynamic of pests and predators. This may result in a new mass development of the targeted pest or a pest of another kind (for further information see also chapter 5.2.1 of the Basic Manual).

Olive fly (*Bactrocera oleae*): As mentioned before, the olive fly is the major pest of olive trees. The yellow-red fly with the typical black dot at the end of its wings attacks both cultivated and wild species of olive and is largely limited to the Mediterranean basin. Its life cycle begins with the fly laying eggs under the skin of the fruit. Subsequently, the larvae develop in the fruit and pupate either in the soil or the fruit itself. Infected fruit may be invaded by fungi, which cause premature fruit drop and also reduce oil quality. Depending on the climate, one to four generations develop in a year. The development and spread of the fly is promoted by moderate temperatures, high atmospheric humidity, a combination of early and later varieties and by neglected or badly pruned olive trees (as the fly finds more humid conditions in the canopy of these trees). An olive mill within 1 km of the trees can also increase the chances of infestation. Severe winters and hot summers greatly limit the activity of the fly.

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Main pests of olives and organic means of control		
Pests	Preventive methods	Direct control methods
Olive fly (<i>Bactrocera oleae</i>)	<ul style="list-style-type: none"> ▪ Proper pruning ▪ Propagation of natural enemies 	<ul style="list-style-type: none"> ▪ Regular mass release of <i>Opisus concolor</i> ▪ Mass trapping ▪ Pheromone trapping ▪ Spraying Spinosad, Neem, rotenone or pyrethrum ▪ Spraying processed kaolin clay mineral
Olive moth (<i>Prays oleae</i>)	<ul style="list-style-type: none"> ▪ Resistant cultivars ▪ Remove and destroy damaged and fallen fruits ▪ Propagation of natural enemies 	<ul style="list-style-type: none"> ▪ Biological control with Trichogramma ▪ Pheromone trapping ▪ Spraying <i>Bacillus thuringiensis</i> ▪ Spraying spinosad, Neem, White oil or pyrethrum
Olive black scale (<i>Saissetia oleae</i>)	<ul style="list-style-type: none"> ▪ Pest-free planting material ▪ Proper pruning ▪ Control of ants 	<ul style="list-style-type: none"> ▪ Biological control (e.g. <i>Metaphycus</i> species) ▪ Wash the trees with soap or apply oils ▪ Apply light mineral or vegetable oil
 <p style="font-size: small; text-align: center;">Trap with attracting food and bait</p>		 <p style="font-size: small; text-align: center;">Trap with attracting pheromone and glue</p>
		

TRANSPARENCY 4.7 (5): MOST COMMON PESTS IN OLIVES, AND POSSIBLE CONTROL MEASURES IN ORGANIC FARMING

Demonstration:

Show farmers the different types of commercial traps used to control the major pests of olive trees. If available, present experimental results on pest control and monitoring of pests with a network of monitoring traps.

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Damage occurs through premature fruit drop and an inferior oil quality (oil made from infested fruit is tainted and more acidic, and it is difficult to separate infested fruits from the harvested crop). In oil production an infestation rate of 10 to 15 % can be tolerated. With table olives, losses result in reduced marketable yield, as an infestation rate of 5 % is usually the maximum permissible. In processing, no more than 12 % of the olives should contain larvae of the olive fly.

Collecting fallen fruits can reduce the spread of the olive fly, by preventing further development of the larvae. The use of harvesting nets helps to avoid infested fruits remaining under the olive trees, which reduces the infection potential for the crop of the following year. Biological control has proved successful by regular releases of the parasite *Psytalia (Opus concolor)*, which attacks the larva and pupa of the olive fly. Grazing sheep and chickens in the grove also reduce the amount of infested fruits left on the ground.

Olive fly is commonly controlled by mass trapping, which involves catching the flies with (non-specific) sticky traps containing an attracting food (protein or ammonia bicarbonate) as bait. The fly is also attracted by the color yellow. There are different types of traps and baits available. Simple baits can be made from a plastic bottle containing water and a dead saltwater fish (e.g. anchovy). The smell attracts the flies. Another low-tech bait is organic liquid fertilizer.

These baits can also be used in combination with yellow traps. Pheromone traps act more selectively, but are more expensive. In cases of severe infestation, additional bait sprays with hydrolyzed protein or insecticides like rotenone or pyrethrum can be used. These non-selective pesticides will also kill natural enemies. It is preferable to use insecticides such as Spinosad or Neem extract that are relatively harmless to natural enemies. Recent results have shown that clay (kaolin) application has an effect on the olive fly too. The processed kaolin particle film technology (product name: Surround®WP; Engelhard Corp. Iselin, NY, USA) has proved to be very effective against the olive fly. When applied on olive trees between May and December this product repels insects without killing them. Hence, its side effects on beneficial arthropods are low. Another new alternative for olive fly control is the use of entomopathogenic fungi, such as *Beauveria bassiana*. However, the effectiveness of this approach still needs to be verified under different climatic conditions.

Rates of olive fly infection are closely related to harvesting time: the earlier the harvest the lower the infection rate, but also the lower the fruits' oil content.

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Olive moth (*Prays oleae*): The life cycle of the olive moth usually involves three generations in a year: the larvae of the first generation feed on flower buds and flowers, those of the second generation feed on the fruit and those of the third generation feed on the leaves. The moth is difficult to detect, as it is active at night and is not very mobile. Typical symptoms resulting from larval feeding are flower buds and flowers that show inhibited development and small webs on buds with particles in spring, premature fruit drop in June/July (in the northern hemisphere), and, from October to March, irregular yellow blotches on the leaves and particles from insect-feeding caught in the silk on the underside of leaves. The moths also tend to lay eggs on pruned branches left in the orchard. Four to five percent of infested flower grapes in the first generation and 20% percent in the second generation of the olive moth are considered critical thresholds in Tunisia. For table olives, the threshold level is at 3 to 4 % infested fruit at harvest, for processing not more than 12% of the olives should contain larvae of the olive moth.

This pest is known to have many natural enemies (e.g. *Chelonus eleaphilus*, *Apanteles utor*, *Elasmus steffani*). Application of pesticides (with exception of *Bacillus thuringiensis*) is also likely to kill these predators. As with the olive fly, promotion of appropriate local weeds or shrubs will help in re-establishing ecological relations between the olive grove and its environment. Species to be chosen in case of moth problems include *Osyris alba*, *Capparis spinosa*, *Malus* spp., *Prunus* spp., *Crataegus* spp., *Vitis* spp. Olive cultivars show significant differences in terms of their resistance to olive moth. Keeping the orchard clean of pruning debris will contribute to control.

A common control method is to hang out traps with an attracting pheromone to catch the first generation of male moths in April/May. If pest pressure is high this should be done in the second generation too. The pheromone also attracts the citrus flower moth (*Prays citri*). Spraying of *Bacillus thuringiensis* is efficient against the young larvae of the first generation. The levels of catches in the traps should indicate the necessity of this measure, which ideally should be timed before blossoming. The treatment should be repeated after eight to ten days if different varieties are grown or if rainfall in the intervening period exceeds 20 mm. Spinosad, Neem, White oil or other natural insecticides can also be sprayed. Biological control with the parasitoids *Trichogramma oleae* or *T. embryophagum* has given promising results in Tunisia. Mass release of *Chrysoperla carnea* has been partially successful in some countries.

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Olive black scale (*Saissetia oleae*): This scale is the most important pest of citrus in the Mediterranean area and a significant pest of olive trees. The scale sucks sap from the plant weakening the plant and hindering fruit development. It can also cause wilting, leaf drop and dieback and encourages the development of sooty mold on honeydew deposits.

Three to five larvae per leaf and 10 scales per m² of olive branches are considered economically critical in Tunisia. Direct control of scales with pesticides is difficult (as the pest is well protected by its wax shield) and must be well timed, and bears the risk of killing beneficial insects. Spraying non-selective pesticides against the olive fly and the olive moth will also kill natural enemies of the scales. Natural control of the scales is further hindered by ants, which 'farm' the scales for their sugary exudates and protect them from their natural enemies. Sticky bands around the tree trunk have proved efficient against ants and thus contribute to the biological control of the scales. Cultural control measures include proper pruning to minimize shaded and humid conditions in the canopy (the larvae dislike hot, dry conditions). Mild winters are favorable to the scales. In countries where control by naturally occurring enemies is not sufficient, enemies (e.g. *Metaphycus* species) have been successfully released in orchards. Washing the trees with soap solutions or spraying with light mineral or vegetable oil is permissible in organic farming, but must be well timed to coincide with the hatching of the young scales. The **olive scale (*Parlatoria oleae*)** is another common scale, which feeds on olive trees. Minor symptoms of olive scale attack are purple discoloration and distortion of olives, while heavy attacks result in a dieback of twigs and branches. The introduction of certain parasites and predators has resulted in natural control of the pest in some countries.

Olive leaf spot (*Cycloconium oleaginum*, *Spilocaea oleaginea*): This fungus is the most potentially serious disease of the olive tree. Infestation can result in extensive defoliation. The disease is mainly a problem in wet years and in areas with high atmospheric humidity. A characteristic symptom is a circular spot on the upper side of the leaves. Several cultivars (e.g. Koroneiki, Lechin de Sevilla, Leccino, Llumet, Canetera, Maalot) show some tolerance against the disease. Prevention by cultural measures consists of appropriate pruning (to ensure good aeration), balanced irrigation and nitrogen management (to reduce sensitivity). In the case of repeated infestations, preventive copper treatment in autumn is recommended. In severe cases, treatment with copper sulfates may be repeated in early spring. Copper, however, has strong side effects on soil microbial species; decreasing dosage, using hydroxide instead of sulfate or replacing copper with lime sulfur or clay will also provide sufficient control and limit copper accumulation.

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Sooty mold (*Fumago vegans*): This type of fungus develops on honeydew produced by scales. Sooty molds reduce the penetration of light and air to the leaves, thus impairing photosynthesis. This promotes leaf drop and reduces yield and quality. For preventive control of the disease, balanced fertilization, balanced irrigation and good pruning are recommended, the latter to ensure good air circulation and penetration of sunlight into the canopy. In the case of severe infestations, direct control is possible by spraying Bordeaux mixture against the fungus, and by controlling the scale insect (see above).

Olive knot: Olive knot is a disease caused by the bacterium *Pseudomonas syringae p.v. savastanoi*, which makes galls and cankers on the twigs and branches of the olive tree. The disease can cause major damage to trees and taint the flavor of the oil. Infection occurs at low temperatures in autumn or spring through wounds from pruning, leaf scars and frost cracks. Rainfall helps spread the infection. When infected, the plant tissue grows uncontrollably and forms galls, which will kill the branches. The disease is spread through rain splash and pruning tools. Pruning (using disinfected tools) and destruction of infected branches as well as consecutive spraying of Bordeaux mixture onto the wounds will hinder any further spread of the disease.

Verticillium wilt: Mainly caused by the soil-borne fungus *Verticillium dahliae*, the disease has a wide range and appears in most moderate to warm climates, except those of hot tropical lowlands. Infested olive trees will show many dying leaves at the onset of warm summer weather. The disease occurs predominantly in poorly drained soils or after prolonged periods of rainfall. It spreads after deep tillage around root systems. A biologically active, well-drained, not over-irrigated soil, which regularly receives considerable amounts of organic material, and a balanced nutrition of the trees, all contribute to controlling this disease. Soil-covering mulch should be kept away from the trunk of the tree. Vegetable crops of the nightshade family (Solanaceae) are hosts to Verticillium and should not be grown in the grove.

4.7. Olives		6
Main diseases of olives and organic control methods		
Diseases	Preventive control methods	Direct control methods
Olive leaf spot (<i>Cycloconium oleaginum</i> , <i>Spirocaea oleaginea</i>)	<ul style="list-style-type: none"> Use tolerant cultivars Ensure good aeration of the canopy 	<ul style="list-style-type: none"> Spray copper
Sooty mold (<i>Fumago vegans</i>)	<ul style="list-style-type: none"> Ensure good aeration of the canopy Control scales 	<ul style="list-style-type: none"> Spray copper
Olive knot (<i>Pseudomonas syringae p.v. savastanoi</i>)	<ul style="list-style-type: none"> Minimize the number of wounds Disinfect pruning tools Spray copper on wounds after pruning 	<ul style="list-style-type: none"> Prune and destroy infested branches
Verticillium wilt (<i>Verticillium dahliae</i>)	<ul style="list-style-type: none"> Use tolerant/resistant cultivars Ensure good drainage of soil Ensure balanced nutrition of the trees Enhance the biological activity of the soil 	

TRANSPARENCY 4.7 (6): MOST COMMON DISEASES IN OLIVES AND POSSIBLE WAYS TO CONTROL THEM ORGANICALLY

4 Management Guide for Crops

4.7.6 Water management and irrigation

The cultivation of olives generally requires irrigation. While it is possible to grow olives without irrigation, olives respond to a regular water supply by yielding more fruit of a better quality, earlier in the season, and becoming less prone to reduce quantity alternate bearing years. Irrigation is therefore essential in large commercial olive orchards. Today, most olive orchards in arid and semi-arid areas are still not irrigated and rely only on rainfall (i.e. in Tunisia 95% of olive areas are not irrigated). In order to keep irrigation sustainable, correct and accurate, control of water resources is essential.

Fruit setting starts in summer, when the vegetative buds change into flower buds. Sufficient water during this period assists in the induction of flower buds. Stress, caused by lack of water, pest or disease, or deficiencies in nutrients can affect fruit development.

Basically, three strategies exist for water management: ploughing in the very dry regions where there is no possibility of irrigation, irrigation, and mulching in partly humid regions (that experience winter rainfall from November to March).

In rain-fed olive cultivation, water management aims to reduce evaporation from soil and to conserve water from rains by repeated soil tillage. This can enhance soil water storage by breaking the surface crust and increasing water infiltration. On the other hand, tillage increases the evaporation of water stored in the soil as the moist soil is exposed to the atmosphere. Depending on the climate, up to eight tillings per season may be appropriate.

Mulching in winter-rainfall areas can conserve considerable amounts of moisture in the soil (50 % more than bare soil).


The amount of irrigation water that is needed depends on the climate, the microclimate in the olive grove, tree density, and soil qualities (i.e. water-holding capacity), the cultivars and the age of the trees. The minimum annual water requirements of an olive orchard are about 2000 m³ per hectare or 200 mm per m². For good crops of canning-sized olives, irrigation comparable to that required by most other tree crops is essential.

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4.7. Olives

Water management and irrigation in olive orchards

- ✓ Maintain the physical and chemical condition of the soil, while conserving the water resources
- ✓ The irrigation system should be appropriate to the cultural environment, cultivars and the training system
- ✓ Frequency and timing to be adapted to the requirements of the trees, soil type, climate, tree density and cultivar
- ✓ Consider tillage to reduce water losses
- ✓ Observe indicator plants in the orchard



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TRANSPARENCY 4.7 (7): PRINCIPLES FOR IRRIGATION IN ORGANIC OLIVE CULTIVATION

Exercise: Irrigation (if appropriate)

Ask the participants to determine the frequency and timing of irrigation in the region by applying the following techniques:

- *Irrigation frequency - using meteorological and soil data, and data related to the ground cover of the olive orchards.*
- *Timing of irrigation - examining soil humidity at 0-15 cm and observing one or two control trees that are used as indicators.*

Alternatively, encourage sharing of experiences amongst the participants or visit a farm and discuss with the olive farmer the necessity for, and management of, irrigation under local conditions.

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Water requirements are highest during flowering and fruit setting in late spring, and again when the fruits increase in size. Irrigation water should be managed so that it meets the trees' water requirements during these critical stages. In table olive production it is considered crucial to have well-watered conditions during the entire season in order to obtain good fruit size. Excessive soil moisture can however result in nutrient leaching and increased pest and disease attacks.

In organic cultivation, low-volume irrigation systems such as drip irrigation systems are usually recommended, as they contribute to an economic use of water and help prevent soil salinization. While in arid climates the drip lines are laid onto the ground, in orchards with a permanent soil cover they may be suspended to allow for the use of mowers.

The frequency of irrigation and the amount of water to be used can be determined with computer programs, using meteorological and soil data and data related to the ground cover of the grove (water budget method). Control plants such as *Malva silvestris* can be used as indicators for soil humidity. Irrigation must be started when the indicator plants begin to wilt. Tensiometers may also be used to determine the timing of irrigation and the quantity of water needed.

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4.7.7 Pruning

In traditional olive farming, little attention is generally paid to pruning. Thus, pruning is done at infrequent intervals and with no distinctive plan. However, regular training and appropriate pruning have proved to be of major importance in achieving a balance between vegetative growth and fruit set (to avoid alternate bearing) and in allowing good penetration of light, air and sprays.

The amount of light in the canopy is regulated by several different factors, such as the density of the trees in the olive grove, their shape, the volume and density of the canopy foliage and the adequacy of pruning. Yields are highly sensitive to the level of solar radiation that penetrates the canopy.

The pruning of olive trees is designed to remove old unproductive or dead wood and to direct the formation of vegetative and flowering buds. In conjunction with irrigation, fertilization and plant protection, pruning makes a valuable contribution to the productivity of the olive orchard. Once the mature olive tree is in balance with its environment (directing most of its effort into forming fruit), it almost stops growing and will require only minor pruning.

Pruning young trees

Very little pruning of young trees is undertaken, so that they will bear fruit as quickly as possible. If any pruning is done at this stage, it is mostly with the intention of shaping the canopy for hand picking.

At the time of planting, young trees are about 30 cm high. It takes between 18 months to 2 years for them to grow into a straight trunked tree of about 2 meters. Between the second and fourth year the trees will build their crowns. During this period pruning should be restricted to removing branches below 1 meter and repairing any damage to broken limbs.

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Pruning of the mature tree

Pruning of fruit-bearing trees is usually carried out every two years, and is best done after harvest, when the tree's sap is still flowing and will close the wounds properly.

Pruning is done in sequences following the shape of the tree, starting from the base and working up to the crown. The base is pruned first, then the apron (where the majority of fruiting takes place), followed by the center, and finally the crown of the tree.

The aim of pruning at the center of the canopy is to improve airflow and light penetration. Branch development should be approximately half that of the apron and crown.

The crown is crucial for the tree's development and is pruned to limit the height of the tree and to shape the canopy. The most preferable shape is hemispherical, (so the olive trees are shaped like an open umbrella). Excessively vigorous shoots are removed, taking care to avoid creating any large holes in the canopy. If necessary, the shoots are cut at the top to create axial shoots. If the outer side shoots are very dense, they are thinned out.

Severe pruning may be required in old trees which are impossible to harvest at the top.

Prophylactic measures after pruning

After pruning, mastics should be applied to speed the healing of large cuts in order to avoid pest and disease infection (e.g. damage by *Euzophera pinguis*). Frequent disinfection of pruning equipment is recommended to avoid spreading diseases (e.g. *Pseudomonas* spp.). Except in case of *Verticillium dahliae* infection, when pruned material must be removed and destroyed, healthy pruning material should be used for compost production.

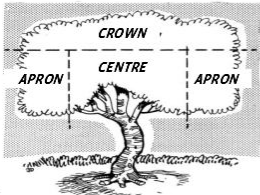
Demonstration:

If possible, arrange a demonstration of how olive trees should be pruned. If it is not possible to demonstrate this in the field, show it with photos or drawings.

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4.7. Olives

Pruning of olive trees is a vital cultural practice



The diagram shows a cross-section of an olive tree canopy. The top part is labeled 'CROWN', the middle part is 'CENTRE', and the lower, wider part is 'APRON'. Dashed lines indicate the boundaries between these sections.

Because ...

- It ensures regular fruiting (balancing vegetative growth and flowering)
- It regenerates the trees and thus contributes to their longevity
- It assists the trees to adapt to local growing conditions
- It helps with disease prevention and permits easier control of pests and diseases
- It conserves water and humidity (as it reduces transpiration)
- It regulates the nutrient requirements of the trees

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TRANSPARENCY 4.7 (8): REASONS FOR THE RELEVANCE OF PRUNING OF MATURE OLIVE TREES

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4.7.8 Harvest and post-harvest handling

The quality of the fruits, and the use to which they can be put (i.e. for oil production or for table use) are greatly influenced by their maturity and integrity at harvest, by good harvesting practices and appropriate post-harvest management.

For best quality oil the olives must be harvested at full maturity, shortly after they have reached their highest oil content. In practice, this is often difficult as the olives ripen sequentially rather than simultaneously. Harvesting by hand allows for more selectivity in only harvesting mature fruits of good quality. Mechanical harvesting is done in one go and is less selective. A good time for mechanical harvesting is when 50 % of the fruits have turned from green to violet. Damaged fruits will rapidly oxidize, and will produce an acid and bitter tasting oil. Careful harvesting is therefore highly important.

The oil in the fruit readily retains the odor of pesticides and other substances. Thus, it is imperative to prevent any residues of pesticides remaining on the fruit at harvest. Chemical contamination during processing must also be prevented.

The following aspects of harvesting are important to maintain the quality of the fruit and oil.

- The fruits should be collected separately, according to variety or degree of ripening.
- For best quality oil, only intact fruits should be collected (a limit of 2 % of damaged fruits is commonly tolerated). Damaged or diseased olives should be kept apart from healthy fruits.
- The olives should not come into contact with the ground. Olives that are muddy or mixed with stones and soil should be carefully washed as early as possible and not mixed with clean fruits. Olives picked straight from the trees give higher quality oils than those picked off the ground.
- Boxes should not be overfilled as the fruits should stay in contact with the air at all times.
- The olives are collected in rigid open containers. Bags are not allowed.
- After harvest, the olives are stored in dry and hygienic conditions avoiding any contact with hydrocarbons (e.g. gasoline).
- When the olives reach the mill they should be graded.
- For best quality oil, the olives should be pressed on the same day that they are picked from the trees. Fruits for oil should not be stored for longer than three days.

