E-TIC

AgriGuide

E-TIC Sahel InfoHubs
Senegal and Mali

Initiative de

icco

Avec le soutien de

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INTRODUCTION

Organic agriculture (OA) is a holistic approach promoting and enhancing agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. OA emphasizes the adoption of best management practices in preference of off-farm inputs, taking into account that regional conditions require locally adapted systems. This strategy is accomplished by adopting best agronomic practices to fulfill any specific function within the farming system.

Practices of organic farming vary worldwide. Some farmers follow the strict production guidelines of a particular regulatory code while others develop their own independent systems and practices. However, all organic farming systems share common goals and practices:

- No use of synthetic fertilizers or pesticides, and genetically modified organisms (GMOs);
- Protection of soils from erosion, nutrient depletion, and structural break down;
- Promotion of biodiversity, favoring the growth of different crops rather than mono-culture;
- No drugs such as antibiotics and hormones, instead, access to outdoor grazing for livestock and poultry.

Within this framework, farmers develop their own organic production systems, according to their agro-ecological conditions such as climate, landraces, social regulations, gender, farmers' food basket preferences, and market opportunity.

OA also provides benefits in resource scarce ecosystems and economies. OA is a tool for sustainable agriculture to efficiently manage natural resources and increase income. Within this concept, Best Practices for Organic Production (BPOP) provides information on best practices on food and cash crops management for small-holder farmers in Senegal and Mali. The BPOP is one of the concrete outcomes of the E-TIC program, an initiative focusing on the use of technology and information in a development context. In Senegal and Mali, E-TIC focuses its efforts on information related to farming, fishing and husbandry. E-TIC was initiated and is coordinated by ICV, and international non-profit organization specialized in the field of communications, ICV recruits, trains and coordinates volunteers for non-profit projects (conference support, cyber-volunteering, language services), both for its own programs and in the context of support provided to its partners. ICV's experience shows that farmers rely on locally available inputs, such as seeds (landraces) and technologies, to improve food production and productivity and to consequently attain food security at household level. The surplus is expected to reach local and national markets, guarantying a certain threshold of quality control, where it possible.

BPOP is an ICV initiative to address the gap in agricultural education. By providing farmers with learning tools aimed at increasing knowledge, we hope to ensure agricultural production and productivity on crops management and income. BPOP seeks to:

- Empower farmers using locally available resources;
- Enhance soil fertility and natural pest control by applying appropriate technologies;

- Establish integrated and diversified organic farming systems to mitigate climate change, and a changing and unpredictable market;
- Provide farmer access to value chains and markets.

To efficiently maintain and use locally available resources and implement sustainable farming practices, farmers are required to:

- Access to knowledge on food and cash crops management and translate into best practices;
- Access to inputs such as seeds and technologies, understanding the mechanisms and processes;
- Access to local and national markets, understanding how the food basket changes over time;
- Access to supporting services, such as technical assistance, research and microcredit;
- Operate into a policy framework favorable to farmers, as producers, buyers and customers.

One of the constraints African farmers face in adopting sustainable agriculture and organic agriculture is the low education level coupled with lack of financial resources. However, based on ICV's experience in Senegal and Mali, farmers, both women and men, always show great interest in new farming methods; especially when they are fully involved in a participatory approach and low-cost technologies contribute to improving their yields, and stabilize and increase their income.

OA is knowledge-intensive. Therefore, education is a key message to developing sustainable agriculture. Farmers need to know how to:

- Analyse, plan and implement sustainable farming;
- Increase resource efficiency and to secure agricultural production and productivity;
- Improve resilience of the production system;
- Improve the value of their food and cash products;
- Become more competitive in the market;
- Be resilient to economic crises and financial turmoil;
- Raise income and improve their food security at household level.

This BPOP version is a dynamic document, tailored to the current and expected reality in Senegal and Mali over the next 3 years.