Discussion:

Visit a farmer or an olive mill and discuss the factors that influence the quality of the fruit and oil with those whose job it is to manage these aspects of the production process.

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Harvest and post-harvest handling of olives

Principles for harvesting:

- Separate fruits according to variety and/or degree of ripening
- No more than 2 % damaged fruits; separate diseased fruits
- Avoid fruit coming into contact with the ground
- Ensure continual contact of the fruit with air
- Store in dry and hygienic conditions
- Press the same day, and not later than 3 days after harvest



Principles for processing:

- Clean fruit
- Appropriate and clean infrastructure
- Careful processing
- Appropriate operating temperatures



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TRANSPARENCY 4.7 (9): PRINCIPLES FOR HARVEST AND POST- HARVEST HANDLING OF OLIVES

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Green ripe olives will produce a green fruity oil whereas black ripe olives yield a yellow sweeter oil. In the northern hemisphere, olives that are used to make oil are harvested between November and January. Table olives are picked by hand between October and mid-November.

Traditionally, olives for oil are harvested by hand or beaten off the tree onto nets spread under them. Machine harvesting (using mechanical branch or trunk-shakers) has become popular on large farms as it speeds up harvesting considerably, saves labor costs and is suitable for most cultivars.

Yields of olive orchards vary greatly. Traditional dry-farmed mature orchards yield from about 1 to 3 tons per hectare, whereas modern irrigated orchards yield between 10 and 15 tons per hectare. Organic olive orchards give similar yields to conventionally managed orchards, and sometimes even higher.

New intensively cultivated trees bear fruit within three to five years, depending on the cultivar. Full production is generally reached from seven to nine years onwards. The best yields are often obtained from mature trees exceeding 250 years of age.

Processing

Olive oil is obtained by crushing the fruits and by pressing or centrifuging the paste, including the seed. Traditionally, granite millstones and hydraulic presses are used and the paste is then allowed to settle so that the oil can be decanted. In modern processing, the paste is centrifuged and the oily phase subsequently settled and centrifuged again, leaving the oil clean and ready to be stored. The use of enzymes to extract the olive oil is not allowed in organic olive oil production. Virgin oil is obtained from fruit that is processed solely with mechanical or physical means. The fruits undergo no other treatment than washing, decanting, centrifuging and filtering. Olive oil that has been obtained according to these methods and has a free acidity, (expressed in terms of its oleic acid content) of not more than 2 grams per 100 grams (2.0 %) can be labeled as "Virgin Olive Oil". Olive oil that has a free acidity of not more than 0.8 grams per 100 grams (0.8 %), can be declared as "Extra Virgin Olive Oil". Good oil has an acidity level of 0.4 to 0.5 % and a pleasing aroma, flavor and color.

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High quality olive oil is rich in mono-unsaturated fatty acid, medium in polyunsaturated fatty acid, and contains small amounts of polyphenols, tocopherols and sterols. Such oil is well-suited for high temperature cooking (due to the predominance of mono-unsaturated fatty acid). Olive oil has useful medicinal properties due to its antioxidant structure and the protective effect of the tocopherols and polyphenols.

Table olives need to be fermented, treated with salt or dried to remove their bitterness and make them palatable.

Olives are highly susceptible to bruising and require careful handling both during harvesting and post-harvest handling.

Olive processing should pay attention to the following issues:

- The processing plant should be cleaned regularly and thoroughly during the harvesting period.
- All parts of the processing plant should be made of stainless steel.
- The processing plant should operate at temperatures below 30 °C.
- On delivery to the oil mill, leaves and small lips should be removed from the fruit.
- The olives should be washed thoroughly with clean and fresh water.
- Metal crushers should be made from stainless steel and operate at low speed.
- The olive paste should be beaten at low speed and at temperatures below 22 °C.
- Plastic filter mats should not be used in pressing.
- The filter mats should be thoroughly cleaned at regular intervals.
- For centrifuging, water temperature should not exceed 26 °C and water should be of good quality.
- For percolation, the metal plates should be cleaned thoroughly at regular intervals.
- Directly after processing the olive oil must be poured into stainless steel storage tanks. In order to avoid oxidation, the tanks should be filled completely, especially if no nitrogen is used. The temperature in the store containers should not exceed 28 °C.

Bottling

Organic olive oil should be kept in glass bottles of a dark colour. The oil should be filtered just before bottling. Bottling should be performed at a room temperature of 20 to 28 °C. The bottles must be filled to at least 90 % of their capacity and remaining air in the top of the bottles may be replaced by nitrogen. The filled bottles should not be exposed to direct light.

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4.7.9 Economic and marketing aspects

Market development

Worldwide consumption of olive oil is increasing due to its health benefits and the growing popularity of Mediterranean cuisine. Growing consumer demand for healthy and nutritional food has led to market demand for organic olive products expanding rapidly over the past decade. Further increases in demand are expected. Organic olive oil production focuses on the top quality extra virgin and virgin product range.

It is likely that the available quantities of organic olive oil will also increase further too, due to the price incentive for organic produce and improved cultural practices in organic olive groves.

Marketing initiatives founded by organic olive farmers in order to enter the organic market have proved to be of great value to the farmers, as they lower the costs for certification and processing, and provide a structure for ongoing training and other support that benefits the members. (One organic olive oil marketing initiative is presented in chapter 3.2 of this manual.)

Economy

Organic cultivation of olives tends to demand more labor than conventional production, mainly due to the introduction of farm compost production, but also because of the maintenance of higher (crop) diversity in the olive grove. Furthermore, in the first years, considerable efforts may need to be directed at marketing, as well as learning organic farming methods.

Although farm compost production demands more labor, and some investments may be necessary at the beginning, it can contribute to lower overall production costs, as it reduces the amount of commercial fertilizers needed. Extensively (traditionally) cultivated olive orchards will experience higher yields after conversion to organic farming due to improved soil fertility and refined cultural practices. In some countries, farmers receive state funding for conversion to organic agriculture and for the necessary organic certification.

If the farmers aim to add value to their olives by organizing the processing of the olives themselves, they will naturally experience higher costs. In this scenario, processing units and storage areas must be rented or installed and new technical and organizational skills developed.

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Economy

- Labor:
 - More labor needed for compost production, higher crop diversity, marketing
- Costs:
 - Reduction as fewer inputs purchased
 - Increase due to certification costs, additional labor and possibility of self-processing
- Higher price of 20-25 % or more (especially, if value added)
- State funding for conversion or certification available in some countries

Market

- Growing demand for high quality oil and fruit
- Increasing organic production
- Nevertheless, major efforts necessary to find good marketing opportunities
- Farmer-led marketing initiatives have proved successful





TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.7 (10): ECONOMIC AND MARKETING ASPECTS OF ORGANIC OLIVE CULTIVATION

Group work: The economic risks and potentials of conversion to organic farming

Analyze the financial risks and potentials of converting local olive cultivation to organic agriculture. If possible, discuss the results of the group work with local organic farmers and see if these reflect their experiences.

Discussion: Standards for marketing

Discuss organic production standards for the marketing of olive oil (including olive washing procedure, extraction methods, enzymes, separation, oil tankers, target retail markets, labels and blending).

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Raising the value of the product by selling bottled or processed olive oil instead of the harvested fruit only, and getting a premium for the certified organic produce, generally justifies the higher investments and costs.

The high ecological value and quality of the produce has so far been rewarded with a price, about 20 to 25 % above the conventional rate. For many farmers, organic olive production provides a remarkably higher income per hectare compared with conventionally produced fruit.

Instead of relying on just one crop or product, most organic farmers aim at diversifying their personal economies by cultivating different crops with different seasonal timing, by diversifying their marketing strategies and also, by finding alternative sources of income, for example, agro-tourism.

Recommended websites:

- *International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC);* www.iobc.ch/
- *Crop guide (in Italian);* www.biopuglia.iamb.it/produzione/quaderni/V2OLIVO.pdf
- *Natural enemies of olive pests (in Italian);* www.biopuglia.iamb.it/arboree/web205.htm
- *Crop guide (in Italian);* www.stuard.it/speciali.asp?IDSezioneSpeciale=831

Recommended readings:

- *Produire des fruits en Agriculture Biologique, Collectif GRAB, 2001. Editions ITAB, 310 pages.*
- *Ullishtaria Organike, Isufi E. et al., Tirana 2005, 132 pages.*
- *Kabourakis E, 1996. Prototyping and dissemination of ecological olive production systems: A methodology for designing as a first step towards validation and dissemination of prototype ecological olive production systems in Crete. PhD Thesis, Wageningen Agricultural University.*

4 Management Guide for Crops

4.8 Cotton

Introduction

Cotton is an extremely important fiber crop, with a production of 23 million tons of fiber (lint) in 2004-2005. The major producers are China, the US, India, Pakistan and Brazil, but cotton also plays a major role in the economies of a number of Central and West African countries. Cotton prices have come down by about 50 % over the last decade. According to Oxfam and other NGOs, this is mainly due to high farm subsidies in the US. The by-products of cotton are the edible oil gained from the seeds and the seed cakes and husks, which can be used as fodder or compost.

Cotton production worldwide consumes more than 20 % of all insecticides used in agriculture. In many areas, irrigated cotton cultivation has led to a significant depletion of ground and surface water resources. Many conventional cotton farmers in the South are in a crisis due to decreasing soil fertility, increasing production costs, resistant pests and/or low cotton prices. In this scenario, an increasing number of farmers turn to organic cultivation in order to restore soil fertility, reduce production costs or to get a better price for their certified organic harvest. In the South, the conversion of smallholder farms to organic cotton is usually facilitated by companies or NGOs that provide extension and inputs, as well as organizing the certification, processing and marketing of the produce.

The major markets for organic cotton textiles are Europe (Germany, Switzerland, the UK and Sweden), the USA and Japan. Consumers in industrialized countries buy organic cotton for health reasons (reduced risk of skin irritation and allergies), but also to spare the environment from agro-chemicals and to support farmers in the South in achieving a sustainable livelihood. While originally most organic cotton production was processed into garments containing 100 % organic cotton fiber, there is a new trend emerging that large garment brands are blending a certain percentage (usually 5-10%) of organic fibers with conventional ones.

Lessons to be learned:

- Overview of the organic cotton production system.
- Familiarity with key technologies for successful crop management.
- Understanding the different strategies (low input or intensive) for organic cotton cultivation.
- Enabling extension staff and farmers to develop the organic cotton system further.

Motivation:

Invite the participants to a brief brainstorming session. Why are they interested in growing cotton organically? Note down the points in key words on a flip chart or board. Compare these aspects with those listed in transparency 4.8 (1). Discuss which of the points are most important to them.

4.8. Cotton		1
Advantages of cultivating cotton organically		
	Conventional cotton	Organic cotton
Environment	<ul style="list-style-type: none"> • Pesticides kill beneficial insects • Pollution of soil and water • Resistance of pests 	<ul style="list-style-type: none"> • Increased biodiversity • Eco-balance between pests and beneficial insects • No pollution
Health	<ul style="list-style-type: none"> • Accidents with pesticides • Chronic diseases (cancer, infertility, weakness) 	<ul style="list-style-type: none"> • No health risks from pesticides • Healthy organic food crops
Soil fertility	<ul style="list-style-type: none"> • Risk of declining soil fertility due to use of chemical fertilizers and poor crop rotation 	<ul style="list-style-type: none"> • Soil fertility is maintained or improved by organic manures and crop rotation
Market	<ul style="list-style-type: none"> • Open market with no loyalty of the buyer to the farmer • Dependency on "spot" market rates • Usually individual farmers 	<ul style="list-style-type: none"> • Closer relationship with the market partner • Possibility to sell products as 'organic' at higher price • Farmers usually organized in groups
Economy	<ul style="list-style-type: none"> • High production costs • High financial risk • High yields only in good years 	<ul style="list-style-type: none"> • Lower costs for inputs • Lower financial risk • Satisfying yields once soil fertility has improved

TECHNICAL MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

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TRANSPARENCY 4.8 (1): SOME REASONS FOR GROWING COTTON ORGANICALLY

4 Management Guide for Crops

4.8.1 Agro-ecological requirements and site selection

Requirements of the cotton crop

Cotton is grown in a wide range of climatic conditions in temperate, subtropical and tropical regions of all the continents. Ideal conditions are in regions with long periods without frost, high temperatures (ideally around 30 °C), ample sunshine and a rather dry climate. Cotton is very sensitive to waterlogging, which causes a reduction in yields (more boll shedding) even when the plant appears to be unaffected. It prefers deep, well-drained soils with good nutrient content. Clay-rich vertisols (so-called 'black cotton soils') are ideal. In such soils cotton plants' long tap roots can penetrate up to three meters which allows them to sustain short periods of drought. However, cotton is also grown on less ideal sites with shallow, sandy soils, under both irrigated and rain-fed conditions. This requires careful selection of varieties and adaptations in terms of management practices.

The right variety for the right site

The ancestors of today's cultivated cotton varieties were perennial, hardy shrubs of the *Malvaceae* family, originating from semi-arid regions. Nowadays, by far the most widely grown species is *Gossypium hirsutum*, often called American Upland cotton, which is available in a large number of hybrid varieties. Less frequently cultivated is *G. barbadense* (Sea Island cotton), the long fibers of which are spun into extra-fine garments. In some regions of India and Pakistan, a number of local 'desi' varieties of *G. herbaceum* and *G. arboretum* are grown besides the 'American hybrids'. They are usually more resistant to pests and to drought, but most have a shorter staple length and thus fetch lower prices in the market.

There are a large number of different cotton varieties available in the seed market, and research stations and seed companies continuously release new varieties. Most of them are bred for producing high yields under high input conditions: using fertilizers, pesticides and irrigation. Organic farmers, however, are more interested in robust varieties, which are resistant or tolerant to pests and produce satisfying yields with a medium manure supply.

To select the most suitable varieties, farmers should consider the site conditions (soil quality, rainfall, availability of irrigation water) as well as the conditions on the farm (availability of manure, possibilities for pest management). Where irrigation is a constraint and rainfall is erratic, it is preferable to have varieties that require less water (e.g. those with a smaller leaf area). In addition, the variety selection needs to consider the buyer's requirements concerning staple length and other fiber quality aspects (transparency 4.8 (2)).

Discussion: Evaluating cotton varieties

How to identify the most suitable cotton varieties for organic farmers in a region? Prepare a table on a paper chart, with columns labeled variety, yields, water requirements, resistance to pests and fiber quality. Ask the participants which varieties are grown in the region and what the farmers' experiences have been with them. Enter the characteristics into the table. Example:

Variety	Yields	Water requirements	Resistance to pests	Fiber quality
Variety X	Good, if sufficient irrigation	High, drought sensitive	Medium, sensitive to sucking pests	25 –27 mm staple, fetches good price


Discuss which varieties are the most suitable ones for good sites and which for marginal sites. Is there a need / interest to compare the performance of certain varieties under organic conditions in plot trials on farmer fields?

4 Management Guide for Crops

4.8. Cotton 2

Selecting the right cotton varieties

American Upland cotton (*G. hirsutum*)



larger leaves

Advantages:

- High yields
- Longer staple (higher price)

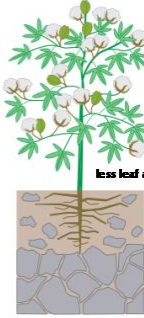
Disadvantages:

- Needs more water
- Needs more manure
- More prone to pests

Suitable for:

- Deep soils
- Heavy soils
- Irrigation

Indian 'desi' varieties (*G. arboreum, G. herbaceum*)



less leaf area

Advantages:


- More drought resistant
- More pest tolerant

Disadvantages:

- Smaller yields
- Mostly shorter staple (lower price)

Suitable for:

- Shallow soils
- Sandy soils
- Little/no irrigation

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TRANSPARENCY 4.8 (2): SELECTING THE RIGHT COTTON VARIETIES

4 Management Guide for Crops

Seeds

Most cultivated cotton varieties are hybrids that are propagated by seed companies and cannot be multiplied without having the parent lines. In India, research stations have also developed a number of improved non-hybrids, and the seeds of these plants can be regrown for a number of years. Breeding varieties specifically suited to organic farming conditions remains a challenge that needs to be tackled in coming years.

Conventionally produced cotton seeds are frequently treated with chemicals prohibited in organic farming. Thus, organic cotton projects need to ensure a reliable supply of suitable untreated seed material or arrange for their own seed multiplication programs.

Alternative treatment of seeds can help to reduce damage by pests and diseases caused before and during germination. Some suggested methods include dipping in cow urine, coating with clay and cow dung and treatment with a suspension of beneficial microorganisms (*Trichoderma* or *Bacillus subtilis*). To enhance the uptake of nutrients some organic farmers treat the seeds with a suspension of *Azotobacter* and phosphorus solubilizing bacteria (PSB).

No Bt-Cotton in Organic Agriculture!

In organic agriculture the use of genetically modified organisms (GMOs) is not allowed. For some years, seed companies have been promoting genetically engineered 'Bt cotton'. It contains genes from the same micro-organism, *Bacillus thuringiensis*, that is used in bio-control against a number of insect pests, also by organic farmers. The Bt cotton plant thus continuously produces an insecticide that prevents bollworms from feeding on it. However, bollworms frequently develop resistance to it, forcing the seed companies to develop new varieties of Bt cotton. Also, there is a risk that the development of resistance makes Bt sprays less effective, thus harming organic farmers.

The cultivation of Bt cotton involves higher financial risks, since the seeds are considerably more expensive and the crop is usually grown with high inputs of fertilizers and pesticides against sucking pests. In India, many conventional farmers who tried Bt cotton complained about crop failure, possibly due to inappropriate varieties, unfavorable climatic conditions, or adulterated seeds. Despite the benefits promised by its promoters, growing Bt cotton seems to be a high-risk strategy.

Organic farmers find it more and more difficult to get cotton seed material that is guaranteed GMO-free. Some certification bodies use test strips to check whether cotton plants contain GMOs.

Demonstration: Organic seed treatment

Collect information about local methods of organic seed treatment or ask the participants whether they know of any. Demonstrate the seed treatment methods in a practical exercise involving the participants.

4 Management Guide for Crops

4.8.2 Diversification Strategies

Rotation crops

It is important that organic cotton is grown in rotation with other crops. This helps to improve and maintain soil fertility and ensures balanced nutrient content in the soil. If cotton is grown continuously on the same field, yields are likely to decrease. Crop rotation and mixed cropping also help prevent build-up of pest populations, diseases and weeds. Pests find it more difficult to move from one host plant to another, and they are controlled by a number of beneficial insects hosted by the rotation crops or intercrops. Crop diversity also reduces the farmer's risk, making them less vulnerable to crop failure and to fluctuating prices. Furthermore, it helps prevent a shortage of labor in peak seasons, as labor requirements are more evenly distributed throughout the year.

Depending on climatic conditions, the market situation and the availability of land, there are a number of suitable rotation patterns, with cotton grown every alternate or every third year. The most suitable rotation pattern for a particular farm depends on a number of factors: soil properties, irrigation facilities, crop prices, market access, and – last but not least – the skills and preferences of the farmer. Transparency 4.8 (3) lists some suitable rotation patterns from organic cotton projects in India and Africa.

On organic farms, cotton should not be grown in fields where the previous year's crop was also cotton (no 'cotton after cotton'). The reason is that if cotton is grown year after year in the same field, the soil nutrients get depleted, pest populations increase and there is a risk of soil-borne diseases. Another crop should be grown between two cotton crops for at least one year, preferably two. If very small land-holdings force farmers to grow cotton after cotton, they should at least use an intercrop (e.g. mung bean, cowpea, or chickpea for harvesting) or a green manure crop (e.g. Sunn hemp or cowpea, to be cut and ploughed back into the soil before flowering).

Particularly good yields are achieved when cotton is grown after pulses (soy bean, chickpea, pigeon pea, groundnut etc.), horticultural crops like chilis or vegetables, and after sugarcane and wheat. Organic farmers should make a point of including pulses in the rotation, as these increase the nitrogen content in the soil by fixing nitrogen from the air.

In some places a crop of wheat, pulses or fodder can be grown after cotton in the winter season. In India, in places where there is sufficient irrigation, farmers usually uproot the cotton crop before the second flush, in order to grow a wheat or chickpea crop in the "Rabi" season. Growing wheat rather than continuing to harvest the cotton is usually more remunerative, as the gains from the wheat crop more than compensate for the loss in cotton

4.8. Cotton				3
Crop rotation – rotation crops				TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS
Rotation Type	1st year	2nd year	3rd year	
Pulses+ cereals	Cotton (winter crop: wheat or pulses)	Pulses (soya, mung beans, cow pea, black gram, pigeon pea), maize or sorghum	Cotton (winter crop: wheat or pulses)	
Vegetable	Cotton (winter crop: wheat or pulses)	Chili, onion or other intensive vegetable crop	Cotton (winter crop: wheat or pulses)	
Sugar cane	Cotton	Sugar cane	Sugar cane	
Diverse rotation (from Tanzania)	Cotton	Sesame, safflower, sorghum or maize	Pulses (mung, chick pea, cow pea, pigeon pea, groundnut)	
Rotation with herbal plants (from Egypt)	Cotton (winter crop: wheat or pulses)	Herbs (aniseed, basil, fennel etc.)	Maize with clover intercrop	

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TRANSPARENCY 4.8 (3): SOME CROP ROTATION PATTERNS

Group activity: Designing suitable crop rotations

Prepare a crop rotation table on a paper chart or board (example given below). Ask the participants what the typical cotton rotation patterns in the area are, and to list them in the table.

Rotation	1 st year	2 nd year	3 rd year	Advantages (+) & Disadvantages (-)
Type 1:	Cotton	Chilli	Cotton	+ high value - lot of inputs needed - risk of diseases

Discuss the advantages (+) and disadvantages (-) of each rotation pattern. Summarize the rotation patterns that are most suitable under regional conditions. Are the participants interested in developing and trying out new patterns? Compare the results with the rotations given in transparency 4.8 (3).

4 Management Guide for Crops

yields and the additional production costs. However, sufficient availability of irrigation water and of labor are important pre-conditions for this.

Green manures and intercrops

Green manure crops for cotton (mainly pulses like Sunn hemp or cowpea, or mixtures containing pulses and cereals) are usually sown between the cotton rows after the cotton seedlings have emerged. They are cut before or at the time of flowering, and are either used as mulch or incorporated into the soil. Intercrops like maize or pigeon pea can be grown in rows every few meters, replacing a row of cotton. Smaller pulses like mung bean, black gram and cowpea, or small millet varieties, can be grown in between the cotton rows, or between the individual cotton plants. Intercrops are usually allowed to mature before being cut and used as organic mulch after the seeds are harvested (Transparency 4.8 (4)).

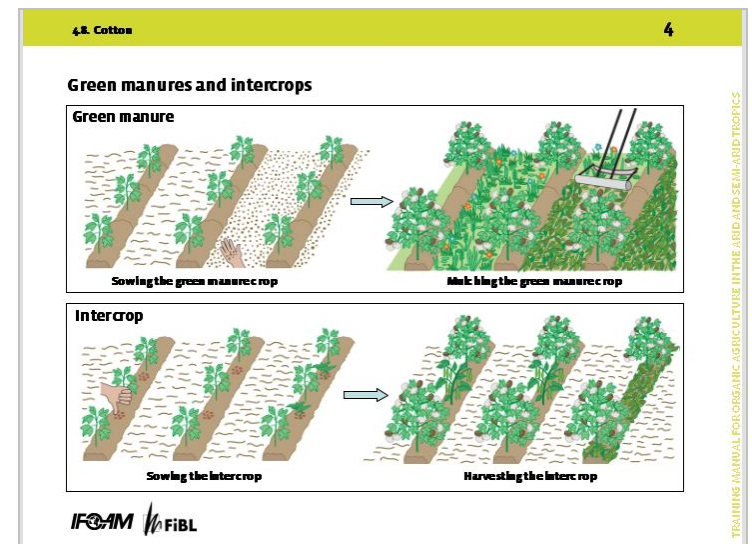
Both green manures and intercrops have the following benefits:

- Distract pests from the cotton crop (especially sucking pests) and attract and host beneficial insects.
- Take up nutrients from the soil, which would be lost to the crop and build up organic matter (better soil structure, water retention, overall fertility).
- Fix nitrogen from the air (legumes) and make nutrients available to the cotton crop when decomposing. Mulch keeps moisture in the soil.
- Suppress weeds.
- Reduce soil erosion through rain or wind.
- Provide additional yield, or fodder for cattle.

On the other hand, green manure and intercrops do compete with the cotton crop for water, light and nutrients. Thus, appropriate timing of sowing and cutting is very important in order to get maximum benefit with minimum competition.

Discussion: Pros and cons of green manures and intercrops

Ask the participants which green manure crops and which intercrops they would suggest for cotton and list them on the board. Discuss the advantages and disadvantages of the suggested options, if possible based on the experience of farmers. Determine which are the most suitable options under local conditions. Are the participants interested in trying them out? See box: Trials on green manures and intercrops.



TRANSPARENCY 4.8 (4): THE SYSTEM OF GREEN MANURES AND INTERCROPS. THESE DRAWINGS SHOW THE SOWING (LEFT SIDE) AND THE CUTTING / MULCHING (RIGHT SIDE) OF GREEN MANURES AND INTERCROPS.

Reference to the Basic Manual:

Concerning the advantages and disadvantages of green manures and intercrops and their uses, refer also to chapters 3.6, 4.2 and 4.5 of the Basic Manual.

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Trials on green manures and intercrops

To try out alternative options for green manures and intercrops, farmers can conduct simple plot trials on their farms. Once a promising option is identified (e.g. intercropping of mung beans), the farmer organizes for the necessary seed material and selects a suitable field for the trial. In the field the farmer chooses three strips with equal numbers of cotton rows of the same length, keeping three strips of the same length and width without intercrop or green manure as control plots. The trial plots and control plots are harvested separately so that the yields can be compared. The yields and the value of the intercrops should also be taken into consideration when comparing the new method with the previous system.

4 Management Guide for Crops

4.8.3 Soil protection and weed management

Soil fertility management


The right strategy to improve and maintain soil fertility in cotton first of all depends on the soil types present in a farm. Light or shallow soils usually have lower water retention and nutrient exchange capacities than deep or heavy soils. The application of compost is important in order to increase water holding and nutrient supply. As these soils are less suitable for intensive production, the variety and crop selection should be adapted accordingly (robust, frugal, drought resistant cotton varieties and rotation crops). Intercropping more drought resistant crops like sorghum, sunflower, sesame or castor can help to reduce the risk of crop failure. Soil cultivation should be shallow and kept to a minimum in order to avoid soil erosion and enhance decomposition of organic matter (transparency 4.8 (5)).

In deep or heavy soils (e.g. black cotton soil), an intensive production system can be established with sufficient inputs of organic manures, intensive crop rotation and green manuring. Frequent shallow soil cultivation helps to improve soil aeration and nutrient supply. It also reduces evaporation and suppresses weeds. When the cotton crop is well established (after 6 to 9 weeks) it is recommended that additional organic manure (e.g. vermicompost or oil cakes) be applied, and that the soil is ridged up in order to accelerate decomposition and to bury the weeds.

Weed management

Proper crop rotation and timely soil cultivation are the most important aspects of successful weed management in cotton. However, this does not mean that the cotton fields need to be kept free of weeds throughout the season. In the initial stage of plant growth, weeds catch nutrients which otherwise would be lost through leaching. These nutrients are returned to the soil and made available to the cotton crop when the weeds are cut. Once the cotton crop has developed a dense stand, weeds usually remain below a level where they significantly compete with the main crop. Some weeds are important hosts for beneficial insects, or act as trap crops by distracting pests from the cotton plant. Careful observation of weed populations and the use of shallow soil cultivation (weeder) combined with selective hand weeding usually allow the experienced organic farmer to keep on 'good terms' with weeds.

To avoid spreading weed seeds through compost, it is important that composts containing weed seeds go through a heat phase during which these seeds are destroyed.

4.8. Cotton		5
Soil types and their management		
Light soils	Heavy soils	
Shallow; roots do not penetrate very deeply	Deep; roots penetrate deeply	
Light colors	Dark colour; cracks when dry	
Sandy; easy to cultivate	Rich in clay; muddy when wet, hard when dry	
Low water retention capacity → affected by drought!	High water retention capacity → less risk of being affected by drought	
Nutrients easily leached out → needs sufficient compost; supply of mineral fertilizers in several doses	Very fertile → needs sufficient manure to meet high productivity demands	
Drought-resistant crops: sorghum, maize, pigeon pea (desi varieties), mung, millet, castor; desi cotton varieties	High performance crops: chili, soya bean, banana, sugarcane, hybrid cotton varieties, pigeon pea (hybrid varieties); wheat	
Intercrop to reduce risk of crop failure	Intensive crop rotation; green manures	
Compost and mulching to improve water holding and nutrient supply	Compost to activate soil life and improve soil structure	
Shallow plowing, little soil cultivation	Deep plowing, frequent intercultural operations (shallow soil cultivation)	
Increase infiltration with trenches and bunds	Risk of waterlogging!	
		

TRANSPARENCY 4.8 (5): SOIL CHARACTERISTICS AND THE MANAGEMENT OF SHALLOW AND DEEP SOILS

Group work: Soil quality and crop management

In plenary discuss the dominant soil types in the region and their properties. Note these down. Divide the participants into 2-3 groups (one for each soil type) and ask the groups to discuss the relevance of the properties of the selected soil for farm management. Each group should then present their answers to the plenary and a general discussion should follow.

Reference to the Basic Manual

Concerning soil properties refer to chapter 3.2 of the Basic Manual, to chapter 4.4 for composting and to chapter 5.4 for weed management.

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4.8.4 Supplying nutrients and organic fertilization

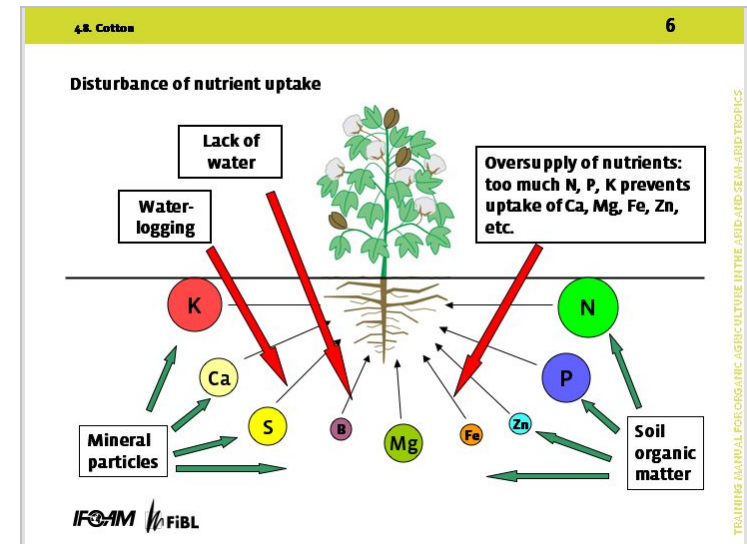
Nutrient supply and uptake

Cotton, like other crops, requires the full range of nutrients in a well-balanced composition. A harvest of 500 kg seed cotton extracts ca. 36 kg nitrogen (N), 14 kg phosphate (P_2O_5) and 15 kg potassium (K_2O equivalents). Some of these nutrients are replaced through nitrogen fixation via legumes (N) and through weathering (P and K). The most common nutrient deficiencies in tropical cotton fields are in nitrogen, phosphorus, sulfur, zinc and boron.

In organically managed soils, the crops largely depend on the nutrients supplied by minerals (weathering and exchange) and by the organic matter in the soil. These take up, store and release nutrients (through exchange, weathering and decomposition). Soil tests have their limitations in providing useful information on nutrient deficiencies, as they only measure the easily available nutrients, but not those bound up in the organic matter. The availability of nutrients to the crop, however, depends on a number of factors such as the activity of soil organisms, the root system of the crop and the water content in the soil.

The uptake of nutrients can be hindered by waterlogging (the roots then lack air) and dryness (there is no nutrient uptake without water). Excessive levels of nitrogen, phosphorus and potassium can disturb the uptake of certain other nutrients like calcium, magnesium and various micronutrients. It is not always necessary to apply additional manure when a cotton crop shows symptoms of deficiency. It may be more efficient to stimulate microbial activity and to overcome the inhibiting factors, through soil cultivation, irrigation or the incorporation of biomass (transparency 4.8 (6)).

The cotton crop may be short of nitrogen because the nitrogen in the soil is being used by micro-organisms for the decomposition of carbon-rich organic material. This phenomenon, known as temporary nitrogen immobilization, may occur when sturdy crop residues or carbon rich manures (e.g. straw-rich farmyard manure or un-decomposed press mud) are present in the soil during the first two months of crop development. Early tillage, proper composting and the timely addition of nitrogen-rich manure (e.g. oil cakes) all help to avoid temporary nitrogen deficiency.



TRANSPARENCY 4.8 (6): DISTURBANCE OF NUTRIENT UPTAKE IN COTTON

Consolidation: Nutrient management in cotton

Ask one of the participants to explain the transparency in his/her own words and to summarize its relevance to crop management in organic cotton.

Reference to the Basic Manual

Concerning soil testing refer also to chapters 3.1.1, and to chapter 3.6.2 of the Basic Manual for information on nitrogen immobilization.

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Organic manures and mineral fertilizers for cotton

Crop rotation and intercropping with legumes, recycling of crop residues and the application of farm produced organic manure (FYM and compost) need to form the basis of nutrient management in organic cotton farming. Organic farmers should not try to copy conventional fertilizer application schemes by substituting NPK-fertilizers with organic manures. Above all, it is very important that they preserve the nutrients that are already available in the soil and on the farm, prevent soil erosion, use all available crop residues and organic wastes, and do not burn crop residues or cow dung.

The cotton plant requires two-thirds (2/3) of its nutrients during the first two months of its growth. To ensure sufficient nutrient supply (especially of nitrogen) during this phase, it is recommended that a basal dose of well-decomposed compost or farmyard manure be applied at the start of the growing season, and be complemented with one or two top dressings of compost and an organic manure rich in nitrogen (e.g. oil cakes, poultry manure from extensive rearing). Top dressings of manure should be applied two to three weeks before the start of square bud formation, as the nutrients are not instantly available but are only released as the manure decomposes.

The nutrient demand can also be met through the use of liquid manures (e.g. cow dung slurry or fermented manures), which can be applied to the soil, through the irrigation system or diluted and sprayed as leaf fertilizer. An advantage of liquid manures is that the nutrients are available almost instantly. Thus they can be used to fine-tune nutrient supply. Fertilizers based on minerals of natural origin (e.g. rock phosphate, muriate of potash, gypsum, lime etc.) should only be applied in addition to organic manures, and only when the soil is deficient in the respective nutrient (transparency 4.8 (7)).

Over-supplying nitrogen will lead to excessive vegetative growth (i.e. shoots and leaves instead of flowers and bolls), which may even lead to reduced yields. Excess manure also makes the plant more attractive to sucking pests (see 4.8.5, box: 'Sucking pests').

4.8. Cotton		7		
Organic manures and natural mineral fertilizers for cotton				
	Comment	Nitrogen (total N)	Phosphate (P ₂ O ₅)	Potash (K ₂ O)
Compost	Soil improvement	0.6 - 1.5 %	0.5 - 1.0 %	0.5 - 2.0 %
Farmyard manure	Less stable humus	0.7 - 1.5 %	0.5 - 0.9 %	0.4 - 1.5 %
Vermi-compost	Very stable humus	0.6 - 1.5 %	0.4 - 0.9 %	0.5 - 1.0 %
De-oiled castor	N- and P-supply	4.5 - 6.0 %	0.8 - 1.8 %	1.3 - 1.5 %
Cane press mud	Soil improvement	1.4 - 1.8 %	0.1 - 1.0 %	0.4 - 0.6 %
Rock phosphate	P-supply, in compost heap	0	15 - 30 %	0
Muriate of potash	Natural potassium fertilizer	0	0	ca. 60 %
Wood ash	K, Mg, Ca, Mg etc.	0	1 - 3 %	1 - 8 %

Note: Figures are given in percent of dry matter. The nutrient contents vary from source to source.

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TRANSPARENCY 4.8 (7): SELECTED ORGANIC MANURES AND MINERAL FERTILIZERS WITH THEIR APPROXIMATE NUTRIENT CONTENTS

Discussion: Suitable on-farm and off-farm manures

Ask the participants which manures and fertilizers are available on the farms, and which are available on the market. List the suggested manures and fertilizers on a board or paper chart along with a comment on their nutrient value. Discuss how nutrient supply can be further improved and what alternative sources of nutrients could be tested.

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4.8.5 Pest and disease management

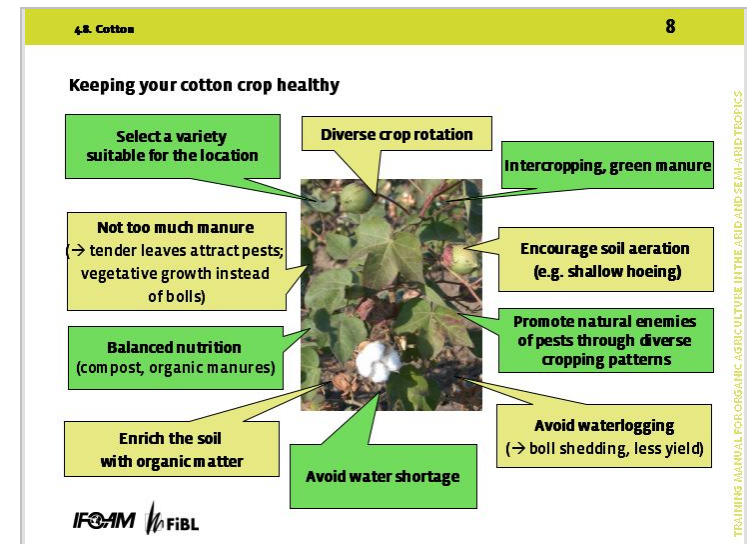
Keeping your cotton crop healthy

A large number of pests feed on cotton: caterpillars (e.g. bollworms), beetles, bugs, aphids, jassids, whitefly, thrips, mites, etc. The healthy cotton plant has some means of defense. It compensates for affected shoots and leaves through additional growth, and produces substances that deter insects from eating them (e.g. gossypol). In conventional farming, cotton is considered a crop that is highly sensitive to pest attack. Large quantities of chemical pesticides such as organophosphates and pyrethroids are sprayed to keep pests under control. This, however, eventually results in the pest problem increasing, as the practice also decimates the natural enemies of many of the pests.

First and foremost, organic cotton farming tries to prevent pests from even becoming a problem (transparency 4.8 (8)). Whenever possible, varieties that are less susceptible to pest attack are cultivated (e.g. those with hairy leaves, higher gossypol content). Plant health is supported through improving soil fertility and ensuring balanced nutrition in the soil (compost, organic manures). Soil conditions are optimized through shallow soil cultivation and careful irrigation (in order to avoid dryness as well as waterlogging).

Diverse cropping systems and natural habitats enhance the control of pest populations through natural enemies such as birds and beneficial insects. Crop rotation helps to avoid the build up of pest populations. Intercrops like pulses, and trap crops like sunflower or maize distract pests from the cotton plants. Experiments from Tanzania have shown that sunflower is an efficient trap crop for the American bollworm (*Helicoverpa* species), which prefers sunflower to cotton. It is even reported that on sunflower plants bollworms attack each other (cannibalism). Every 15 meters in the cotton plot a row of sunflower is sown, at the same time as the cotton crop. The flowering plant attracts a number of beneficial insects and birds. In Africa, beneficial ants have been observed visiting the sunflower plants and efficiently controlling bollworms. The sunflower seeds provide additional income to the farmers. In some projects, maize and okra are used as trap crops, but they may even contribute to increased bollworm populations.

Through properly implementing such preventive measures, the pest problem in organic cotton can be greatly reduced. A certain level of pest attack will not significantly reduce the cotton yield. Below this 'economic threshold', the cost and effort to control the pest is higher than the damage it causes. In such calculations one should take into account both the cost of the pesticide and the labor for fetching water and for spraying. As long as pest infestations remain below the threshold levels, farmers should wait and see whether the natural enemies



TRANSPARENCY 4.8 (8): WAYS TO KEEP THE COTTON CROP HEALTHY

Demonstration: Insect zoo

Collect different varieties of pests and their natural enemies (ladybird beetles, lace wings, assassin bugs, spiders) from a cotton field and put them in glass jars, together with some twigs of cotton (stuck in wet cotton wads to keep them fresh). Ask the participants to identify the different insects. Observe whether signs of predation (insects feeding on others) are seen.

Reference to the Basic Manual:

For more information about the relationship between plant health and balanced nutrition refer to chapter 4.1 of the Basic Manual. For more details about insect zoos refer to chapter 5.2.1.

4 Management Guide for Crops

are able to control the pests, and keep damage to the crop to a negligible level. In most of the semi-arid tropical regions, diseases are not a big problem in organic cotton.

Organic management of major cotton pests

Crop rotation, intercropping and trap crops are probably the most effective preventive pest management strategies in cotton. In a diverse field, natural enemies are capable of keeping pest attack within a tolerable level. Natural enemy populations can be increased through the provision of suitable habitats (e.g. intercropping flowering plants, using mulch, and setting up bird perches). Only when the preventive measures are not sufficient to keep pests below the economic threshold (e.g. due to adverse weather conditions), should direct measures such as spraying botanicals (e.g. Neem, Derris) or microbial sprays (e.g. Bt-spray, NPV spray) be used (transparency 4.8 (9)).

A major pest in tropical cotton cultivation is the bollworm (*Helicoverpa*, *Pectinophora* and *Earias* species). If bollworm populations reach the economic threshold, a number of direct control methods that are permissible in organic farming can be used. Microbial preparations (Bt and NPV) can be used against American bollworm (*Helicoverpa armigera*). Pheromone traps and dispensers attract and confuse the adult moths and thereby prevent the laying of eggs. Sprays of Neem formulations and locally prepared botanical extracts are comparatively cheap methods of controlling bollworms and other pests. In India, organic farmers are using diluted cow urine and buttermilk sprays with great success. However, most of these sprays also affect beneficial insect populations and thus should be used only when really necessary.

Sucking pests






Sucking pests such as aphids, jassids, white flies, thrips and mites usually attack plants which are stressed. Stress can be caused by imbalanced nutrition (too much or too few nutrients, especially nitrogen). An Indian farmer concluded from his own observation: 'With high manure application, the cotton leaves are getting sweet and attract sucking pests!' Stress can also be caused by water shortages or by waterlogging. Just like humans or animals, plants also have a kind of immune system, which usually enables them to fight the attack of sucking pests. In stress situations, the immune system works less effectively.

Conclusions for crop management:

- Neither too little nor too much manure (no 'overfeeding').
- Careful irrigation, avoid dryness and water logging.
- Shallow soil cultivation to encourage soil aeration and decomposition of organic matter.

Discussion: Methods of pest management

Prepare a table with the headings shown in transparency 4.8 (9). Ask the participants what the most significant cotton pests in their area are. Discuss what preventive and what direct methods could be used to keep the pests below the economic threshold level. What are the advantages and disadvantages of each method? Are there new methods that could or should be tested in field trials?