GLOSSARY OF TERMS

Aflatoxin: Naturally occurring mycotoxins (toxic secondary metabolite), produced by a fungus known as Aspergillus (*Aspergillus flavus* and *Aspergillus parasiticus*). Mycotoxin is reserved for the toxic chemical products produced by fungi that colonize crops. One mold species may produce many different mycotoxins and/or the same mycotoxins as another species. *[FR: Aflatoxine]*

Agro-ecological zone: A land resource mapping unit, defined in terms of climate, land form and soils, and/or land cover, and having a specific range of potentials and constraints for land use. Essential elements in defining an agro-ecological zone are: growing period, temperature regime and soil units. *[FR: Zone agro-écologique]*

Biennial plant: A plant that completes its life cycle in two years. *[FR: Plante bisannuelle]*

Bio-pesticide: Are substances derived from plants or animals which allow to limit and manage pests. They consist of beneficial micro-organisms, and can be bacteria, viruses, fungi and protozoa, beneficial nematodes or other safe, biologically based active ingredient. *[FR: Biopesticide]*

Certified organic: Refers to a product that has been produced in accordance with specific regulations and that has been inspected and approved by an accredited certifying agent. Rules governing organic certification require that an organic production system is managed "to respond to site-specific conditions by integrating cultural, biological and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity" (USDA, 1990). *[FR: Certifié biologique]*

Conventional agriculture: Refers to an industrialized agricultural system characterized by mechanization, extensive monocultures, high and indiscriminate use of chemical fertilizers and pesticides, with an emphasis on maximizing productivity and profitability. *[FR: Agriculture conventionnelle]*

Crop diversity or agro-biodiversity: The variety and variability of plants and other micro-organisms used directly or indirectly for food and agriculture. It comprises the diversity of genetic resources (varieties, landraces, and breeds) and species used for food, fodder, fibre, fuel and pharmaceuticals. It also includes the diversity of non-harvested species that support production (soil micro-organisms, predators, pollinators), and those in the wider environment that support agro-ecosystems and their diversity. *[FR: Diversité des cultures ou agro-biodiversité]*

Crop rotation: A repetitive cultivation of an ordered succession of crops (or crops and fallow) on the same land, helping to prevent pests and diseases and providing additional nutrients. One cycle often takes several years to complete. *[FR: Rotation des cultures]*

Cultivar: Is a plant or group of plants selected for desirable characteristics that can be maintained by propagation. Most cultivars, also called landraces, have arisen in cultivation but a few are special selections from the wild. Popular ornamental garden plants like roses, camellias and daffodils are cultivars produced by careful breeding and selection for flower color and form. The world's agricultural food crops are almost exclusively cultivars that have been selected for characteristics like improved yield, flavor, and resistance to disease. *[FR: Cultivar]*

Food security: Exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life. The concept is built upon three pillars, such as food availability, food access, and food utilization. *[FR: Sécurité alimentaire]*

Genetically Modified Organisms: An organism whose genetic characteristics have been altered by the insertion of a modified gene or a gene from another organism using the techniques of genetic engineering. *[FR: Organismes génétiquement modifiés]*

Hybrid variety: Organism that is an offspring of two parents that differ in one or more inheritable characteristics. In agriculture, hybrids are bred to combine the favorable characteristics of the parents. *[FR: Variété hybride]*

Improved fallowed: Farming practice adopted to increase soil fertility, and to control weeds, diseases and pests. It consists of a period when a piece of land is set aside and is ploughed to improve the micro-biological, chemical and physical condition of soil. *[FR: Jachère améliorée]*

Inter-cropping: Growing of two or more crops on the same field per year, either simultaneously or, in the case of relay intercropping, with an overlapping period. Simultaneous systems refer to the cultivation of two or more crops either intermingled or with distinct row or strip arrangement. *[FR: Culture intercalaire]*