4.8. Cotton		9	
Pest management in cotton			
Pest	Preventive measures	Direct control measures	
 Bollworms (<i>Helicoverpa</i> and others)	<ul style="list-style-type: none"> ▪ Trap crops: sunflower, okra, castor ▪ Handpick damaged capsules ▪ Encourage natural enemies ▪ Remove cotton stalks ▪ Cattle grazing after picking is over 	<ul style="list-style-type: none"> ▪ Bt-spray, NPV spray ▪ Neem, botanical preparations ▪ Buttermilk spray ▪ Pheromone traps, light traps ▪ Trichogramma cards 	
 Aphids, jassids, thrips, whitefly (<i>Bemisia</i>)	<ul style="list-style-type: none"> ▪ Intercrop mung, cow pea, etc. ▪ Avoid excessive manure application ▪ Avoid waterlogging and water shortage ▪ Promote natural enemies by growing flowering plants 	<ul style="list-style-type: none"> ▪ Neem, botanical preparations (chili, sweet flag, turmeric, etc.) ▪ Soft soap spray ▪ Cow urine spray ▪ Potato starch spray ▪ Yellow sticky traps 	
 Cotton stainers (<i>Dysdercus</i>)	<ul style="list-style-type: none"> ▪ Frequent soil cultivation to destroy the eggs (also along field borders) ▪ Encourage birds (turmeric-colored rice, bird perches, trees) ▪ Avoid stand-over of cotton 	<ul style="list-style-type: none"> ▪ Pyrethrum spray ▪ Botanical sprays (Neem, custard apple, garlic bulb, sweet flag, sweet basil, Derris species) ▪ Grazing of chickens 	
 Cutworms (<i>Agrotis</i> and other species)	<ul style="list-style-type: none"> ▪ Early soil cultivation ▪ Remove weeds in and around fields ▪ Encourage birds, spiders, etc. (bird perches, trees, hedges) 	<ul style="list-style-type: none"> ▪ Apply Neem cake into the soil ▪ Pyrethrum, Derris or thyme spray ▪ Cutworm baits ▪ Hand picking or Bt-spray at night 	
			

TRANSPARENCY 4.8 (9): DIRECT AND INDIRECT PEST MANAGEMENT METHODS OF SELECTED MAJOR PESTS IN COTTON.

Reference to the Basic Manual:

For more information about the preparation and application of botanical pesticides refer to chapter 5.3 of the Basic Manual.

4 Management Guide for Crops

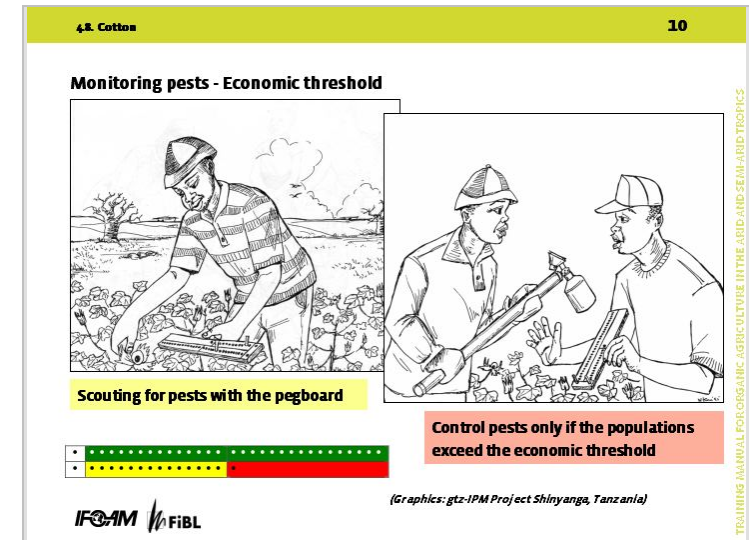
Monitoring

A key to successful pest management in cotton is the careful and continuous monitoring of pest levels in the cotton fields during the critical growth period (approx. four weeks after sowing up to the second harvest). Monitoring helps to ascertain precisely when a pest population reaches the economic threshold, thus necessitating direct control measures. For monitoring, farmers randomly inspect a number of cotton plants while crossing the field in diagonals (transparency 4.8 (10)). The following table lists the economic threshold levels established for IPM in conventional farming. They should be crosschecked with local advisory services or agricultural research stations to adapt them to local conditions.

Pest	Threshold level
American bollworm (<i>Helicoverpa</i>)	1 larva per 5 plants, 5–10% damage to bolls or 15 flared squares with a hole on 30 plants
Pink bollworm (<i>Pectinophora</i>)	5% rosetted flowers
Spotted bollworm (Earias)	1 larva per 5 plants, 5–10% damaged shoots or bolls
Cotton leafworm, tobacco caterpillars (<i>Spodoptera</i>)	2 larvae per 10 plants or 3 skeletonized leaves with young larvae
Cotton stainer	2–3 individuals per leaf
Aphids	20% infested plants
Jassids	5–10 insects per plant
Thrips	5–10 nymphs/adults per leaf
Mites	5% infested plants
Whitefly	5–10 nymphs/adults per leaf

(Source: adopted from Aventis and Avena; University of Nebraska)

For monitoring American bollworm populations, farmers in some African cotton projects are using simple pegboards for scouting. They check 30 randomly selected cotton plants for flared square buds (infested by bollworms), moving the pegs in the board one step ahead for every inspected plant (left side) and for every infested bud (right side). If 15 flared square buds are found, the economic threshold is reached and it is recommended that Neem-based formulations be sprayed.



TRANSPARENCY 4.8 (10): MONITORING PESTS WITH THE HELP OF A PEGBOARD, AND THE CONCEPT OF ECONOMIC THRESHOLDS

Demonstration: Monitoring

Prepare pegboards for scouting American bollworms and other pests, bearing in mind the economic threshold levels recommended for the area. Explain the system of monitoring and the scouting method with the help of the pegboards to the participants. In a cotton field, ask the participants to try out the scouting method in groups. Compare and discuss their results and determine whether or not direct control methods need to be implemented.

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4.8.6 Water management and irrigation

In rain-fed cotton, and in regions where irrigation water is limited (i.e. in most semi-arid cotton growing areas), major emphasis should be given to increasing the infiltration of rainwater into the soil and preserving soil moisture. For this, the application of compost and organic manure is crucial. Shallow soil cultivation (hoeing) breaks the soil capillaries thereby reducing evaporation. Mulching also helps preserve soil moisture. In some regions, black plastic mulch is used, but its ecological and economical suitability is doubtful. Active rainwater harvesting through pits or trenches leading to wells can help to recharge groundwater levels and thus improve the availability of irrigation water. Where little irrigation water is available, alternate-furrow irrigation can still help irrigate the crop. If rains fail after the seedlings have germinated, it can even be worthwhile to save them through bucket irrigation, plant by plant.

With irrigated cotton, the application system, intensity and timing of irrigation are crucial for good yields and healthy plants. When the cotton leaves start wilting in the morning sun, it is time for irrigation. In India, some farmers use a local plant called 'croton' to indicate water stress: when the croton plant first starts to wilt, it is time for the next irrigation. During the first six to seven weeks after sowing, irrigation should be moderate in order to avoid excessive vegetative growth and to encourage cotton roots to penetrate deeply into the soil. For monsoon-sown cotton in India, the first irrigation should not be done until August, after the first square buds have formed. The cotton crop is very sensitive to waterlogging, which causes increased boll shedding, which affects yields. Waterlogging causes general yellowing of the plant and stunted growth. It also reduces the availability of nutrients. Thus, in fields prone to waterlogging (heavy soil), measures that improve soil structure (organic matter application) are more relevant than the application of fertilizers. It is important that furrow irrigation be done quickly (not exceeding four hours). This can be achieved by ensuring that the rows are short.

In India, drip irrigation systems are becoming increasingly popular for cotton. They enable farmers to start cotton cultivation before the onset of the rainy season, to bridge dry periods and to protect at least part of their fields from drought. Drip systems make it possible to grow 'more crop per drop' as the water directly reaches the root zones of the plants and less is lost to infiltration and evaporation. It also discourages weeds from growing between the cotton rows. Recently, several new low cost drip systems have come on the market. These allow farmers to install drip irrigation systems with lower investment costs, but the cheaper systems are usually less durable.

Group discussion: Water management

Together with the participants, identify the most important constraints in water management in cotton for the area and note them down (e.g. decreasing groundwater level, waterlogging, water shortages before the rainy season). Discuss promising approaches to overcoming these constraints (e.g. water harvesting, irrigation timing, drip irrigation). Select approaches you want to develop further and form one group for each approach. The groups should describe the approach in detail, discussing the required technology, the advantages and disadvantages of such a system and any experiences that farmers have had with it thus far. The results of the group work should be presented in plenary and discussed.

Reference to the Basic Manual:

For more information about irrigation and water management in organic agriculture refer to chapter 3.5 of the Basic Manual.

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4.8.7 Harvesting and post-harvest handling

Picking, storage and quality issues

The price of cotton depends on its quality: the less contamination and the longer the staple, the higher the price. Therefore, cotton picking should be done with care, avoiding leaves and damaged or immature cotton. Cotton can easily be graded while harvesting by using a second, smaller picking bag for inferior quality. It is important that no unripe cotton is picked, as it will not absorb the dye well enough and thus will attract a lower price.

If farmers store the harvested cotton before selling, they should take care to avoid any contamination by dust or chemicals. The storage place needs to be clean and dry. Damp conditions can lead to the growth of fungus, with significant loss of quality. If the organic harvest is stored in the same facilities as conventional cotton (e.g. in ginneries), care must be taken to separate the organic and non-organic produce clearly and to avoid any mixing.

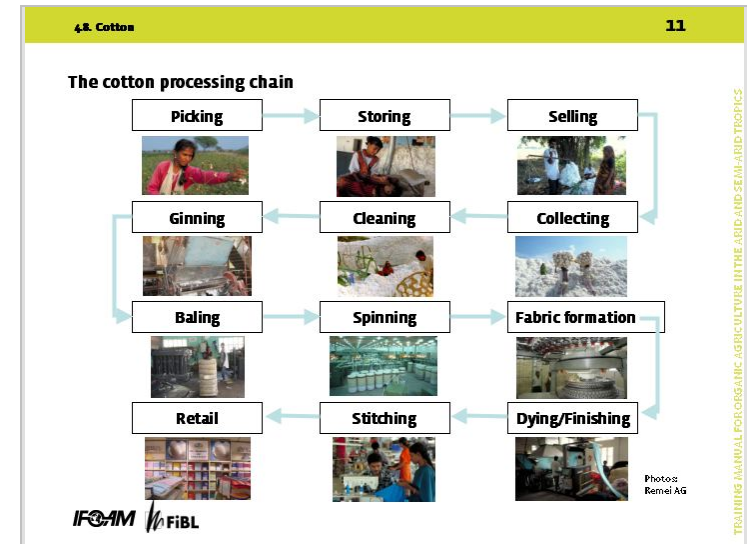
For this it is important to:

- Instruct the warehouse personnel accordingly.
- Document incoming and dispatched organic lots separately.
- Demarcate the different cotton qualities with signs e.g. using color codes.

Processing

Throughout the entire organic cotton processing chain it is important to avoid contamination and to separate organic from conventional cotton (transparency 4.8 (11)). As most spinning mills and processing entities process organic and conventional cotton on the same machinery, it is important to maintain a clear separation and to clean the equipment before processing an organic lot. Some labels and brands have certain restrictions on which dyes can be used.

Some large garment brands have decided to blend a certain percentage of organic yarn into their entire range of articles rather than to sell organic clothes. As a company, they communicate to consumers that they support organic cotton farming, which helps them to improve their corporate image.



TRANSPARENCY 4.8 (11): STEPS IN THE COTTON PROCESSING CHAIN

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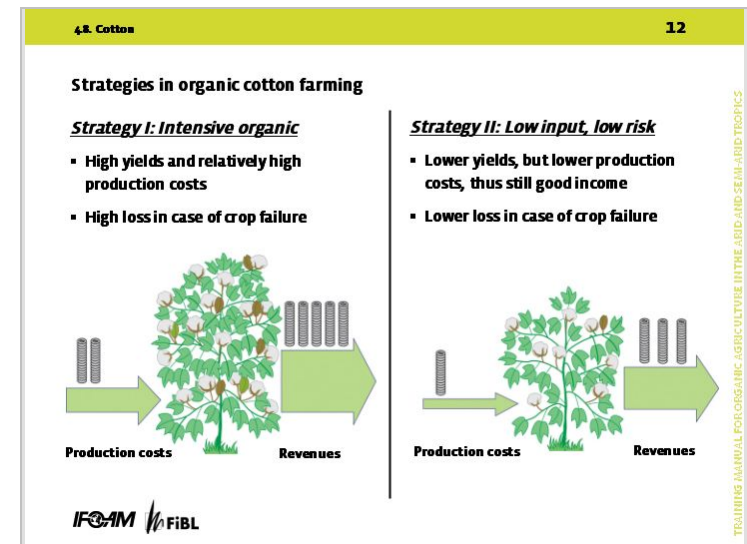
4.8.8 Economic and marketing aspects

Strategies in cotton production

To improve their income, farmers can attempt to increase crop yields, to reduce costs of production (inputs and labor) and/or to achieve a better price for their produce. Intensive organic farming aims to achieve higher yields through optimum nutrient supply and crop care. It also generally provides a better price. In marginal conditions, where there is sufficient available family labor, it can be equally efficient to focus on the reduction of costs of production (low input strategy). This can be achieved by avoiding the use of commercial organic manures and pest management products, and relying solely on on-farm means. The low external input strategy can also help to reduce risk in areas of frequent crop loss due to drought, hail or other natural calamities, as farmers need to invest less money in the crop (transparency 4.8 (12)).

Cotton is grown in rotation with a number of food crops, which also need to be managed organically. Crop production is therefore diversified in comparison to most conventional cotton growing systems, which, contributes to better food security in the region. Organic cotton projects should also cover the rotation crops within their extension system. Together with the farmers they should develop suitable crop management methods for these crops. If necessary, access to suitable inputs for pest and nutrient management should be facilitated.

Organic cotton lint is usually produced for export to Europe, the US and Japan, as domestic markets for organic fiber crops have not yet been developed extensively in the South. Organic cotton farmers can also benefit (and reduce their dependency on cotton prices) if they can find a market with a better price for their rotation crops. Some projects try to organize export links for some of these crops (e.g. soy bean or other oil seeds). However, in some countries like India there is also a growing potential for developing organic supply chains within the domestic market. More and more spinning mills are also interested in becoming partners in environmentally and socially sound supply chains. This way the value-added via processing can be realized locally. Furthermore, linkages between farmers and spinning mills can be strengthened if organic cotton is processed. The domestic market in South Africa for cotton and other organic products is also increasing rapidly.



TRANSPARENCY 4.8 (12): TWO STRATEGIES TO IMPROVE FARM INCOME: 1.) INTENSIVE ORGANIC WITH HIGH PRODUCTION COSTS (HIGH RISK!) AND HIGH REVENUES; 2.) LOW INPUT WITH LOWER PRODUCTION COSTS (LOWER RISK) AND LOWER REVENUES

Discussion: Organic management strategies

Discuss what strategies participants have observed amongst cotton farmers. What are the advantages and disadvantages of these strategies? Are they related to certain types of farms (small or big, marginal or fertile soils)? Which strategy would they recommend to organic cotton farmers?

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Recommended reading:

- *Naturland (2004, 2nd edition): Organic Farming in the Tropics and Subtropics. Cotton.* www.naturland.de.
- *Myers & Stolton (1998): Organic Cotton. From Field to Final Product.* Intermediate Technology Publications. London.
- *Ton, P. (2002). The International Market for Organic Cotton and Ecotextiles-Report, Pesticide Action Network United Kingdom.* www.pan-uk.org/Cotton.
- *SDC, WWF, Maikaal bioRe (India) Ltd. (2004): Organic Cotton Manual.* www.fibl.org.
- *ATTRA: Organic Cotton Production.* www.attra.ncat.org.
- *G.A. Mathews (1994): Insect Pests of Cotton.* CAB International. Wallingford.

Recommended websites:

- *Organic Exchange, a platform of the organic cotton industry, providing market links and information, with a detailed world overview on organic cotton production.* www.organicexchange.org/
- *The International Organic Cotton Directory:* www.organiccottondirectory.net/
- *The Cotton Project: Moral Fibre, of the Pesticide Action Network (PAN).* www.pan-uk.org/Cotton/
- *International Competence Centre for Organic Agriculture, India (ICCOA) provides services for organic cotton production.* www.iccoa.org
- *Australian Cotton Cooperative Research Centre.* www.cotton.pi.csiro.au/
- *Crop profile of Gossypium hirsutum.* www.fao.org/ag/agl/aglw/cropwater/ecocotto.htm
- *Online Information Service for Non-chemical Pest Management in the Tropics.* www.oisat.org/home.html
- *The organic cotton projects Maikaal bioRe (India) and bioRe Tanzania of Remei AG.* www.remei.ch

4 Management Guide for Crops

4.9 Watermelon

Introduction

The watermelon (*Citrullus lanatis*) belongs to the *Cucurbitaceae* family and is a warm season crop. It is mainly grown in the tropics, subtropics and summer-dry warm to temperate zones. Watermelons are believed to have originated in South and East Africa, and south of Asia.

4.9.1 Agro-ecological requirements

Soil

Watermelon roots can reach a depth of 80 cm and a lateral length of about 2 meters. Watermelon prefers well-drained sandy loam soils, but also grows well on sandy soils. Lighter soils, which warm up quickly after a cold period, are usually used to produce early yields. Heavier soils lead to more marked vegetative growth and later maturation of the fruits. Watermelon plants do not tolerate waterlogged soils. The ground-water level should be deeper than 1 meter, and the preferred soil pH is 5.5 to 6.8. Soils with a high level of organic matter provide a good nutrient supply and ensure vigorous growth.

Water

Due to their sensitivity to diseases, watermelons are best grown in the dry season. Yet they do need a lot of water. The water requirement for the total growing period of a crop (100 days) ranges from 4,000 to 6,000 m³ per ha (400 to 600 mm (= liters per m²)). The ideal annual rainfall is 500 to 750 mm, and the minimum and maximum quantities of water that can be tolerated are 400 and 1800 mm respectively. The optimum relative humidity of the air should be 50 to 60 %.

Temperature

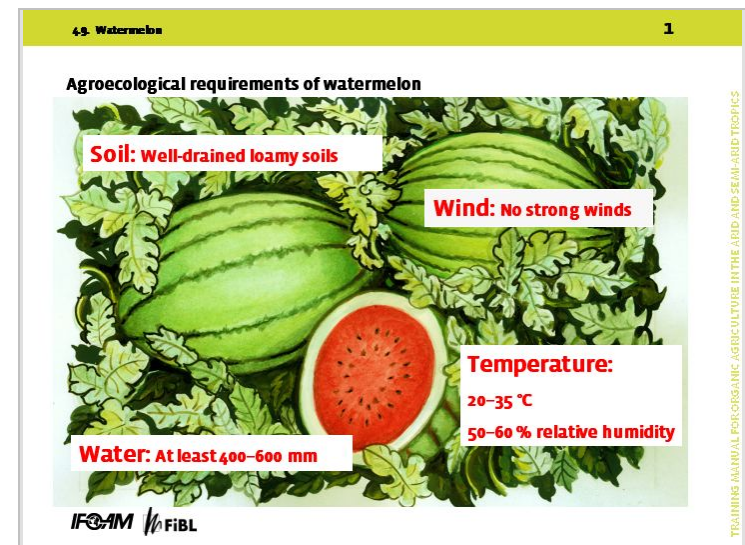
Watermelon requires temperatures between 20 and 35 °C. Below 15 °C watermelon plants stop growing. Temperatures below 2 to 3 °C lead to the death of the plants and above 35 °C they do not produce any flowers. The ideal temperature for seed germination is 22 to 27 °C. Rapid germination is promoted when there is little variation between day and night temperatures. The ideal temperature for fruit development is 30 to 35 °C. Watermelon requires a photoperiod of at least 12 hours of light per day.

Lessons to be learned:

- Diversification is important in order to reduce the pressure of pests and diseases and to improve soil fertility.
- Weed management is mainly preventative, and focuses on maintaining low weed pressure.
- Water management aims to conserve moisture in the soil and to use irrigation systems that save water and keep disease infections low.

Introduction

Introduce the participants to the topic by inquiring about popular fruits in the region, especially during the dry and hot season. Mention cucurbits and find out whether cucurbit vegetables and fruits are grown. Why are they grown? Which factors are considered to be relevant for successful cultivation? What advantages and inconveniences are linked to watermelon cultivation? Note the key factors on the board and refer to them later on.



TRANSPARENCY 4.9 (1): AGRO-ECOLOGICAL REQUIREMENTS OF WATERMELON

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Wind

Watermelon plants are sensitive to injury due to wind. In areas with strong winds, windbreaks are recommended. Intercropped grain or legume crops may protect young plants. Physical contact between wind-breaking plants and watermelon plants must, however, be avoided. As soon as the wind-breaking crop competes with the watermelon plants for water, it should be worked into the soil and no longer cultivated.

4.9.2 Diversification strategies

In organic agriculture a reasonably high diversity of crops and natural vegetation are aimed at in order to reduce the incidence of pests and diseases, improve soil fertility, enhance the production of plant material to feed animals and to obtain fuel wood and other products.