Inorganic compounds: Are chemicals used for pest control, such as application of sulphur, lead arsenate, copper and lime mixtures, borax and chlorates, and mercury compounds. Inorganic pesticides are based on chemical elements that do not break down, and therefore many of them have very severe environmental and toxicological effects in their use. *[FR: Composé inorganique]*

Organic agriculture: Refers to a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved (IFOAM, 2008). *[FR: Agriculture biologique]*

Organic farming standards: Established national standards governing the methods used to grow, process, and market organic agricultural products. Standards prohibit the use of genetically modified ingredients, irradiation to decontaminate products, and sewage sludge as fertilizers for any food sold as an organic product. *[FR: Normes de l'agriculture biologique]*

Push-pull method: A technique involving intercropping silverleaf desmodium, a fodder legume, with maize, napier and Sudan grass to provide both immediate and long term benefits. Aromas produced by the desmodium repel (push) pests like the maize stem borer while scents produced by the grasses attract (pull) the stem borer moths and encourage them to lay eggs in the grass instead of in the maize. Napier grass produces a gummy substance that traps the stem borer larvae reducing the population. Desmodium roots produce chemicals that stimulate germination of Striga seeds, but preventing them from attaching successfully to maize roots. The Striga dies and the number of seeds in the soil is also reduced. Desmodium is ground cover and a nitrogen-fixing legume. *[FR: Méthode push-pull ("pousser-tirer")]*

Pesticide: A pesticide is a substance intended to prevent, destroy, repel or control any animal pest or disease caused by micro-organisms, as well as unwanted weeds. Pesticides can affect harmful pest animals and micro-organisms through direct contact, feeding or other kinds of effective exposure during stages of growth. *[FR: Pesticide]*

Recycling (seeds): Practice to select seeds of particular plants for the next farming season. *[FR: Recyclage (semence)]*

Rhizobia and mycorrhiza: Rhizobia are bacteria that form symbiotic associations with legumes. The bacteria form nodules on the roots of the host plant in which they fix nitrogen. Rhizobia supply the plant with nitrogen and in turn the plant supplies the bacteria with essential minerals and sugars. Mycorrhizas are fungi that form symbiotic associations with plant roots. *[FR: Rhyzobia et mycorhize]*

Sap-sucking insects: Insects that insert their beaks into stems, leaves, or roots to suck plant juices. Insects can also be a virus carrier. Above ground examples are: aphids, chinch bugs, and scale. They can be controlled with predatory insects. A below ground example are nematodes which requires fumigation for immediate termination. *[FR: Insectes suceurs de sève]*

Synthetic organic chemicals: Are chemically derived from mineral oil products. After the introduction of insecticides and herbicides in the 1940s, their use spread rapidly throughout the world and continued to increase during the 1950s and 1960s. *[FR: Substance organique de synthèse]*

Tillage: Manipulation of the soil with tools to obtain optimum environmental conditions for seed germination and seeding establishment. *[FR: Labour]*

Threshing: Separation of grain or seeds from the husks and straw. *[FR: Battage]*

Weevils: Any beetle from the *Curculionoidea superfamily*, characterized by the head of the adult, more or less prolonged by a beak, generally curved, and larvae that is legless and curved. Adults or larvae of many species are serious enemies for our crops. Weevils are less than 6mm (0.24in) long. *[FR: Coléoptères]*

Wind winnowing: Method for separating grain from chaff. It is also used to remove weevils or other pests from stored grain. Winnowing is the complementary operation of the threshing. *[FR: Vannage au vent]*

ACRONYMS

AB	Agriculture biologique
ACCRM	Association des collectivités, cercles et régions du Mali
AMM	Association des Municipalités du Mali
ANICT	Agence Nationale d'Investissement des Collectives Territoriales
BPOP	Best Practices for Organic Production
CNCAS	Crédit Agricole du Sénégal
CNSL	Baume de cajou (Cashew Nut Shell Liquid)
CO_2	Dioxyde de carbone
CO2	Carbon dioxide
CPS/MDR	Cellule de Planification et de Statistique du Ministère du Développement Rural
CRESP	Centre de Ressources pour l'Emergence Sociale Participative
DAP	Phosphate diammonique $(NH_4)_2HPO_4$
DAP	Diammonium phosphate (NH4)2HPO4
DDT	**D**ichloro**d**iphényl**t**richloroéthane - insecticide organochloré
DNAMR	Direction Nationale de l'Appui au Monde Rural
DNCC	Direction Nationale du Commerce et de la Concurrence
DNCT	Direction Nationale des Collectivités Territoriales (du Mali)
DNSI	Direction Nationale de la Statistique et de l'Informatique
DRCC	Direction Régionale de l'Appui au Monde Rural
EAC	Enquête Agricole de Conjoncture
EREV	Earth Rights Eco-Village Institute
FAO	Food and Agricultural Organization
FMDR	Fonds Mutuel de Développement Rural
GIE	Groupement d'Intérêt Economique
GMOs	Genetically Modified Organisms
GMP	Groupement Mutualiste Pastoral
Ha	Hectare (10,000 square meters)
HCCT	Haut Conseil des Collectivités Territoriales
KfW	Entwicklungsbank
MFR	Microfinance en Milieu Rural
MMPB	Meilleures méthodes de production biologique
NPK	Azote – Phosphore - Potassium
NPK	Nitrogen – Phosphorus - Potassium
OA	Organic agriculture
OAV	Organisation Autonome de la Vallée
OGM	Organismes génétiquement modifiés
OHVN	Office de la Haute Vallée du Niger
OMA	Observatoire du Marché Agricole (Mali)
OMBEVI	Office Malien du Bétail et de la Viande (Mali)
OPAM	Office des Produits Agricoles du Mali
ORS	Office Riz Ségou
ORTM	Office National de Radiodiffusion et de Télévision du Mali

PAM	Programme Alimentaire Mondial
pH	Unité de mesure permettant d'évaluer l'acidité ou la basicité d'une solution aqueuse.
pH	Measure of the acidity or basicity of an aqueous solution
PPIV	Petits Périmètres Irrigués Villageois
PRMC	Programme de Restructuration du Marché Céréalier (Mali)
SAED	Société Nationale d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal, created in 1967
SAP	Projet Système d'Alerte Précoce
SCN	Service Civic National du Sénégal
SDRS	Société de Développement Rizicole du Sénégal (no longer exists)
Senelec	Société National d'Electricité du Sénégal
SRI	System of Rice Intensification (Système de riziculture intensive)
UREA	Nitrogenous fertilizer

BEST PRACTICES ORGANIC PRODUCTION

Working steps

To achieve the above, this initiative includes the following working steps, as:

- **Collection of information.** Since 2008, ICVolunteers (ICV) and its partners in Senegal and Mali have collected existing knowledge on farming practices through field a technology-enhanced decentralized field study, questionnaires, surveys and other lessons. Specialized in the field of communications, ICV recruits, trains and coordinates volunteers for non-profit projects (conference support, cyber-volunteering, language services), both for its own programs and in the context of support provided to its partners.

  This wide collection lays the foundation for the development of new informative materials. Run by ICV, the E-TIC program aims to provide tools and training components so that small farmers, herders and fishermen are better able to reach local and national market and sell their products. Through the creation of a portal and a series of training courses for field connectors (youth, women, community radio journalists), the E-TIC project aims to provide knowledge relevant for efficient and effective farm management. Relevant collected material is available online at www.e-tic.net.

- **Production of the AgriGuide of Best Practices on Organic Farming.** In 2011 and 2012, ICV and its partners in Senegal and Mali developed this interim manual.

- **Validation.** From 2012 onwards, the drafted BPOP will be validated by stakeholders in Senegal and Mali through dissemination trials and improved stepwise in the months to come. The process will be based on a defined procedure and resulting feedback.