Intercropping and crop rotation

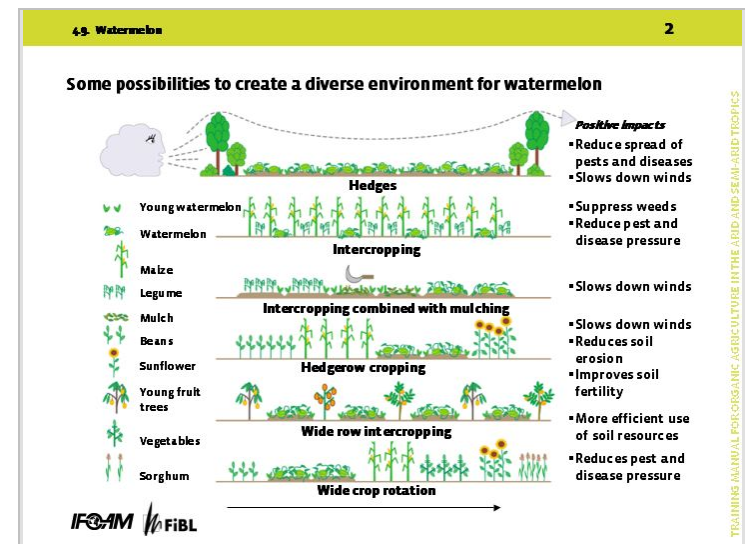
In watermelon cultivation the following diversification measures may be used:

- Planting hedges of leguminous (*Leucaena leucocephala*) or non-leguminous plants to reduce the prevalence of pests and diseases. Planting *Gliricidia sepium*, *Erythrina* and other drought resistant trees such as windbreaks reduces damage to the fruits resulting from wind.
- Intercropping of watermelon with maize, beans or pumpkin to increase crop diversity in the field, reduce pressure from weeds, pests and diseases and to improve farmers' income security as they are not reliant on one single crop.
- Cover crops of legumes or grains (e.g. sorghum) planted between the rows of young watermelon to protect the watermelon against strong winds. The cover crop is cut for mulch as soon as it competes with the crop for water and nutrients. The mulch helps to reduce water evaporation, to protect the soil and to nourish soil organisms.
- Hedgerow cropping of legumes (mucuna, cowpea, chickpea, leucaena, broad beans), non-leguminous plants (sorghum, sunflower), vegetables (e.g. tomatoes), shrubs and trees (preferably legumes, which are cut back when the watermelons are planted and periodically pruned during cropping) protects against wind and hinders soil erosion. The crop residues supply the farm with valuable organic material, which can be used for composting, mulching or animal fodder.
- Wide row intercropping with young fruit trees (e.g. citrus, tamarind or guava) and young forest trees (e.g. gliricidia, acacia) improves the use of soil resources and increases diversity in the field. Intercrops should not, however, compete with watermelon for light.

Motivation: Impacts of crop rotation

To introduce the subject, ask the participants which factors should be considered when planning a rotation with watermelon. If the participants have experience with growing watermelon, try to get more detailed information from them on watermelon rotations. Possible questions include: Why is diversity important in watermelon cultivation? What possibilities exist to create diversity within the field? What impacts may the measures have on crop, soil, microclimate etc.? What aspects must be considered? What specific experiences have they had growing watermelon?

Note the answers on the board and refer to them later on. Refer to chapter 4 of the Basic Manual concerning general aspects of crop rotation.



TRANSPARENCY 4.9 (2): SOME POSSIBILITIES TO CREATE A DIVERSE ENVIRONMENT FOR WATERMELON

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- A wide crop rotation with legumes, watermelon, intercropping maize-legumes crops, vegetables (e.g. tomatoes) and sunflower reduces the risk of transmission of soil-borne pests and diseases. In light and sandy soils with nematode problems (*Meloidogyne spp*) watermelon should not be grown after legumes or solanaceae.

To avoid serious problems with soil-borne pathogens, watermelon and other related species (*Cucurbitaceae*) should not be replanted in the same place for a period of more than four years running. Watermelon responds positively to the incorporation of green manure pre-crops such as *Stizolobium* and *Mucuna*, which cover the soil rapidly, hinder weed development, increase the organic matter in the soil and improve its general structure. However, the cultivation of green manures in arid and semi-arid tropical areas strongly depends on the availability of irrigation.

An example of a possible crop rotation cycle:

Legume – watermelon – maize or sorghum – vegetable – sunflower – chickpea – sorghum.

Suitable varieties

In general, the selection of the right variety of watermelon for organic production depends on various factors such as the availability of seeds, site conditions, resistance to diseases and pests, and market requirements. Some varieties are resistant against Fusarium and Anthracnose. Further important characteristics to be considered are fruits with a strong rind (to reduce the risk of damage during transport), a long storage and shelf life, medium-sized fruits, fruits with a small mesocarp (which is the white tissue between the rind and the fruit flesh) and a sweet and juicy flesh.

The growth period of watermelon usually lasts from 80 to 110 days. The establishment of the crop takes 10 to 15 days, the vegetative period lasts 20 to 25 days, flowering 15 to 20 days, yield development (fruit filling) 20 to 30 days and ripening 15 to 20 days. Before cultivating watermelon on a larger scale for the first time, it is recommended that the agronomic characteristics of available varieties be compared on small plots.

To ensure that fruits develop properly, as a general rule not more than four fruits are tolerated per plant. To reduce the time spent pruning, varieties with a low flower production are preferred. The harvest date depends on the number of fruits per plant and on the uniformity of ripening.

Sharing experiences: Varieties

If the participants have experience with growing watermelon, invite them to share experiences concerning the selection of the variety by asking the following questions:

- What characteristics are taken into account when choosing the variety of crop to be planted? Do the criteria vary at all? Are any criteria decisive?
- Which varieties or cultivars are grown?
- To what extent do the varieties that are being grown fulfill the criteria?

Adapt the transparency to the participants' own conditions.

4.9. Watermelon		3	
Watermelon types and varieties			
Form	Type	Traits	Resistances
Long	Charleston Gray	<ul style="list-style-type: none"> Grey rind, red flesh Resistant to transport Adapted to arid and tropical conditions Weight about 28-35 pounds Varieties:.... 	Anthracnose ●●●● Fusarium ●●
Long	Jubilee	<ul style="list-style-type: none"> Green rind and darkveins, bright red flesh Adapted for hot and humid conditions Weight 25 pounds Varieties:....
Oblong	Crimson Sweet	<ul style="list-style-type: none"> Light green rind and darkveins, red flesh Varieties:....
Oblong	Peacock	<ul style="list-style-type: none"> Dark green rind, red-orange flesh Resistant to long distance transport Weight about 25 pounds Varieties:....
Round	Sugar Bay	<ul style="list-style-type: none"> Deep green rind and thin, light red flesh Some varieties susceptible to transport Weight 8 to 25 pounds Varieties:....

TRANSPARENCY 4.9 (3): WATERMELON TYPES AND THEIR CHARACTERISTICS

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Propagation and nursery management

Watermelon cultivation requires considerable space in order to allow uninhibited growth of the vines. When sown directly into the field, seeds are sown 2 to 3 cm deep into the soil on mounds or elevated beds at a distance within the row of about 2 meters and a distance of 2 to 3 meters between the rows. The sowing distance may vary depending on the variety and the irrigation system used. When the young plants have 2 fully developed leaves, they are thinned out to three plants per mound.

Instead of sowing directly into the field, watermelon plants may be raised in a nursery for about three weeks before being transplanted into the field. When sown into pellets, pots or cell packs, two to three seeds may be sown per pot and thinned to the best one or two plants.

The nursery substrate should be made of ripe and rich compost. Fresh compost hampers germination and causes root burns. To get a substrate with a stable structure for unhindered root growth, components such as sand, vermiculite, perlite, coconut-fibre or rice-chaff, can be added. This will of course depend on their availability. The healthy and well-developed seedlings with at least two pairs of leaves are then planted at a distance of 60 to 90 cm within the row. It is advisable to place the seedlings in the open air in full sunlight for a couple of days before planting them out in their final position.

In Central America three sowing patterns are commonly used.

- Hexagonal system: plants 3 x 3 meters apart; this pattern is used for the winter crop.
- Rectangular system: plants 2 x 3 meters apart; this pattern is used for cultivation during residual humidity.
- Double line system: plants 2 x 2 meters apart a hexagonal, double line planting layout.

If watermelon is to be intercropped with other plants, the sowing/ planting distances must be adapted accordingly.

Sharing experiences: Nursery management

Invite the participants to describe their experiences of (organic) propagation of watermelon in the nursery.

If the participants do not have any experience with this, discuss with them (ideally on a farm) practices that are adapted to their conditions.

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Production planning

The appropriate time to sow watermelon depends on various factors. Traditionally the anticipated price for watermelon on national and export markets will influence the cultivation period of the crop. The date for sowing or planting is chosen so that the harvest does not coincide with a period of low prices on the market or unfavorable agro-ecological conditions.

In Central America watermelon is grown during the following periods, but not all of them are good for organic production:

- Cultivation during the rainy season - The crop is sown in May or June to be harvested between August and October. This schedule carries high risks for organic production as both pest and disease pressures are high and weed growth is also strong. In these countries, rain during the early stages of growth is also uncertain.
- Cultivation during the period of residual moisture from the last rains - The crop is sown in November or December to be harvested between February and April. One advantage is that this timing allows the farmer to grow a legume crop before the watermelon, which satisfies the nitrogen needs of the watermelon. On the other hand, it might be necessary to irrigate the crop, especially between the setting of the fruit and the beginning of the harvest, when water demand is about six liters per m² per day.

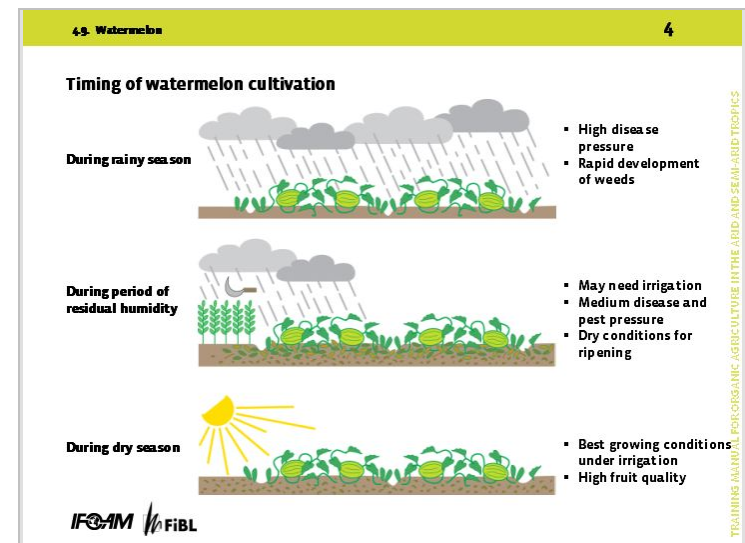
Cultivation under irrigation during the dry season - In this case watermelon is sown during the dry months of December and January, and the fruits are harvested in March and April. This timing offers the best growing conditions for watermelon, but requires irrigation during the whole cultivation period (the total water requirement being 400 to 600 liters per m²).

Exercise: Planning watermelon cultivation

Discuss the factors that are relevant for planning the cultivation of watermelon. Include the participants' practical experiences of growing watermelon in order to plan the cultivation of the crop together.

The following questions may be helpful:

- How are the rains distributed throughout the year?
- Is there any possibility of irrigating the crops? What irrigation system is being used? Which crops can be irrigated? What quantities of water are available?
- How is market demand for watermelon? Are there any price fluctuations on the market?
- What other factors play a role when planning watermelon cultivation (e.g. pre-crop)?



TRANSPARENCY 4.9(4): TIMING OF WATERMELON CULTIVATION

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4.9.3 Soil protection and weed management

Soil protection

If not protected by a dense crop, soil is at risk from both inner erosion (i.e. leaching of fine particles to deeper soil layers) and surface erosion. The risk of this is particularly high when planting with wide interspaces on bare soils and for the first 30 to 40 days, until the leaves cover the soil. Means to prevent erosion in young and widely spaced crops are living mulch (i.e. cover crop or green manure) or dead mulch (i.e. straw, leaves, crop residues, compost).

If there is no alternative to cultivating watermelon on a slope, adequate measures must be taken to prevent erosion and runoff. Such measures include terracing the slope, erecting protective barriers and planting in lines along the contours. Intercropping or living barriers may further reduce the risk of surface erosion.

(Regarding soil protection measures refer also to chapter 3 of the Basic Manual.)

Field preparation

In order to provide good growing conditions for watermelon, special attention must be paid to soil and seedbed preparation. Watermelon grows best on sandy loam soils which are well-drained and slightly acid. On very heavy soils the plants develop slowly and fruit size and quality are generally inferior. In shallow soils, a disk harrow is commonly used to prepare the field to a depth of 10 to 15 cm. In deep soils, soil preparation depends on the previous crop or green manure and the kind and the quantity of weeds. In cases of high weed pressure a plough or a chisel plough is used. Both tools can be combined with a disk harrow. In addition to ploughing and disking, subsoiling promotes deeper rooting in soils with compacted layers.

Crop residues and green manure (*Stizolobium* spp., *mucuna*, and spontaneous vegetation) must be incorporated superficially into the field four to five weeks before planting. If the bare soil is exposed to the sun between seedbed preparation and the sowing or planting of the watermelon, soil-borne pests and diseases are reduced. The seedbed is prepared with a furrow opener to build beds 15 to 38 cm high and 2 to 4 meters wide. The watermelon plants are grown on the beds, and the furrows can be used for irrigation. If water is the limiting factor, the installation of a micro-irrigation system will be necessary.

Watermelon vines can reach a length of 5 meters.

Sharing experiences: Soil cultivation

Prepare a table on a paper chart or the board, on which you record the participants' experiences with soils and specific soil management practices (see example below). Invite the participants to share their experiences.

What impacts do different soil cultivation practices have on soil characteristics such as water infiltration capacity, risk of crusting or erosion, weed pressure, layering, water management etc.? Discuss the advantages (+) and disadvantages (-) and thus the suitability of different soil types (if there are different soils in the region) and of soil cultivation measures for growing watermelon.

Soil types	Soil cultivation measures	Impacts: Positive (+) Negative (-)
Shallow soils	- Shallow ploughing - Incorporation of organic matter	
Deep and heavy soils	
Sandy soils	

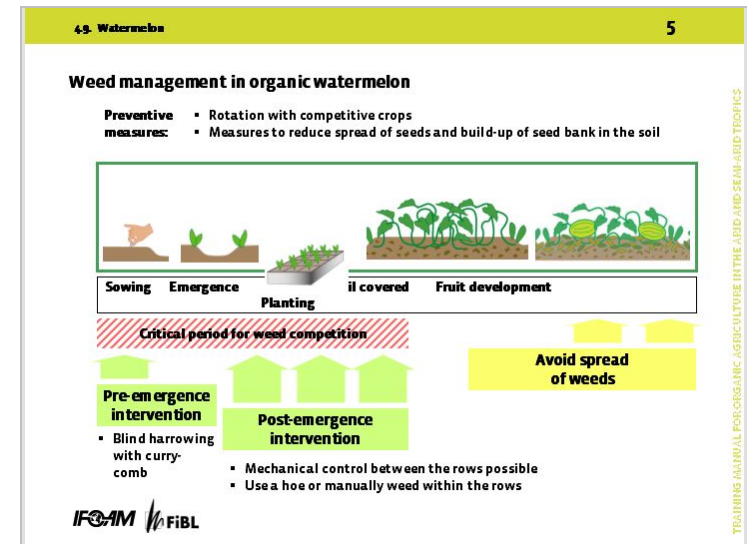
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Weed management

Most crops do not necessarily need to be free of weeds during the entire cultivation period. This is also the case for watermelon. In watermelon stands, weed competition must be avoided during early growth until the soil is covered. If watermelon is sown directly into the field, weed competition may be higher due to the crop being exposed to weeds for longer than it would be if the crops were planted out from the nursery. As soon as the crop covers the soil, weeds are effectively suppressed.

How to reduce weed pressure at different stages of the crop:

- **Before sowing or planting** - Preventive measures are of major importance. They include a proper crop rotation, which includes competitive crops (e.g. sorghum – *Cajanus cajan* – watermelon), green manures (e.g. *Stizolobium*), weed cures (= superficial soil cultivation to control weeds before sowing), mulching and the prevention of a dispersion of weed seeds into the field.
- **After sowing, before emergence** - If watermelon is sown directly into the field, the young weeds can be controlled by superficial mechanical intervention (e.g. with a curry-comb) at the stage of one to two leaves, before the watermelon seedlings emerge. For this, watermelon is sown only seven days after seedbed preparation in order to allow weeds to germinate and to grow to one to two leaves. Before the watermelon plants emerge, the weeds are uprooted with a curry-comb.
- **After the emergence of the watermelon** - After the watermelon plants have emerged, the weeds between the rows can be removed mechanically as long as the vines of the watermelon plants have not begun to run. Within the rows, weeds are best eliminated with a hoe. When the watermelon plants have three to four leaves, weeds, diseased plants and surplus plants should be removed. Once the vines run across the rows, the weeds may be allowed to grow. For good soil coverage, it is advisable to line out the vines in all directions.



TRANSPARENCY 4.9 (5): WEED MANAGEMENT IN WATERMELON

Discussion on appropriate weed management methods:

Discuss which weed management methods can be applied to organic watermelon cultivation according to specific conditions. Use the transparency to facilitate the discussion, if it proves helpful.

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Cover the soil or keep it open?

An alternative to bare soil is to cover it to prevent weed germination. In conventional and commercial production, plastic ground mulches are commonly used to suppress weeds. However, in organic farming, biodegradable mulches are preferred as they do not create any disposal problems and can be recycled. Organic mulches such as straw, leaves or compost are applied around the plants after they have been established. Although this practice is labor intensive, it helps to conserve soil moisture, attract earthworms and finally enrich the field with organic matter. Living mulches grown between the rows can also help to suppress weeds and at the same time protect the watermelon plants from strong winds. Living mulches must, however, be cut down before they start competing with the watermelon plants for nutrients and water.

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4.9.4 Supplying nutrients and organic fertilization

Like all cucurbits, watermelon grows well in soils that are rich in organic matter. A biologically active soil forms the basis of an appropriate and balanced nutrient supply. With nutrient needs of 80-100 kg of N, 25-60 kg of P and 35-80 kg of K, watermelon is considered a crop with medium nutrient demands.

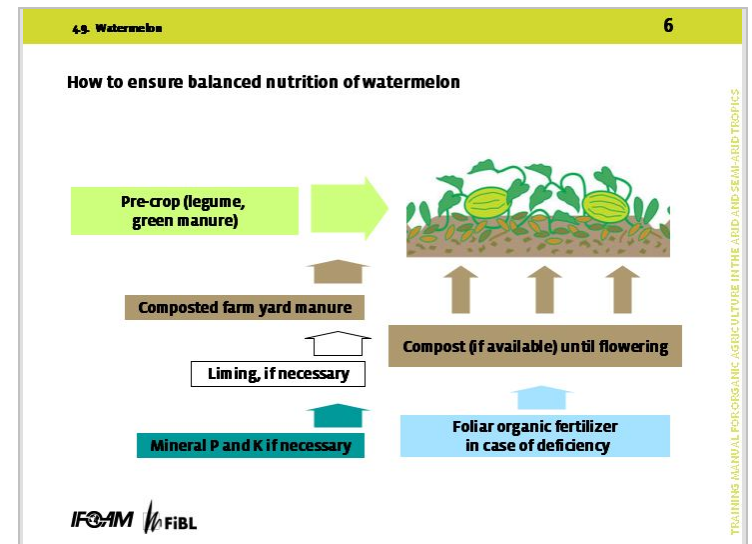
If watermelon is cultivated as the first or second crop after a legume (e.g. pigeon pea) or after a vegetable crop following a green manure, the plants generally find enough nutrients in the soil to develop properly. A good alternative to a leguminous pre-crop is to apply composted cow manure. The recommended amount of cow manure is about 30 to 40 tons per hectare applied during soil preparation at least one month before planting. To enhance the growth of the watermelon plants and ensure adequate yields, small amounts of compost can be applied until flowering.

Mineral fertilizers such as phosphoric rock and potassium sulphate are only recommended if a soil analysis shows that they are lacking in the soil. Depending on the organic standards, permission may be necessary for the application of such fertilizers. Foliar organic fertilizers such as plant extracts, liquid organic fertilizers, etc., which are produced by the farmer, do not need any permission to be applied. Before applying foliar fertilizers on a large surface, possible harmful effects should be tested for through trial application on a small plot. Some plant or compost extracts can cause leaf burn and may severely damage the crop.

Watermelon is known to be sensitive to manganese toxicity, which is a common problem in soils with a pH below 5.5. Watermelon seedlings react to manganese toxicity with stunted growth and crinkled leaves. Older plants exhibit brown spots on older leaves. The best solution to manganese toxicity is to apply lime during seedbed preparation. A pH of 6.0 should be maintained to avoid pH related deficiency problems. If the soil lacks calcium, the plants will develop blossom end rot. The same symptoms can, though, be due to water-saturation in the soil, which may occur after long periods of rain.

Motivation: Principles of plant nutrition

Before you give any information on watermelon nutrition, remind participants about the principles of plant nutrition in organic farming. This can be done by comparing the fertilization strategies within organic and conventional farming practices and their impacts on soil, and availability of nutrients. Refer to chapter 4.1 of the Basic Manual.



TRANSPARENCY 4.9 (6): APPROACH TO A BALANCED NUTRITION OF WATERMELON

Exercise: Watermelon fertilization under local conditions

Divide the participants into groups and place all the previously gathered information on crop rotation at their disposal. Ask the participants to draw up a fertilization plan for organic watermelon that is dependent on crop rotation, agro-ecological conditions and available nutrient sources. The following questions may be helpful: How must crop rotation and management of organic matter be planned in order to satisfy the nutrient requirements of the watermelon crop? Are additional measures necessary? Ask the participants to present their results and discuss the inputs together.

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4.9.5 Indirect and direct pest and disease management

Watermelon is susceptible to physiological disturbances as well as to pest and disease attacks. It is generally not attacked as heavily as many other fruit and vegetable crops.