  The validation refers to the quality of collected information, illustrations, recommendations, suitable local languages and layout. This participatory development process contributes to highly practice-oriented materials in terms of both content and methodology.

  The ultimate goal is to support farmers in Senegal and Mali in promoting and implementing organic and sustainable farming practices.

- **Wider dissemination.** Following the development and validation of the BPOP materials for Senegal and Mali, ICV and its partners intend to facilitate dissemination and sharing of experiences. Additionally, the market potential for organic products from Senegal and Mali will be explored and gaps for developing the organic markets analyzed.

Recommendations

Converting from conventional to organic production does not simply mean replacing chemical fertilizers and pesticides with organic elements. Food and cash crops must be grown in a balanced farming system including other crops. Instead of troubleshooting, organic farmers should try to prevent problems and avoid substitutes to conventional inputs as far as possible. It requires an in depth understanding of nutrient and pest management and the ability to continuously observe and learn.

For farmers to get satisfactory yields and income in organic farming it is necessary to adopt a number of integrated measures in a system approach, ensuring that interaction among soil, plants, environment and people is well balanced. The following factors need to be applied simultaneously:

- *Site selection including climatic and soil conditions.* Suitable measures to improve and maintain soil fertility and avoiding soil erosion. Cover crops or lay out mulches in perennial crops provide protection to the soil. The ideal soil is a well-drained, light, loose, finely grained, sandy loam with plenty of lime and sufficient organic matter. It is also possible to achieve good yields on soils which neither harden nor crust over, nor create water-logging;
- *Landraces selection.* Selecting local varieties suitable to agro-ecological conditions. Varieties are selected according to specific factors such as climatic conditions, yield potential, resistance to infections or duration of growing period to maturity. If farmers plant the wrong cultivar for a given area, the crops may not have adequate soil moisture for proper growth, especially if the rainy period is much shorter than the growing period of the variety;
- *Planting and other agricultural practices.* Use types and amounts of manures, such as green manure or cow dung, at the right time. Start recycling valuable farm by-products. Establish on-farm compost production based on harvest residues and manure, if available, and mix the compost with the topsoil. This will bring stable organic matter into the soil and improve its structure and its capacity to feed the plants and store water. Green manures can provide plant material to feed soil organisms and build up soil fertility. Establishment of crop rotation and crop diversity for fostering natural balance. Diversify the farming system. Select appropriate annual crops for the area and rotate them in a planned sequence. Include legume crops such as beans or leguminous feed crops in the rotation to provide nitrogen to the subsequent crops. Plant hedges and flower strips to encourage natural enemies and to control pests. Crop diversity reduces a farmer's risk, making farmers less vulnerable to crop failure and prices fluctuation. Further, it prevents shortage of labor in peak seasons, as labor requirements are more evenly distributed throughout the year.
- *Harvesting.* Timely harvest to avoid storage losses of food and cash crops;
- *Post-harvesting.* Monitoring of crops and protection against pests according to the concept of economic threshold levels;
- *Technical assistance.* Capacity building for farmers, testing for continuous improvement;
- *Markets including road networking.* Market and commercial infrastructures availability and development;

- *Food Security.* Policy development at country and regional levels. Sufficient documentation for inspection and certification, where present and required.

Priority organic recommendations for conversion include:
- Improving the soil fertility through the application of quality compost. Compost is a highly valuable fertilizer in organic farming. Instead of burning the crop residues after harvest, collect them for compost production, or work them into the soil. Animal manures and plant materials should be regularly collected for compost making. Additional measures to control soil erosion such as digging trenches and planting trees along the hillside, and covering the soil with living or dead plant material should be considered;
- Implement planned crop rotation and intercropping systems. A combination of annual and perennial crops including leguminous green manure cover crops is needed. Combine selected or improved crop varieties;
- Growing nitrogen-fixing legumes between annual crops to feed soil and crops;
- Integration of livestock into the farming system. Planting rows of nitrogen-fixing trees between annual crops and fodder improves growing conditions for crops and encourages growth, while providing additional feed for the ruminant animals. Better housing is also needed to facilitate collection of animal manure for field use.