The following circumstances have been found to lead to problems with pests and diseases:

- Poor soil fertility and a soil pH of below 6.0 or above 7.0
- Mechanical injury due to careless cultivation
- Overhead irrigation or persistent rains
- Cultivation of disease-sensitive varieties
- Poor drainage of the soil, keeping the watermelon roots wet for extended periods
- Insufficient crop rotation

As with all organically grown crops, preventive measures have a high priority in pest and disease control in watermelon cultivation. General preventive measures are listed in chapter 5.1.2 of the Basic Manual. The most important preventive measures for watermelon are as follows:

- Selection of tolerant or resistant varieties to diseases (e.g. Anthracnose, Fusarium, etc.) and pests
- Selection of varieties adapted to local conditions
- Disease-free seeds or planting material
- Diverse cropping systems (e.g. intercropping, crop rotation, green manure) including hedges to reduce the dispersion of the spores of pathogens
- Biologically active soil and balanced nutrition
- Control of weeds, which can host diseases and pests
- Timing of the crop (e.g. cultivation during the dry season)
- Appropriate crop maintenance (irrigation, removing infested plant parts to prevent spreading of the disease)
- Adequate crop rotation

Preventive measures help to reduce pest and disease problems. Nevertheless, the direct application of natural pesticides may sometimes be necessary. Regular checking of the crop is essential in order to check the development of a pathogen at an early stage.

Motivation: How can disease problems be prevented?

Ask the participants what preventive measures they know of to control diseases in watermelon. Once they have given their answers, show transparency 5.1.2 b of the Basic Manual, and point out the measures that have not already been mentioned.

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Disease management

The following foliar diseases are common in watermelon:

Anthracnose, caused by the fungus *Collectotrichum orbiculare*. This causes angular or irregularly shaped brown to black leaf spots. Lesions of Anthracnose also occur in the stem and fruit. Plants can become infested at any stage of growth. A few warm and rainy days can destroy an entire crop, giving the field a burned appearance.

Downy mildew is caused by the fungus *Pseudoperonospora cubensis*. Infested plants show irregular yellow areas on the upper leaf surface. In later stages of disease development, the center of these areas turns brown, while the outer part remains yellow. Under humid conditions the fungus builds fuzzy, grayish cushions on the underside of the leaves. Under favorable conditions downy mildew develops rapidly, giving the entire field a scorched appearance.

Cercospora leaf spot is caused by the fungus *Cercospora citrullina*. Characteristic symptoms are circular brown spots on the leaves with white or tan centers. Heavy attacks lead to defoliation. Wet conditions and warm temperatures enhance Cercospora. It is transmitted by crop residues and by weeds of the *Cucurbitaceae* family, to which watermelon belongs. Preventive measures include avoiding waterlogged conditions, a wide crop rotation, and hindering the spread of spores through wind by applying copper.

Mosaic Virus infections lead to characteristic intermingled light green or yellow patches on the leaves. The virus can damage foliage and fruits. Mosaic viruses are transmitted by insects (e.g. aphids). Preventive measures include the cultivation of resistant varieties, controlling host weeds, measures to increase biodiversity, the use of pest traps (plant traps, sticky traps etc.) and avoiding watermelon cultivation near other vine crops.

The following root and vascular diseases are common in watermelon:

Damping-off where the seedlings wilt and die, or plants do not emerge. Damping-off can be caused by different fungi such as *Rhizoctonia solani*, *Phytlum* species etc. Damping-off is related to infested residues from previous crops and to environmental conditions (e.g. conditions that hinder rapid emergence, such as wet soil and cool temperatures).

Fusarium wilt, caused by the fungus *Fusarium oxysporum*, spreads to new areas on seeds, in soil attached to equipment or with drainage water and man. The first symptom is a temporary wilt of the vines, especially during the hottest period of the day. Wilt symptoms progressively develop and the plant eventually dies. Stems that are cut lengthways, show a brown discolored vascular system. *Fusarium* can be controlled using resistant cultivars, but most important is prevention through a rotation of five to seven years, a biologically active soil and a neutral pH.

Sharing experiences: Diseases in watermelon

Ask the participants which diseases they know of that infest watermelon or other cucurbits in the region. How relevant are they? What preventive and what direct measures against them prove to be effective, not so effective or ineffective?

4.9. Watermelon		7
Some diseases of organic watermelon and their control		
Diseases	Preventive control measures	Direct control measures
Anthracnose	<ul style="list-style-type: none"> Cultivation pause of at least 4 years between cucurbits Grow resistant varieties 	<ul style="list-style-type: none"> Apply copper, if high risk of infection Immediate elimination of infected plant parts
Downy mildew	<ul style="list-style-type: none"> Keep leaves dry Grow resistant varieties Good aeration within the crop Avoid cultivation next to other watermelon fields 	<ul style="list-style-type: none"> Regularly monitor fields for symptoms of downy mildew Apply copper, if high risk of infection Alternative: applications of Myco-Sin (sulfuric acid clay mineral) in alternation with Myco-San (compound with sulfuric basalt) or of powder stones mixture
Damping-off	<ul style="list-style-type: none"> Use disease-free seeds Work in crop residues Avoid wet and waterlogged soils for a longer period Good cultural and soil practices (high beds, sanitized nursery substrate, etc.) Increase soil activity by adding organic material (compost, animal manure, etc.) 	

TRANSPARENCY 4.9 (7): SOME DISEASES OF ORGANIC WATERMELON AND THEIR CONTROL

4 Management Guide for Crops

Pest management

Several pests are known to attack watermelon plants. To reduce the risk of an uncontrollable increase of pests and to maintain the pests below the economic threshold level, organic farmers must stress preventive pest management. Organic producers apply the following strategies according to local conditions:

- Enhance nutritional balance and healthy plants by improving soil fertility.
- Avoid waterlogging, soil compaction and exposing soil-borne pests to the sun (through appropriate seedbed preparation).
- Foster the natural habitats of birds and beneficial insects by increasing the diversity of the cropping system, a wide crop rotation and by erecting wind barriers and natural fences.
- Grow trap crops (e.g. zucchini). The trap crops are planted around the field. Trap crops should be planted earlier than watermelon. The pests on the trap crops are controlled with botanical insecticides.
- Install yellow sticky traps against flying pests. These traps largely serve simply to monitor pest populations, but can to some extent be used to diminish pests. For best results, place the traps along borders or in the affected areas.
- Avoid early infestation by pests by avoiding proximity of watermelon to potentially infested crops, erecting barriers to hinder dissemination and monitoring continuously.

The following pests can be found in watermelon:

White flies suck on the green plant parts and thus weaken the watermelon plants. When white flies are very numerous, the sticky honeydew that they produce causes black mould on the leaves. White flies can transmit viruses such as the stunted mosaic virus and the leaf curl virus. Preventive management focuses on the elimination of weed hosts, cultivating healthy and strong seedlings, using reflective plastic mulch, growing windbreaks to impede the spread of white flies, avoiding the cultivation of watermelon next to infested crops, using sticky traps and using crop traps.

Leaf miners suck on the green plant parts and eat into the leaves. As a result of this, the leaves wither and drop off. Defoliation of the crop late in the season can lead to the fruit being scalded by the sun. Leaf miners can become a significant pest in watermelon, if the preferred host is not available. Preventive measures include ensuring that plants remain vigorous through proper organic fertilization and watering, the elimination of weed hosts, enhancing biodiversity to favor natural enemies such as *Dygliphus* spp., *Opius* spp., and *Dacmusa* spp. and sowing tomatoes intercropped with beans. Natural insecticides such as

Discussion: Preventive measures against pests

Relating to chapter 5.1.2 of the Basic Manual and the transparency below, discuss effective preventive measures of pest control.

4.9. Watermelons 8

Measures to reduce pest attack on watermelon

Improve soil fertility


- Crop rotation
- Soil protection (mulch)

Balanced nutrition and healthy plants

- Add organic material to soil
- Compost
- Green manuring
- Animal manure

Carry out appropriate soil bed preparation

- Avoid waterlogging
- Avoid soil compaction
- Expose pests to the sun



Foster the natural habitats of birds and beneficial insects


- Diversify the cropping systems (intercropping)
- Wide crop rotation
- Natural wind barriers
- Natural fences

Traps

- Trap crops
- Suppressive crops
- Yellow sticky traps

Avoid early infestation

- Avoid cultivation near infested crops
- Natural barriers to reduce spread

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TRANSPARENCY 4.9 (8): STRATEGIES TO REDUCE PEST ATTACK ON WATERMELON

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Neem, rotenone, pyrethrum preparations, oil or spinosad, *Bacillus thuringiensis* can be used for direct control. Yellow sticky traps of about 30 cm x 30 cm are helpful in order to reduce the amount of leaf miners during the cropping period.

Cutworms feed on the surface of the stems, leaves, roots and buds of the watermelon plants. During the day, cutworms remain underground where they feed on the roots. At night they come out and attack the parts of the plant that are above ground. Cutworm damage is most severe in seedlings or young watermelon plants. To prevent cutworm the following methods can be used: early soil preparation one month before planting turns the worms or pupae up to the surface where they dry out in the sun or are eaten by predators; rapid establishment of the crop; eliminating weeds that serve as host plants, thereby reducing the number of egg-laying sites available to the cutworm. In organic agriculture, cutworms can be controlled directly with light traps using natural pyrethrum or molasses, by applying liquid or powder preparations of *Derris elliptica* or by spraying natural pyrethrum extracts (*Chrysanthemum cinerariaefolium*) on the plants.

Cucumber beetles chew holes into the leaves and scar runners and young fruits. The beetles can also feed on the stems, the pistils of the flowers and the roots. Several species of cucumber beetle attack watermelon plants (e.g. *Diabrotica undecimpunctata*, etc.). Cucumber beetles are sometimes confused with lady beetles, which are beneficial predators. Preventive measures include avoiding cultivation next to maize (as the cucumber beetle also feeds on maize), growing squash as a trap crop (including treatment of the beetles on the squash) and promoting natural enemies. For direct control rotenone, sabadilla or pyrethrum, mamme or Neem natural extracts can also be sprayed. Red plastic mulch is said to repel the beetle.

Nematodes can reduce the yields of watermelon crops. Infested plants appear stunted and chlorotic. The most effective preventive measure against nematodes is to avoid fields with high nematode populations. A crop rotation with sorghum and a weed-free fallow keeps the nematode population in the soil low. Trap crops (e.g. zucchini), which are planted earlier than watermelon on the perimeter of the field (on 2 to 3 % of the field's surface), attract the nematodes away from the watermelon.

Sharing experiences: Pest control in watermelon

Ask the participants what pests they know to appear locally on watermelon or on cucurbits in general. What preventive and direct measures may control them effectively? Use the tables to complete the answers.

4.9. Watermelon		9
Some pests and their control in organic watermelon		
Pests	Preventive control measures	Direct control measures
White flies	<ul style="list-style-type: none"> Eliminate weed hosts Select healthy and strong seedlings Use reflective plastic mulch Sow windbreaks Avoid cultivation next to infested crops Use traps 	<ul style="list-style-type: none"> Apply Neem, rotenone, pyrethrins, oil, soap and spinosad Apply <i>Beauveria bassiana</i>
Leaf miners	<ul style="list-style-type: none"> Ensure vigorous plants through balanced supply of nutrients and water Eliminate weed hosts Increase botanical diversity to favor natural enemies Use trap crops such as tomatoes intercropped with beans 	<ul style="list-style-type: none"> Apply natural insecticides such as Neem, rotenone, pyrethrins, oil or spinosad Apply <i>Bacillus thuringiensis</i> Use leaf miner traps
Cutworms	<ul style="list-style-type: none"> Turn the worms and pupae up to the soil surface during soil preparation Enhance rapid crop establishment Eliminate weeds before the watermelon crop 	<ul style="list-style-type: none"> Install light traps Use baits with pyrethrum or molasses Apply derris extracts or powder

TRANSPARENCY 4.9 (9): SOME PESTS AND THEIR CONTROL IN ORGANIC WATERMELON

4 Management Guide for Crops

Spider mites suck on the plants and thus weaken them. Light infestations can be tolerated, but heavy attacks can lead to yield reduction. Natural predators and parasites can control spider mites effectively (lady beetles, lacewing larvae, etc.). Controlling host plants such as *Convolvulus arvensis* hinders the development of the mites. For direct control, spray applications of horticultural oil, insecticidal soap, hot pepper wax, pyrethrum products or sulphur are used. An effective but expensive (if available) method is to release predator mites.

Aphids also feed on the plants by sucking plant sap. As a result of this the leaves curl downwards and crumple. Aphids also act as vectors of the mosaic virus. Very vigorous crops also attract aphids due to an oversupply of nitrogen. Natural enemies can control the aphid population very effectively. Aphid development is encouraged by diverse environment with many flowers. Reflecting mulches may confuse the aphids. For direct control, insecticide soap, hot pepper wax, garlic sprays, horticultural oil, rotenone, pyrethrum or Neem extracts can be used. Intensive monitoring until the plants have reached full size allows for timely intervention against this pest and minimizes losses.

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4.9.6 Water management and irrigation

Water is a critical factor in watermelon cultivation. As a matter of fact, watermelon fruits consist 92 % of water. A uniform supply of water is essential to ensure the establishment of the crop and to obtain vigorous plants, which resist attacks by pests and diseases and result in higher yields and better fruit quality.

The water requirement for the total growing period of a watermelon crop (100 days) ranges from 4,000 to 6,000 m³ per ha. Water deficits during the establishment of the crop may delay maturity and cause gaps in production. Water stress in early vegetative growth results in reduced leaf area and reduced yield. The most serious yield reductions will result from water stress during flowering and fruit development. When water supply is insufficient, watermelon plants tend to develop end rot on leaves and vines due to calcium deficiency. If the crop is irrigated, the amount of water given should be reduced as the fruit approaches harvesting in order to avoid fruit rupture and to enhance the flavor.

Where evaporation is high and rainfall is low, irrigation at intervals of seven to ten days is generally necessary. More intensive irrigation is needed if the soil is sandy and has a low water retention capacity. Under dry conditions irrigation must be provided from sowing to flowering and during the first part of fruit development. A relatively dry soil during the ripening period of the fruit increases the sugar content and helps to avoid the flesh becoming fibrous and less juicy.

Furrow irrigation is the most common irrigation method in watermelon cultivation. However, under dry conditions and on light soils, drip irrigation may be more appropriate. This uses water more efficiently than sprinkler irrigation and does not enhance weed growth. In conventional farming, drip irrigation is used in combination with plastic mulch, which reduces the water requirement by as much as 30 %. If overhead irrigation is used, the crop should be watered in the early morning to avoid long periods of wet leaves as this encourages foliar diseases.

Attention should also be paid to the quality of the water used for irrigation. Water with a high calcium content can clog the drippers, although drippers or dripping lines can be cleaned with acid (e.g. vinegar or citric acid). The water should be free of toxic substances and microbes (i.e. coliform bacteria), which are hazardous to human beings.

Sharing experiences: Irrigation

Encourage the participants to share their experiences of crop irrigation. Are any crops irrigated? Which crops? What method(s) is/are being applied? Have irrigation practices changed in the past? What criteria define the irrigation strategy? If the participants have grown watermelon in the past, collect information specifically concerning this crop.

Based on transparency 3.5.3 b of the Basic Manual, have a discussion about whether any new irrigation strategy needs to be developed for organic cultivation of watermelon.

Prepare a table and fill it out while the participants give the information.

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4.9.7 Other maintenance methods

Pollination is mainly done by insects (bees, ants, etc.) and does not need special intervention. Pruning the fruits, however, is an important maintenance measure in watermelon cultivation that helps improve marketable yields.

Misshaped and damaged fruits and fruits with blossom end rot are removed as soon as they are visible. Pruning increases the amount of marketable fruit and the size of the fruits. It also promotes new fruit set when this is desired. Depending on market requirements, the number of fruits per plant must be limited. In order to get large watermelons, not more than two or three well-shaped fruits are left to grow per plant. To avoid diseases spreading, the plants should not be pruned when the vines are wet. Excessive vegetative growth should be regulated by withholding irrigation and nitrogen supply rather than by pruning the vines. Removing leaves limits photosynthesis and hence sugar development.

4.9.8 Harvest and post-harvest handling

Harvest generally begins 30 to 45 days after full bloom and continues for several weeks with three to four cuttings every three to five days. The flesh of the typical red-fleshed watermelon, for example, changes from immature pink to ripe red and then to overripe within ten to fourteen days. Overripe fruits have a watery, mushy texture and are low in sugar. Watermelon fruits rapidly become over-mature. The following indicators help to determine the right moment to harvest:

- The outer ring of the pale patch on the underside of the fruit becomes creamy or light yellow.
- The peduncle becomes hard and fibrous.
- The tendrils to the fruit wither.
- The leaf closest to the fruit turns partially brown.
- The top of the fruit becomes slightly soft.
- When tapping the fruit, the sound is muffled and hollow.
- The rind loses its waxy appearance.
- The rind becomes harder to pierce with a fingernail.
- Depending on the variety, markings on the rind may become visible.
- And last but not least - open a few fruits to determine the stage of ripeness.

Group work: Harvest and post-harvest handling

Divide into groups and discuss the following questions:

- *What is the best method to determine the maturity of a watermelon?*
- *How are watermelons handled best during harvesting in order to avoid damage and disease infections?*
- *How should the fruits be handled and stored in order to maintain their marketability and quality, especially if they are transported over long distances?*

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Abundant rain or irrigation shortly before or during harvest may lead to the fruits cracking. This risk may, however, be reduced if the fruits are harvested in the afternoon and if the stem is cut instead of the fruit being pulled off. A stem of at least 5 cm in length must be left on the plant to avoid fruit rot and lesions to other fruits.

Watermelons should be dry and not covered in dew when loaded. They can either be packed in straw and bulk-loaded packed or placed in corrugated fiberboard padded bins. Long distance haulage should be done at 12 to 15 °C.

4.9.9 Storage

Watermelons are stored at relatively high temperatures, but with low humidity. Storage below 10 °C for longer periods can lead to chilling injuries. Storage for a week at 0 °C can cause pitting, color loss and bad flavor. The recommended temperature for longer storage is between 13 and 16 °C. At this temperature the fruits can be kept for two to three weeks.

Recommended websites:

- *Crop water management -*
www.fao.org/ag/agl/aglw/cropwater/watermelon.stm
- *Crop information in Spanish -*
www.abcagro.com/frutas/frutas_tradicionales/sandia.asp
- *Technical guide about watermelon (in Spanish) -*
www.agronegocios.gob.sv/comoproducir/guias/sandia.pdf

4 Management Guide for Crops

4.10 Avocado

Introduction

Avocado is an evergreen tree which is grown under a wide range of ecological conditions across the tropics and subtropics. The agricultural importance and the social recognition of the fruit differ from area to area. For many centuries avocados have been part of the diet of people of Central America, but it has not been widely eaten elsewhere. Today the avocado fruit is grown in Mexico, Central America, the Greater Antilles, Chile, Peru, Spain, the Canaries, Israel, South Africa, Sri Lanka, India, Indonesia, Philippines, Thailand, Vietnam and many more countries.

The avocado has a high nutritive value and a great commercial potential. The fruits are rich in antioxidants and the vitamins E, C and A. They contain up to 30 % fat, primarily monounsaturated oleic acids. In countries where it is grown the local market is often limited as its taste is not always appreciated. Compared to other tropical fruits, the quantities of fruits that are exported are quite small.

Organic avocados are grown in all the major avocado producing countries. In some countries, such as Chile, all the organic production is exported. Chilean exports of organic avocado go almost entirely to the USA.

Avocado trees generally demand only moderate maintenance and grow well under organic management. In subtropical regions organic avocados are grown in orchards as a main crop, while in tropical regions avocado trees are often cultivated together with other trees in fruit gardens.

Lesson to be learned:

- *Avocados can be cultivated organically with no major problems.*
- *Appropriate soil management, pruning and irrigation can be key factors in obtaining good yields and high quality fruits.*
- *Organic avocado cultivation definitely needs additional manpower for production and distribution of compost.*
- *Marketing opportunities and synergies must be considered carefully.*

Visit: A conventional and an organic avocado orchard

If possible arrange a visit to a conventional and an organic farm with avocado production.

Ask the participants to make observations about the following aspects of (organic) farming and their impact on avocado cultivation (depending on the participants' knowledge, ask them to make general recommendations for organic avocado cultivation).

- *Plant diversity: Are there differences in plant diversity? Does this have any observable effects on system stability and plant health?*
- *Soil: What are the characteristics of the soils? (Use soil-testing methods such as the spade-sample diagnosis presented in chapter 3.1 of the Basic manual.) Compare soil fertility and spontaneous flora? Is there any necessity to improve soil quality? What possibilities exist for doing this?*
- *Plant nutrition and health: Are there any observable differences in the trees? What are the differences in the farming methods? What preventive measures are used?*
- *Ask the participants to interview the farmers on economic issues. What is the farmers' opinion about conversion to organic avocado production?*

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4.10.1 Agro-ecological requirements and site selection

Avocado (*Persea americana*) originates in the rainforests of the humid subtropics and highland tropics of Central America. Although commercial production has extended to the lowland tropics and the cooler semi-arid regions and avocado trees can be grown over a wide range of climatic and soil conditions, proper site selection remains the key to successful organic avocado production.

Climate

There are three races of avocado, with differing genetic characteristics. This makes it possible to cultivate this crop over a wide range of environments ranging from cool, summer-dry Mediterranean to subtropical and humid tropical climates. The diverse agro-climatic zones offer opportunities for off-season production.

The tree is not very tolerant of cold temperatures and this is the main factor that restricts avocado cultivation in the subtropics. Avocado trees grow well in the arid subtropics and in Mediterranean areas but temperatures around 0 °C can affect fruit production and the tree itself (Mexican cultivars may tolerate temperatures as low as -5 °C). Varieties that are more tolerant to the cold do not have a very high fruit quality. Very hot and dry conditions during flowering and fruit set can cause flowers and young fruits to drop. Alternating hot and cold temperatures disturb fruit development. The best temperatures for fruit development are 25 °C during the day and 20 °C at night, although many of the varieties cultivated today do well under somewhat lower temperatures.

Avocado trees build a shallow root system with relatively few root hairs. This limits the uptake of water and nutrients. Prolonged periods with low relative humidity and low temperatures result in severe stress and loss of productivity (due to leaf dropping). Thus, for high yields, avocado trees need a moist soil all year round. Excessive rainfall during flowering and fruit development reduces fruit set and leads to fruit drop and losses due to anthracnose. Well distributed annual rainfall of 1200 mm is considered sufficient for rain-fed avocado cultivation. In arid climates, with less than 300 mm of rain per year irrigation is required to successfully cultivate avocado trees.


Relative atmospheric humidity should be below 60 %. Higher levels of air humidity may encourage diseases on leaves, flowers and fruits, whereas very dry air reduces pollen fertility.

Strong winds can cause major damage especially on young fruits. Dry winds during flowering reduce pollination.

Good access of light to the branches is essential for fruit production. On the other hand strong solar irradiation can burn the branches and fruits.

4.10. Avocado1

Agro-ecological requirements of avocado trees





Climate:

- Tolerance to different climates due to three eco-races
- No climates with temperatures below 0 °C
- Ideal temperature is 25 °C at day, 20 °C at night
- Relative humidity below 60 %
- Ideal rainfall is 1200 mm of rain distributed over the year; down to around 300 mm per year with additional irrigation

Soil:

- Wide spectrum of soils possible
- Sensitive to poor drainage
- Relatively intolerant to salinity (differences between eco-races)
- Optimum range of pH between 5 and 6
- Good quality irrigation water essential



TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.10 (1): AGRO-ECOLOGICAL REQUIREMENTS OF AVOCADO TREES

Note:

To evaluate the potential of successful organic avocado cultivation in a specific context, additional aspects must be considered such as marketing possibilities, logistics, investments (especially in the case of a new plantation) and others. These aspects are considered in section nine of this chapter.

Group work: Site selection

After having presented the agro-ecological requirements of avocado, ask the participants to work in groups and evaluate the suitability of the crop for the area. What are the most critical factors?

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Soil Characteristics

Avocados can be grown in a wide range of soils, but are extremely sensitive to poor drainage. Waterlogging for more than 24 hours can kill the trees. Deep soils are also important, as obstructions to the roots can cause avocado trees to die suddenly of phytophthora, sometimes after three or four years of healthy growth.

Avocado trees are intolerant to saline conditions. Affected trees will develop burned and dried leaves. West Indian seedlings are more tolerant to salt than Mexican seedlings, with Guatemalan ones having an intermediate salt tolerance. The optimum pH range is between 5 and 6.

Good quality irrigation water is of major importance for economically viable yields under arid conditions. In organic avocado cultivation attention should be paid to water salinity, heavy metal contamination and toxic bacteria. Water analysis is essential before selecting a new site for organic avocado production.

4.10.2 Diversification strategies

Designing an organic orchard

When planning an organic avocado orchard the same criteria are applied as for other organic orchards. The trees should be relatively widely spaced to allow for good ventilation (to reduce disease pressure) and the orchard should be diversified (to reduce disease and pest pressure, reduce the economic risk, make better use of aerial and soil space and protect the soil).

Avocado in agro-forestry systems in humid climates

In humid climates avocado is sometimes cultivated together with other crops in an agro-forestry system. In such a system the avocado trees can serve as shade trees for tea and coffee and/or they can be intercropped with other perennial crops such as coconut, banana, jackfruit, rambutan, mangosteen and other fruit trees. Organic growers may prefer tall trees since they are more convenient in mixed gardens.

Ideally, an avocado orchard should be a diverse mosaic: the avocados mixed with cover crops in the alleyways, with other small fruit trees planted under the avocados and with hedges and flower fallow plots in and around the orchard. In pure avocado stands the space to grow additional crops is limited to the alleyway.

Motivation:

Ask the participants how they imagine the ideal organic orchard to be. What may be the reasons for differences from a conventional orchard?

Note the keywords on the board and refer to them later on. Do the participants' ideas correspond with the information presented in this chapter? Did the answers contain additional aspects or were any aspects missing?

4 Management Guide for Crops

Crops that can be cultivated in the alleyways of avocado orchards include beans, maize and aloe vera. Cover crops of sorghum or maize raise the soil organic matter and inhibit root rot. Aloe vera extract has multiple uses in the cosmetic, pharmaceutical and fruit juice industries. The choice of appropriate crops will depend on personal needs, preferences, marketing possibilities and the climatic conditions. For example, strawberries have been successfully cultivated in avocado orchards.

Suitable Races and Cultivars

There are three distinct horticultural races of avocado: the West Indian (var. *americana*), Guatemalan (var. *drymifolia*) and Mexican (var. *guatemalensis*) races. There are also cross breeds of these races. Many of the commercially important varieties are cross breeds of the Guatemalan race with one of the other two races. Pure West Indian types are generally unsuitable for export market but are preferred by local consumers.

All three races are adapted to different tropical and subtropical conditions. The West Indian race is best adapted to the humid tropics, but cross breeds with Guatemalan cultivars perform well too and are considered valuable for extending the harvest season. In subtropical regions cross breeds of the Guatemalan and the Mexican races predominate since they combine the tolerance of cold temperatures of the latter with the superior horticultural traits of both.


Breeding criteria include the universally desired objectives of yield, fruit quality, vigor, adaptability, etc., together with some specific objectives for avocado such as an attractive pulp without fibers, slow oxidation, high oil content, a seed that does not stick to the pulp and long persistence on the tree when ripe (see transparency 4.10 (2)). For rootstocks, resistance to *Phytophthora* is the most important trait.

A special aspect in variety selection is due to the unique flowering habit of the avocado trees: avocado flowers have both male and female organs but, to avoid self-pollination, the two parts do not open at the same time. Two flowering types can be distinguished: type A and type B (see transparency 4.10 (3)). The flowers of type A varieties open in the morning as receptive females, then close in the afternoon until the following afternoon, when they reopen for pollen shed. The flowers of type B-varieties open in the afternoon as receptive females, close overnight and reopen the following morning to shed pollen. If establishing an avocado plantation in an area where avocado trees have not been previously grown at least one variety of each type must be selected to ensure that pollination overlaps with the flowering periods. The proportion of A and B type varieties can be 4:1 or 2:1 with the preferred variety planted in majority.

4.10. Avocado		2		
Eco-races of avocado and their characteristics				
	West Indian	Guatemalan	Mexican	
Climate	Tropical	Subtropical	Semi-tropical	
Cold tolerance	Least	Intermediate	Most	
Salt tolerance	Most	Intermediate	Least	
Disease resistance	Higher	Susceptible to <i>Verticillium wilt</i>	Susceptible to diseases due to very thin skin	
Fruit bloom to maturity	5-9 months	9-12 months or more	6-8 months	
Fruit size	Variable	Variable	Small	
Fruit colour	Green or reddish	Green	Green to purple or black	
Skin thickness	Medium	Thick	Very thin	
Skin surface	Shiny, leathery	Rough and warty	Waxy bloom	
Seed cavity	Variable	Tight	Loose	
Oil content	Low (3-10 %)	High (8-15 %)	Highest (up to 30 %)	
Pulp flavour	Sweet, mild, watery	Rich	Anise-like, rich	

Source: Nakasone et al. 1998, FBL

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TRANSPARENCY 4.10 (2): CHARACTERISTICS OF THE THREE AVOCADO RACES

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The flowering period lasts from late autumn to spring, depending upon the cultivar and climate.

A large number of avocado cultivars can be found. Hass (type A) and Fuerte (type B) are the most widely grown cultivars. Some other important cultivars include Bacon, Zutano, Booth 7, Booth 8, Sharwil and Ettinger.

Propagation

Propagation from seeds is common in many countries. However, for commercial production it is not recommended, as the trees will show a great variability in fruit characteristics, root growth and pest and disease resistance. Propagation from seeds also carries considerable risk of transmitting seed-borne diseases such as the sunblotch viroid. The more commonly used and preferred method for large scale propagation is grafting. This method is generally only used in specialized avocado nurseries. Seedlings may be used as rootstocks.

Grafting is less demanding, faster and more economical in the use of scion materials. For cleft-grafting, 6 to 12 month old seedlings are used as rootstocks. Bud wood sticks, with well-developed terminal buds, are selected from the season's mature growth. These develop new shoots within three to four weeks. While in conventional agriculture many avocado trees are produced in containers in media without soil, organic growers use media that consist of a mixture of compost and earth.

The seeds for seedling production are taken from mature fruits and are sown directly into the nursery or into polyethylene bags. After six to eight months the seedlings are ready for transplanting.

Bought trees should be certified to avoid the introduction of diseases, pests and viruses and to ensure the authenticity of rootstock and cultivar. Nurseries have been a major source of dissemination of root rot (*Phytophthora cinnamomi*). Some organic standards require the use of trees from certified organic nurseries.

4.10. Avocado 3

The two flowering types of avocado

FLOWERING TYPE	Some of the varieties	FIRST DAY		SECOND DAY	
		Morning	Evening	Morning	Evening
FLOWERING TYPE A	Simmonds	FEMALE FLOWER OPEN	FLOWER CLOSED	MALE FLOWER OPEN	
	Choquete				
	Hass				
	Lula				
	Tomar				
	Head				
	Fin Morton				
	Mexicola				
	Topo Topo				
	Lana Hass				
FLOWERING TYPE B	Harvest	FLOWER CLOSED	FEMALE FLOWER OPEN	MALE FLOWER OPEN	
	Ettinger				
	Toninaga				
	Fuerte				
	Sharwil				
	Bacon				
	Zutano				
	Booth 7				
	Guato mala				
	Hall				
Hall					
Colo Topo					

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TRANSPARENCY 4.10 (3): FLOWERING TYPES OF AVOCADO

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Planting

Before planting a new orchard on flat or gently rolling terrain, the land should be cleared and deeply ploughed to break any possible soil compaction in lower soil layers. It should then be harrowed two or three times to achieve the desired soil tilth and to level the field. A few months before planting avocado trees, some organic growers sow vigorous legumes (i.e. *Canavalia* sp. or *Cayanur cayan*), mulching them shortly before planting the avocado trees. This green manure supplies organic material to the soil and stimulates soil life.

Installation of water traps around the tree basins is recommended. This can help avoid soil erosion on sloping land and collect rainwater. On slopes it is preferable to plant the trees on half-moon terraces in order to prevent erosion.

Depending on the vigor of the variety and its growth habit, young trees in pure avocado stands should be planted 8 to 12 meters apart from each other, giving a population of 100 to 150 trees per hectare. Varieties with a spreading growth pattern require wider spacing of not more than 50 to 80 trees per hectare. This is necessary to allow for the development of other crops and to create a diverse orchard,

In early spring, planting holes deep and wide enough to accommodate the root system (60 to 90 cm wide and 60 cm deep) should be dug. These holes should be filled with compost or farmyard manure and topsoil (at a ratio of 1:1). As most soils in wet zones are acidic, pH should be adjusted (to between 5 and 6) by liming, following organic standards. Stakes are then put in place. Before planting, the leaves of the trees are cut in half to reduce transpiration. Having removed the container or polyethylene bag, the young trees are placed into the planting holes, taking care to ensure good contact with the surrounding soil. As for other trees, immediate watering and proper shading and protection from wind are essential.

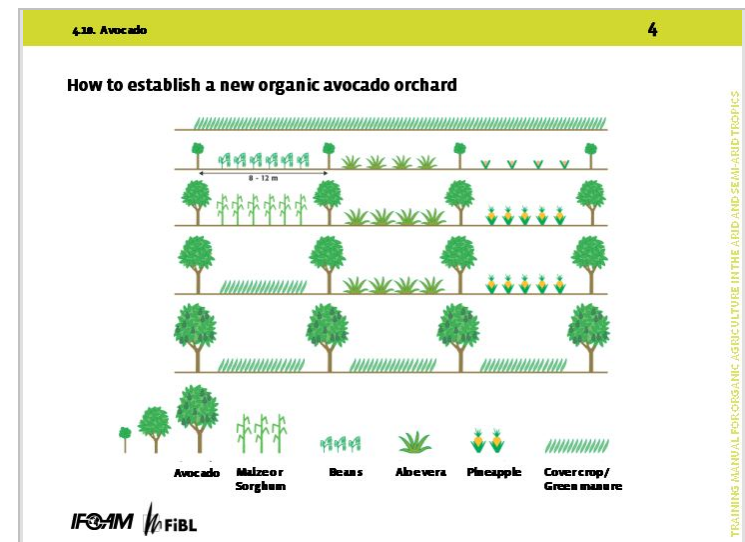
Where avocado trees are propagated by budding or grafting, it is common to plant the trees deeper than normal, so that the graft is at or below ground level. As the tree grows the soil is mounded around the trunk to assure that the graft union is kept below ground level. Thus, even trees killed back to ground level by severe cold will regenerate themselves from varietal wood rather than from rootstock.

Maintaining 10 cm thick, fibrous mulch of wheat, sorghum or rice straw around young trees suppresses weed growth, conserves soil moisture and protects and encourages the development of the root system.

Group activity:

Visit a field intended for planting an organic avocado orchard and work on the following issues in groups:

- Analyze the advantages and possible limiting factors of this site for organic avocado production
- Propose an orchard design, creating a mosaic of production units
- Propose intercropping possibilities during the period when the avocado trees are establishing themselves
- Propose a green manure before planting avocado trees



TRANSPARENCY 4.10 (4): HOW TO ESTABLISH A NEW AVOCADO ORCHARD

4 Management Guide for Crops

4.10.3 Soil protection and weed management

During the first two or three years after planting it can be important to avoid competition by weeds and grasses. Organic growers do this by cutting the accompanying plants when they start to compete with the avocado trees for light and water. The plants are mulched to improve moisture retention during the dry season. As avocado trees build plenty of roots near the soil surface, weeding with a plough or a disk harrow is not recommended, as any damage to the root system may enhance infections by *Phytophthora*. Weeding is usually carried out manually using a scythe or mechanically with a grass cutter.

Organic mulches, such as straw, rice husk and wood chips may be used in the first years to protect the soil from erosion, suppress weeds, and enhance root growth and soil fertility. As avocado trees have a rapid turnover of leaves these fallen leaves will, after a few years, supply enough organic material to build a thick layer of mulch.


In bearing orchards, competition by weeds (mainly grass) is not a problem, because of the size of the trees and because the canopy provides enough shade to prevent excessive growth of the soil cover. Nevertheless green mulch under the canopy is recommended (for reasons see above).

As an alternative to mulching, a cover crop can be grown, if the conditions allow. A suitable leguminous cover plant for orchards in the humid tropics is *Peuraria*.

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Weed management in organic avocado production

Young plantations:
Weed control is important in the first years of the plantation to avoid competition.
Possibilities:
Cover crops
Mulch under the trees



Fruit-bearing orchards:
The canopy now provides enough shade to prevent excessive growth between the trees.
Weed control at this stage is no longer considered necessary.



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TRANSPARENCY 4.10 (5): WEED MANAGEMENT IN YOUNG AND BEARING AVOCADO ORCHARDS

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4.10.4 Tree nutrition and fertilization

Tree nutrition in organic avocado cultivation has the following objectives:

- ✍ To guarantee satisfactory yields and ensure ideal fruit quality.
- ✍ To improve soil microbial life and strengthen plant vitality.
- ✍ To minimize pest and disease problems.
- ✍ To avoid nutrient losses by leaching or volatilization.

Commercial avocado orchards generally need to pay more attention to proper fertilization than garden or agro-forestry systems. If soil fertility is not maintained, fruit yield and quality may decline after several years of fruiting,

Although avocado trees have low to moderate nutrient needs overall, an appropriate nutrient supply must be ensured to satisfy the needs in specific phases of fruit growth:

- **Potassium** is the nutrient that is of highest importance in avocado cultivation and is of special importance for flower induction, fruiting and fruit quality. Potassium uptake is greater during the long period of fruit production (when the tree is carrying fruits of different sizes and stages, a stage that lasts for 8 to 10 months between first flowering and last mature fruit).
- High yielding trees have elevated **Nitrogen** needs in order to build sufficient leaf surface to ensure good fruit development. Excessive nitrogen supplies to bearing trees stimulates vegetative growth and reduces fruiting, and may result in alternate bearing.
- Avocado has a limited need for **Phosphorus**. However, before and during the long flowering period phosphorus and boron uptake are increased. In soils with phosphorus fixation, additional fertilization may be necessary.

To ensure appropriate fertilization, the physical, chemical and biological characteristics of the soil and the specific needs of the trees must be known. Various micronutrients such as iron, zinc and boron have a strong influence on growth, nutrient uptake and yield of the avocado trees. Zinc and boron deficiencies may require specific attention.

Young avocado trees are best fertilized by regular application of farmyard manure with a high nitrogen content that will encourage vegetative growth. Fruit bearing trees should be fertilized with 25 to 50 kg of compost per tree per year which will generally provide enough macro and micronutrients for the trees. The compost should be applied before winter. A second application is advisable – if feasible – near the peak of fruit set. The compost is usually applied in a ring around the trunk of the tree or in shallow holes dug beneath the tree's canopy. Another method that has proved effective is to apply chicken manure filled into a hole on the hill side of the tree, where it is left to decompose. After four or five months the manure is dug-out and distributed around the tree.

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Key aspects of avocado fertilization

Circumstances:


- Overall low to moderate nutrient needs. Elevated needs in specific phases of fruit growth.
- Potassium of major importance for flower induction, fructification and fruit quality.
- High yielding trees have higher nitrogen demand.
- Greater demand for phosphorus and boron before and during flowering.
- Strong influence of iron, zinc and boron on growth, nutrient uptake and yield.

Recommendations:

- Fertilization based on compost (application of 25 to 50 kg per tree before winter; second application – if feasible – near the peak of fruit set).
- 200 g of dolomite per square meter every 2 to 3 years in the winter.
- Green manure intercrop.

Analysis of compost from an avocado orchard

- ✓ pH : 4.77
- ✓ Organic matter (%): 67.25
- ✓ Nitrogen (ppm) : 2.72
- ✓ Phosphorus (ppm) : 21.65
- ✓ Potassium (ppm) : 448.25
- ✓ Calcium (ppm) : 69.17
- ✓ Magnesium (ppm) : 35.00
- ✓ Zinc (ppm) : 0.50
- ✓ Iron (ppm) : 7.18
- ✓ Manganese (ppm) : 3.80
- ✓ No nematodes detected, but beneficial biological organisms like *Penicillium*, *Rhizopus*, *Trichoderma*



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TRANSPARENCY 4.10 (6): KEY ASPECTS OF FERTILIZATION OF AVOCADO TREES

Exercise: How to make your own compost

Design a compost mixture for avocado groves, based on the organic materials (manure, straw, etc.) that are available locally. For additional information on making compost see chapter 4.4 of the Basic Manual.

Make proposals on how to combine the compost with other nutrient sources.

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Avocado trees benefit from liming: 200 g of dolomite per square meter every two to three years in the winter is recommended. Micronutrient deficiencies can be corrected by applying a commercial product that contains the missing elements (some certifiers demand written permission prior to the application of micronutrient fertilizers). Not all fertilizers may be allowed by organic standards. Some farmers apply liquid fertilizers (based on vermi-compost, minerals, micronutrients and micro-organisms) in addition to compost.

To supply the trees and intercrops with nitrogen, and improve the fertility and drainage capacity of the soil, leguminous green manure crops may be cultivated (a mixture of equal parts of a legume, a grass and "mostaza" does also well).

4.10.5 Pest and disease management

Serious infestations by pests and diseases are rare in avocado trees in most production regions. Nevertheless some pests and diseases do occur on avocado and may cause serious losses in some areas. Root rot (*Phytophthora cinnamomi*) is a serious, soil-borne disease that can kill the tree. Other diseases that can cause damage to avocado trees and fruits are Cercospora spot on the fruit, Anthracnose (*Colletotrichum gloeosporioides*) in warm humid climates and sunblotch. In storage, fungi can cause stem-end rot. The tree and the fruits of avocado may be subject to attack by various pests. Depending on the climate and the area mealybugs, mites or thrips or fruit-spotting bugs, caterpillars and loopers may pose problems. Some of these can cause considerable losses in yield and marketable fruit.

Pest management

The appearance and pressure of pests varies strongly depending on the area and the climate. In the relatively dry climates of Chile mealybugs, red mites and thrips are prevalent, whereas in the humid climates of Indonesia the leaves of avocado trees may be completely eaten by the caterpillars of *Cricula* moths.

Mediterranean fruit fly (*Ceratitis capitata*) and the **Oriental fruit fly** (*Dacus dorsalis*) are widespread in Africa, Latin America and Europe and do attack avocado. The adult flies lay eggs under the skin of ripening fruits. In a rapid cycle the larvae feed on the fruit, pupate in the soil underneath the trees and emerge as new adults. Although the larvae rarely develop in the avocado fruits, fruit fly attack can still damage the fruits, and this may lead to them being excluded from some markets. In organic farming the pest is controlled by mass trapping using food baits that use permitted insecticides (i.e. Spinosad) and by releasing parasites (*Diachasmimorpha tryoni*) and nematodes. Sterile insect technology is not permitted.

Discussion: Disease and pest management

Go to a farm and inquire about the main pests and diseases in avocado cultivation and strategies that are applied for their control.

Inform the participants about approaches that may be applied in organic farming and discuss these together. You may want to supply additional information to the participants (using chapter 5 of the Basic Manual).