General aspects of organic vegetable production

Organic vegetable production requires flexibility and the application of new technologies from the producers. In addition to the general challenges related to vegetable production, farmers in tropical and subtropical regions are confronted with the following production constrains:
- Poor soils with low content of organic matter;
- Climate stress (floods, cyclones, drought);
- Lack of locally adapted production technologies and slow technology transfer;
- Lack of locally adapted varieties and good quality of seeds;
- Fast development of pest and disease infestations;
- High post harvest losses;
- Lack of adequate logistic and marketing facilities.

Organic agriculture is an alternative for vegetable growers in Sub-Saharan Africa and a valid contribution to food security at household level.

FARMERS'S BOX FOR LEARNING AND SHARING

The following boxes are recurrent topics to be discussed among farmers to grasp their knowledge and understanding of farming issues.

General
- Have farmers experienced any decline in food and cash crops yields over the years?
- What do farmers think the main causes of declining yields are?
- What do farmers think needs to be done to improve food and cash crops yields?

Site selection, crop rotation, pest-disease management, harvest and post-harvest storage
- Understand the relevance of site selection, landraces and preparation of planting material;
- What ecological, economic and social factors influence the cultivation of food and cash crops in the area (soil characteristics, household preferences, market demand, national and international economic policies, infrastructure, marketing structures etc.)?
- What relevance do growers attribute to intercropping and crop rotation for soil fertility?
- Do growers see any advantages/inconveniences in intercropping/rotating crops?
- Seed selection and multiplication;
- Recognize potential for crop rotation improvement; do growers see any potential improvements to production?
- Learn locally adapted combinations for intercropping;
- Understand the relevance of soil fertility management for improved food and cash crops cultivation and options for its implementation in the local context;
- Understand the relevance of and the approaches to pest and disease management;
- Managing Striga weed, weevils in stored grains;
- Identifying strategies to reduce harvest and post-harvest losses;
- Organic farming and certification.

Leguminous
- How much attention growers pay 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?
- Do growers perform experiments in alley cropping leguminous trees? Under what conditions is it advantageous to combine trees with annual crops?

Millet
- Millet is the cereal with the highest tolerance to heat and drought;
- Application of cultural practices in millet results in higher and more secure yields.

Rice

- Recognize diversification strategies in rice production;
- Learn good husbandry practices in rice production, especially on System of Rice Intensification (SRI);
- Develop awareness on how to improve incomes and organic certification of rice production;
- Different cropping patterns may increase total yield and improve soil fertility.

Sorghum

- Sorghum is suited to hot and dry conditions and can contribute to sustainable agriculture;
- Where sorghum is grown with low inputs, considerable increases in yield is possible with improved management practices (timing, rotation, soil fertility, cultivar selection, cropping system);
- The demand for sorghum is expected to increase. To improve the market potential of sorghum and overcome constraints, concerted action along the whole supply chain is necessary;
- What comes to growers and buyers mind when thinking of sorghum?
- What are the good reasons for growing sorghum?
- What constrains sorghum cultivation?
- Is more or less sorghum being grown in the region? Why?
- What do consumers think about sorghum? Social aspects involved in sorghum consumption.

IDENTIFIED FOOD AND CASH CROPS

- Cereals: maize, millet, rice, sorghum, wheat, fonio
- Vegetables: cabbage, carrots, onions, salad/lettuce, tomatoes
- Roots and Tubers: cassava, potato/sweet potato
- Fruits: mango, water melon, banana
- Pulses: cowpea bean, groundnut
- Nuts: cashew
- Fibers: cotton

Cereals

Maize

Maize (*Zea mays L.*) is a major staple food in sub-Saharan Africa. It can be used as food, feed for animals and as a source of industrial raw material. In sub-Saharan Africa, maize is grown mostly by small-scale farmers under rainfed conditions mainly for human consumption. It is consumed as green maize fresh on the cob, or is baked, boiled or roasted.

Low yields in sub-Saharan Africa can be attributed to a variety of factors:

- Poor soil fertility as one of the leading challenges for small-scale farmers. The increasing population density resulted in land exploit intensification and forced farmers to shorten or abandon the previously well followed fallow periods. As a result, nutrients and organic matter in the soil have become heavily depleted and this has resulted in reduced soil fertility and productivity.
- The use of low quality seeds. Poor seed selection and limited use of new improved commercial varieties are among the reasons farmers are not able to cope with the productivity demand.
- Unsuitable crop husbandry practices such as late planting, poor weed management, pest and disease attacks (stem borers) and the Striga weed are important constraints that lower maize yields. High post-harvest losses especially due to improper drying and storage, lead to molding and attack by the maize weevil during storage.
- Soil moisture stress is a continuous problem for many farmers who continue cultivating maize under rainfed conditions. The erratic nature of rainfall, including distribution leads maize to severe soil moisture stress; reducing yields significantly.

Selection of suitable varieties

The choice of appropriate maize varieties for a given location is important, as it makes a significant contribution to yield improvement. Furthermore, farmers must also consider the differences between modern varieties and traditional varieties. Wrong variety selection can lead to a poor harvest or total crop failure. Therefore, it is important to carefully select varieties that match with local growing conditions; including climatic conditions, nutrient level of the farm as well as cooking habits and dietary requirements of the consumers.

Traditional varieties as landraces
Small-holder farmers in sub-Saharan Africa grow traditional maize varieties. Seeds are collected from the farmer's previous crop (recycling). These varieties have been developed based on specific farmers' criteria and have become, over the years, adapted to local growing conditions (landraces). Besides being well-adapted to local conditions, such varieties are adapted to low nutrient levels and farmer cooking habits. Seed may also withstand local pest and disease pressures well. Traditional varieties are locally available and farmers can reproduce their own seeds for replanting. Nevertheless, yields of traditional varieties are generally low to moderate due to the poor methods of selecting seeds and to poor management.

Improved varieties
Besides traditional varieties, there are several improved open-pollinated and hybrid varieties of maize on the market in most places. They differ from one another with regard to characteristics such as yield potential, growth period and their adaptability to specific growing conditions like drought, pests or diseases. Hybrids are higher yielding than open-pollinated varieties, if grown under suitable conditions. However, hybrid varieties are expensive because new seeds need to be bought for every planting season. On the other hand, improved open-pollinated varieties are often higher-yielding than traditional varieties and farmers can produce their own seed of open-pollinated maize varieties, reducing costs for purchasing improved commercial varieties.

Recommendations of on-farm multiplication of maize seeds

Farmers can produce and multiply on-farm seeds from open-pollinated maize varieties. The following recommendations are meant to guide farmers in seed production:

- Select a suitable open-pollinated variety for the agro-ecological zone. This can be sourced from the existing preferred maize crop on the farm, neighbors, the national maize program or a local seed company.
- Choose the best plot and weed it. Maintain a distance of at least 300mt from any nearby maize crop of a different variety. This would avoid cross-pollination between varieties and maintain the characteristics of the preferred variety. Alternatively, farmers can sow the preferred variety one month earlier or later than neighboring maize fields.
- Plant maize seed crop early and carefully. Examine and manage the maize plants as they grow to ensure a healthy growth and development.
- Select healthy looking maize plants, particularly those not infected with diseases or attacked by pests. The selected plants should have cobs of good size with well filled seeds. Label the cobs in the field and let them mature properly.
- Harvest the cobs when the plants start to dry, but making sure cobs do not get mixed with cobs from other maize varieties. Allowing the cobs to over-dry will predispose them to infestation by weevils on the field.
- Dry the cobs further with their sheath cover, on a clean and dry surface in the sun.
- Remove the sheath cover and shell the dried cobs, being careful not to damage the seeds by taking the best seeds, which come from the middle of the cob. After shelling, dry the seeds further; well dried seeds crack when bitten. Clean the seed by removing all dirt and foreign matter and small and damaged seeds. Pack the seeds in a sack to stand on pallets in a clean, dry and well-ventilated store. Maintain a distance of about 0.5mt away from the wall of the room.