*You may also discuss the efficiency of biological control methods, if the participants are familiar with them (e.g. with reference to *Pseudococcus* spp. that are controlled by the larvae of *Cryptolaemus mounstrouzieri*).*

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Borers (*Nipponoclea albata*, *N. capitoe*, *Xylosandrus compactus*) can cause damage by boring tunnels into the trunk and twigs of the trees. Lime wash and lime sulfur are used as repellents. In some areas biological control is used (i.e. with *Beauveria bassiana*).







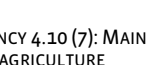

Scale insects feed on avocado in some areas. Olive black scale (*Saissetia oleae*) is a common pest. Scales suck the sap, weaken the plant and can cause wilting and dieback. They also encourage the development of sooty mold growth, which reduces yield and the quality of the produce. Trees under water stress are less prone to attack. Organic methods of control include washing the trees with soap or spraying with oil.

Mealy bugs, including the Avocado (or spiked mealy) bug (*Nipaecoccus nipae*), which is also a pest on palms, banana, citrus and cocoa and *Pseudococcus* species, can cause major losses to avocado by sucking the sap from leaves, shoots and fruits and causing premature drop of the fruits. The excretion of honey sap results in the development of black sooty molds. Where they are present, predators (i.e. *Cryptolaemus mounstrouzieri*) and parasitoids generally control this pest. The application of pesticides, which also kills natural enemies, may result in an uncontrolled development of mealy bugs. In cases of high pest pressure, mineral oil sprays can be applied.

Thrips such as the Greenhouse thrip (*Heliethrips haemorrhoidalis*) can cause the fruits to blemish and make them unmarketable. The pest is naturally controlled by predatory mites (*Euseius hibisci* and *Anystis agilis*) and the minute pirate bug. Orchards with ground cover have fewer thrip problems, as natural enemies can develop in the ground litter.

Mites such as the red mite (*Oligonychus yothersi*) and the brown mite (*Bryobia rubrioculus*) can attack avocado trees, although they also feed on other fruit trees (e.g. mango and coffee). The pest mainly occurs in Central America. Infested leaves turn brown and drop. Mites are generally controlled by their natural enemies. Powders can be applied to the ground but are not generally very effective.

Moths, especially the Avocado moth (*Stenoma catenifer*), are a major pest in Central and South America, where mass attack can lead to total fruit loss. If there are no fruits present the larvae can burrow into twigs, and may kill small trees. The moths lay eggs on the skin of the fruit, and the larvae bore into the pulp and seed. Pupation occurs in the soil. The pest can be present throughout the year if there are host plants with diverse flowering periods, and this allows several generations to develop in the space of one year. Where the moth has made a hole into the skin, the fruit turns dark and fungi develop. Often the fruits drop prematurely. The pest is dispersed with infested fruits and on shoots.

4.10. Avocado		7
Major pests of avocado and their organic control		
Pests	Control methods	
Fruit flies		<ul style="list-style-type: none"> • Mass trapping (combination of food baits with organic insecticides, such as Spinosad) • Mass release of the parasite <i>Diachasma morpho tryon</i> • Mass release of nematodes for control in the soil • Application of plant extracts such as Neem
Borers		<ul style="list-style-type: none"> • Preventive application of lime wash and lime sulphur as repellent • Biological control (i.e. with <i>Beauveria bassiana</i>)
Scales		<ul style="list-style-type: none"> • Wash the trees with soap or apply oils • White oil (mineral oil)
Mealybugs		<ul style="list-style-type: none"> • Encourage natural control by predators (i.e. <i>Cryptolaemus mounstrouzieri</i>) and parasitoids • In case of high pressure mineral oil can be sprayed
Thrips		<ul style="list-style-type: none"> • Encourage natural control by predatory mites such as <i>Euseius hibisci</i> and <i>Anystis agilis</i> and the minute pirate bug • Spray pyrethrum or Neem
Mites		<ul style="list-style-type: none"> • The mites are generally controlled by their natural enemies • Encourage natural control by predatory mites • Spray soap or pyrethrum
Moths		<ul style="list-style-type: none"> • Select tolerant cultivars • Remove and destroy damaged fallen fruits • Biological control by encouraging or release of parasitoids (i.e. <i>Trichogramma pretiosum</i> and <i>T. annulata</i>) • Spray <i>Bacillus thuringiensis</i> or Pyrethrum
		

TRANSPARENCY 4.10 (7): MAIN PESTS IN AVOCADO AND POSSIBILITIES OF CONTROLLING THEM IN ORGANIC AGRICULTURE

4 Management Guide for Crops

Control methods include removal and destruction of damaged and fallen fruits. One recommended method of biological control is to collect fallen infested fruits and put them in screened boxes, which allows the parasitoids to fly away, but not the moths. Mass release of *Trichogramma pretiosum* and *T. annulata* is practiced in some areas. Cultivars also show different levels of sensitivity to attack by *S. catenifer*.


Besides the pests mentioned above, fruit-spotting bugs can cause deep fruit lesions and fruit abortion, and various webbing caterpillars and loopers can also cause serious economic losses.

Disease management

A number of diseases occur on avocado trees. The most serious are root rot (*Phytophthora cinnamomi* and *Verticillium* sp.), sunblotch and Anthracnose.

General prevention measures against diseases include the use of certified trees, planting in deep and well-drained soil, ensuring good aeration of the trees and orchards, appropriate irrigation, avoiding damage to the roots and trunk, and encouraging an active soil by establishing and maintaining a permanent organic mulch under the tree canopy.

Root rot: *Phytophthora cinnamomi* causes root rot and tree decline, yellowing of leaves, sparse foliage, wilting of leaves and dieback of shoots. The soil-borne disease is commonly found in acid soils with poor drainage. As the pathogen can be transmitted by plant material or soil, no soil or growing medium should be imported into a farm that is free of the disease. Care should be taken to sterilize farm machinery and tools that have been used elsewhere, to avoid infestation of areas that are free of the pest. Trees should be propagated from healthy plants or seed. Preventive control measures include the use of tolerant rootstocks such as Morton Grandee, Thomas, Barr-Duke or Duke-9. To avoid infestation it is essential to avoid planting in waterlogged areas and to ensure adequate drainage. Ploughing underneath the tree canopy should be avoided. A heavy permanent organic mulch under the tree canopy, that reaches 60 cm beyond the canopy, reduces the risk of an infection. In the case of an infection the pest can be controlled by only cultivating non-susceptible crops for at least four years. Good pruning practice and the application of copper to wounds (2% Bordeaux mixture) and covering with wax all help to prevent the infection of wounds. In some (suppressive) soils micro-organisms naturally suppress the disease.

4.10. Avocado		8
Major diseases of avocado and their organic control		
Diseases	Preventive measures	Direct control methods
Root rot	<ul style="list-style-type: none"> ▪ Use tolerant rootstocks ▪ Propagation from healthy plant material ▪ Adequate drainage or avoiding planting in waterlogged areas ▪ No plowing underneath the tree canopy to avoid root injuries ▪ Heavy mulch ▪ Avoid flood irrigation 	<ul style="list-style-type: none"> ▪ Good pruning practice ▪ Preventive copper applications on wounds (Bordeaux mixture 2% and cover with wax)
Anthracnose	<ul style="list-style-type: none"> ▪ Use tolerant cultivar ▪ Avoid damaging the fruit at harvesting 	<ul style="list-style-type: none"> ▪ Preventive spraying of Bordeaux mixture
Sunblotch	<ul style="list-style-type: none"> ▪ Disinfect pruning and propagation tools ▪ Use registered/safe rootstock and scion materials 	<ul style="list-style-type: none"> ▪ Destroy infested trees ▪ Young plants: exposure to 56 °C for 15 minutes
Cercospora spot, Powdery mildew, Stem-end rot and Scab	<ul style="list-style-type: none"> ▪ All cultural measures 	<ul style="list-style-type: none"> ▪ Preventive spraying of Bordeaux mixture
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TRANSPARENCY 4.10 (8): MAIN DISEASES IN AVOCADO AND POSSIBILITIES OF CONTROLLING THEM IN ORGANIC AGRICULTURE

4 Management Guide for Crops

Anthracnose: The pathogen *Colletotrichum gloeosporioides* (*Glomerella cingulata* var. *minor*) causes small brown to black spots on the fruit. The spots can grow larger and cause the fruit to crack across the spot. Another strain of the same fungus causes leaf spot. Although the disease needs a relative humidity of nearly 100 % to germinate from spores, it can also occur in drier situations. Cultivars of avocado show different degrees of susceptibility (Fuerte is one of the most susceptible). The pathogen is commonly present and mostly affects damaged or ageing tissue. Thus the best control measure is to avoid damaging the fruit at harvesting. Direct control is possible by preventive spraying of Bordeaux mixture.

Sunblotch: The Avocado sunblotch viroid is widespread throughout the world. The viroid is transmitted through infected seed or scion material, pruning and propagation equipment, and also by root grafting between trees. The disease distorts the growth of the trees and fruit, and causes significant economic loss. Preventive control measures include disinfecting, pruning and propagation tools and the use of registered/safe rootstock and scion materials. Exposure of young plants to a temperature of 56 °C for 15 minutes kills the pathogen. Destroying infected trees in the orchard is the only measure of direct control.

Cercospora spot, powdery mildew, stem-end rot and scab: These diseases are only rarely encountered in semi-arid regions, but pose serious problems in the humid tropics. They affect leaves, young stems and fruit. Cultural measures can act as preventive controls. Direct control is possible by preventive spraying of Bordeaux mixture.

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4.10.6 Water management and irrigation

Avocado trees do not tolerate either water stress or excess moisture, especially when drainage is inadequate. Water stress causes high flower abortion, young fruits to drop during early spring, and heavy fruit drop during autumn. Any means of providing supplementary irrigation to the crop can minimize flower and fruit drop resulting from dry periods at these times.


In most organic orchards soil covering plants or mulches are used to reduce water loss. Soil drainage, soil management, tree density and canopy size determine irrigation requirements and frequencies. Only 50 % of the tree's normal requirements should be given in the middle of the cool season and spring, in order to favor flowering rather than vegetative growth. When fruit set is completed, irrigation should revert to the normal amounts. Higher rates are necessary during flowering, when the fruit is approaching maturity, and if the weather is too dry. In drier climates, and regions with longer dry periods, irrigation at intervals of three to four weeks during the dry months is beneficial. To avoid moisture stress during the winter season, mulching with dry grass or dry leaves is recommended.

On level land, sprinkler irrigation can be used. The most efficient methods of water use are micro-sprinklers or drip irrigation. Mature trees require eight or more drippers around the tree. On steep slopes, micro-irrigation systems are the most appropriate. Flooding is undesirable as it promotes root rot.

High water quality is essential. The water supply should preferably be filtered and should be free of chemicals, heavy metals, and toxic bacteria. Low salinity levels are also essential. Regular water analysis is compulsory for organic certification.

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Water management and irrigation





Important concerns of organic avocado growers

Water retention capacity is increased thanks to high level of organic matter and permanent soil cover- less need for irrigation

Negative effects of irrigation on the soil (salinization, contamination) and to fruit quality should be minimized

Economic use of water must be ensured, use of water saving micro-irrigation

Use good quality irrigation water



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TRANSPARENCY 4.10 (9): PRINCIPLES OF WATER MANAGEMENT

Sharing experiences: Irrigation

Go to a farm and discuss with the participants and the farmer the need for irrigation and its advantages and disadvantages. Discuss possible ways of saving water (i.e. water-saving irrigation systems).

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4.10.7 Other maintenance methods

Pruning

Avocado trees vary in shape ranging from tall, upright trees, to widely spreading forms with many branches. Avocado trees can attain heights of 15 to 18 meters. Training and pruning is not adopted in home gardens. In commercial avocado cultivation however, training and pruning are strongly recommended.

Young avocado trees are normally trained under a modified leader or open center system. When newly established plants reach a height of about 70 cm, the growing tips are pinched off to allow development of more side shoots to form a more circular shaped tree. While the trees are still young, especially during the first few years, the plants are trained into a desirable shape by allowing three well-spaced branches to develop, and eliminating the rest. Once the trees have attained the desired form, pruning is confined to the removal of diseased, infested and interlacing branches and water shoots. After harvesting, the trees should be pruned. The upright branches, water shoots, dead wood, infested branches, and the branches that are not exposed to the sun should be pruned off.

In spreading varieties branches are thinned and shortened. Heavy pruning has been found to promote excessive vegetative growth, reducing yield. A loss of bearing volume in the lower third of the tree should be avoided. Generally organic avocado orchard trees are pruned more frequently and more systematically than conventional orchard trees to ensure good aeration and to prevent the closure of the canopy. Once trees become too large to manage they are rejuvenated by scaffold pruning to 1.5 to 2.0 meters.

Protection from frost

Avocado's tolerance to frost can be improved by using frost-tolerant races, rootstocks and cultivars. Deep planting and subsequent mounding of the soil around the trunk are the best methods for ensuring that the avocado trees will survive severe frost, even if the top is completely killed. When a severe frost is forecast, additional soil is mounded around the trunk for extra protection and watered thoroughly two or three days before the cold weather is expected.

Young trees can be draped (not wrapped) with a blanket during a severe frost. Providing an additional heat source under the tented tree will probably save the leaves as well. Frost-damaged wood should be cut out in the spring. If only limb damage occurs, wait until re-growth commences and cut back to live tissue. If the tree is killed to the ground, it is cut off at ground level. The regenerated tree will be naturally multi-trunked and excess sprouts should be removed, selecting just one stem to reform the tree.

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4.10.8 Harvesting and post-harvest handling

Avocado plants grown from seeds start to bear fruits five to six years after planting. Grafted varieties will produce a few fruits two years after establishment. Yields can vary greatly depending on the climate, the variety and management practices. Mature trees may produce between 5 and 10, or even up to 30 tons of avocados per hectare in very well-managed orchards.

Indicators of maturity

Maturity is reached when the fruit has softened and become palatable without the flesh shriveling once it is picked from the tree. There are several indicators for maturity, including the percentage of fat, dry matter, and the skin color. As the fruit approaches maturity, the percentage of fat in the pulp reaches the standard level that characterizes each cultivar. At the same time the percentage of dry matter of the fruit comes to a constant level. Mature fruits of purple varieties change their color from purple to maroon, whereas fruits of green varieties become greenish-yellow. Fruits are ready for harvest when the color of the coat of the seed within the fruit changes from yellowish white to dark brown. For loose-seeded varieties, an indication of fruit maturity is a hollow sound when the fruit is tapped manually. Some pickers shake the fruits to see whether the seeds are no longer clinging.

Avocado fruits do not ripen on the tree; the fruits remain hard as long as they stay on the trees. Mature fruits ripen six to ten days after harvesting. Some cultivars, especially Guatemalan/Mexican hybrids, can be stored on the tree and can accumulate oil for two to four months after reaching maturity. These can be harvested according to marketing schedules. However, on-tree storage can promote alternate bearing and crop failure in the following year.

Fruits of the West Indian race or West Indian/ Guatemalan hybrid cultivars cannot be stored on the trees for long and will drop, if not picked when mature. For these cultivars maturity is best defined by setting a picking date and a minimum fruit size each year, based on how readily fruit samples ripen to a satisfactory eating condition.

Harvest

Fruits are harvested prior to full maturity in order to prolong their shelf-life during long distance transportation. Harvesting is done manually by a picker climbing the tree or using a ladder and taking a basket or jute bag. Fruits that cannot be reached by hand are harvested with the use of a long bamboo or aluminum pole fitted with a wire hook at one end. After picking, the fruit should be protected from direct sunlight.

Motivation: Harvest and post-harvest management

Visit a packhouse and/or a processing plant. Discuss the requirements of organic avocado processing and traceability.

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Post-harvest handling of avocado


Transport: Fruits ripen during transport (not more than 14 days)

Storage: Unripe avocados can be stored for up to four weeks if the temperature is kept between 5.5 and 8 °C

Cleaning: With roller brushes

Sorting: All diseased, injured and defective fruits are removed

Packing: Labelling must comply with organic standards and regulations



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TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.10 (10): POST-HARVEST HANDLING OF AVOCADO

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Post-harvest handling

Care needs to be taken when picking the fruits. They should be harvested at the appropriate stage of maturity, when they are still hard and have a minimum oil content of 12 %. In moderate climates the fruits are harvested when they have a 9 % oil content.

Hard, mature fruits are harvested and allowed to ripen during transport and distribution. Depending on the stage of maturity and the surrounding temperature the avocado fruits take 4 to 14 days from picking to reach the ripe, edible stage. Up to 14 days transportation time is considered acceptable, though unripe avocados can be stored for up to four weeks at temperatures of between 5.5 and 8°C with a modified storage atmosphere.

In the packhouses, fruits are cleaned with roller brushes to remove field bloom, scale insects and traces of fungicide and give the fruit an attractive luster. Cleaned fruit passes through graders, (where all diseased, injured and defective fruits are removed) and are separated into size categories for packing. General size class standards may not be so relevant for organic avocados (by agreement with the buyer). Packing cartons and labeling must comply with organic standards and regulations.

The storage temperatures required to delay ripening varies depending on the cultivar: West Indian race, 12.5 °C; Guatemalan race, 8 °C; Mexican race, 4 °C.

A relative humidity of 80 to 90 % is recommended. Fruits can be ripened at 25 °C or by exposure to ethylene at 15 to 17 °C for 24 hours and then transported to the market. Both methods are allowed within organic marketing.

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4.10.9 Economic and marketing aspects

Economic and commercial considerations are of utmost importance to avocado producers, including organic ones. Decisions to convert to organic farming or to go for a new crop such as avocado are always related to the desired future development of the farm and improving its financial viability. Smallholders should not rely on avocado production (or any other single crop) alone, but to grow different crops that complement each other well.

Before deciding to plant an avocado orchard, a number of aspects must be evaluated, including production costs and risks, needs for additional labor, potential benefits and synergies along the supply chain.

The economic success of an organic farm can often be dependent upon devising marketing strategies that enable an organic premium for all of the farm's produce. This generally involves building marketing channels for second-class organic avocados (out grades) too (e.g. through direct sales, avocado oil, etc.).

Economic challenges

From a conventional farming perspective the economic challenges of organic farming are likely to include the following:


- Finding additional labor to manage organic management practices (e.g. production and application of compost).
- Substitution of expensive imported inputs by low-cost alternatives (e.g. own production of seeds for cover crops, use of farmyard manures).
- The yields may be lower and the investments higher during conversion.

Compost production represents the most important additional labor input when converting to organic avocado production. On larger farms, with more than 10 hectares, significant investments in compost production and compost application may be necessary. The economics of a conversion to organic farming must be planned carefully. Cooperation with other organic farmers in the area can be essential in lowering costs, through for example, sharing equipment and inputs, applying for common certification or cooperating in other ways.

For an established organic farmer, starting avocado production raises somewhat different questions, such as whether the labor required for the crop will fit well with the schedule for the other crops and management practices.



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Economic aspects and marketing of organic avocado



- Economic and commercial considerations are of high importance
- The decision to convert to organic production is always related to the future development of a farm and to increasing the farmer's income

Find additional labor for intensive organic management practices
Find ways to substitute expensive imported inputs by low-cost alternatives
Markets for all farm products and second class organic avocados
Volumes and continuity (cooperation with other farmers!)
Highly specialized commercial infrastructure
Quality requirements
Supply chain: coordination from production to market

TRAINING MANUAL FOR ORGANIC AGRICULTURE IN THE ARID AND SEMI-ARID TROPICS

TRANSPARENCY 4.10 (11): ASPECTS THAT MUST BE CONSIDERED WHEN OPTING FOR ORGANIC AVOCADO PRODUCTION.

Sharing experiences: Farmers who converted to organic

If possible invite farmers (or visit them on their farms) who converted to organic farming. Discuss the challenges and risks of conversion with them.

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Marketing and trading challenges

Avocado growers face similar marketing challenges to other fruit growers. The main challenge may be getting access to a premium market and being able to supply the volumes needed with the desired continuity. The difficulty of transporting large volumes of this very perishable fruit over large distances limits the distances between the fields and the packing facilities and the packing and storage facilities and the markets. If appropriate facilities for storage and transport are available (e.g. cold chain), the distance to the market may be of diminished importance for avocados.

Only Mexican and Guatemalan cultivars are marketed internationally. The West Indian cultivars are only marketed locally, as they are even more perishable than the other races. Specific market information is essential and can often be difficult to obtain. One route of potential interest into international markets, particularly for smallholders, could be the Fair Trade label.

To ensure volumes and continuity smallholders may need to cooperate with other farmers. This can also help lower the costs for organic certification. It is important to maintain a focus on meeting quality requirements in the post-harvest process. Organizing the marketing of the produce all the way to the consumer has proved to be profitable in many cases. Highly specialized commercial infrastructures are necessary for fresh fruit and avocado oil production. Great improvements have been made in recent years in growing techniques. Market development now depends upon these being matched by improvements in post-harvest technology.



TRANSPARENCY 4.10 (12): SUCCESS FACTORS FOR ORGANIC AVOCADO PRODUCTION

Exercise: Draw a plan for conversion to organic farming

Invite the participants to draw a plan for conversion to organic farming. Ask them to:

- Make propositions on how to develop a feasibility study for the conversion of a conventional farm.
- Compare costs and income and the economic and marketing challenges of organic avocado production with conventional cultivation and with other organic crops.
- Propose ways to substitute expensive imported inputs by low-cost alternatives.
- Make proposals on how to cooperate in avocado marketing by organizing a marketing initiative.

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Recommended reading:

- *In Spanish - J.A. Samson. 1991. Fruticultura tropical. Editorial Limusa.*

Recommended websites:

- *Information in Spanish - www.infoagro.com*
- *General information on the crop - www.hort.purdue.edu/newcrop/morton/avocado_ars.html*