Improved fallowing

Traditionally, farmers would restore soil fertility after a period of cultivation by leaving part of their land uncultivated for up to 5 years for fertility to restore, while new and more fertile land is cultivated for food production. However, the increasing population density has drastically reduced the amount of land available for farming, forcing farmers to shorten the fallow period or even to abandon the fallowing practice entirely. A natural short fallowing of overworked land will result in little or no improvement in soil fertility. It is therefore important to improve fallowing systems.

Experience has shown that the inclusion of improved short duration fallows of 1 to 3 years in rotations is important for significant improvement in soil fertility. Multi-purpose trees can be used to improve fallows. For example, improved fallows using Sesbania (*Sesbania sesban*) have been found to be a good way of adding significant amounts of nitrogen and organic matter to soil. Green manure cover crops can also be used. Soil fertility is improved and the productivity of following maize enhanced. It is recommended to establish improved fallows by planting different fallow species, as they make plant nutrients available for a longer period.

Weed management

Successful weed management in maize is achieved by using a combination of measures including:

- Prevention of introduction and spread of weed seeds, by using clean seeds and equipment.
- Improved fallowing by using a dense covering legume that covers the soil well, such as lablab or mucuna, will suppress weed growth thus reducing its multiplication. This should be alternated with a cover crop within the maize crop to completely suppress the weed.
- Manual weeding to remove the weeds is also necessary. Maize is greatly affected by weeds during the first 10 weeks of growth.

Management of Striga weed

Two species of Striga are found in sub-Saharan Africa: *Striga hermonhica* in West and Central Africa and *Striga asiatica* in Eastern and Southern Africa.

Striga is a parasitic weed that only grows by attaching itself to roots of a host plant like maize. Striga sucks nutrients from maize plants, leading them to be smaller and weaker. The attack brings to yield losses and complete crop failure. Once Striga becomes well established on the ground it is difficult to control it, partly due to its high reproductive capacity. Striga also produces thousands of seeds, which can survive in the soil for several seasons and germinate only when a cereal crop is planted. Successful Striga management is achieved by using a combination of measures, also used for weed management, as follows:

- Prevention of Striga introduction and spread of weed seeds. Use clean seeds and equipment as well as Striga resistant or tolerant maize varieties, in case they are available;
- Legumes that are grown in rotation or intercropping with maize stimulate the germination of Striga, but inhibit post-germination growth of the weed because it cannot grow on the roots of legume crops. It is recommended to plant green manure

and fodder crops such as desmodium, sesbania, crotalaria or fodder grasses like Napier grass for at least two seasons and to plant maize or cereals only once every two to three seasons until all Striga is eliminated.
- Intercropping maize with desmodium or other legumes such as mucuna between rows of maize has been shown to improve soil fertility and significantly suppress Striga weeds.
- Farmers can also regularly walk through their fields and uproot any growing Striga plants. However, this should be done early enough before the Striga produces seeds and before it greatly affects the maize.

Storage pest and disease management

The most common storage pests of maize are the Angoumois grain moth (*Sitotroga cerealella*), the larger grain borer (*Prostephanus truncatus*), grain weevils (*Sitophilus spp.*) and rodents (mostly mice). They can be managed by a combination of measures:
- Early harvest of the maize to prevent or reduce infestation of the maize cobs in the field.
- Growing suitable varieties where the husk covers all of the grains.
- Proper drying of the maize grain is an important procedure in storage pest prevention. For maize to be stored safely, it must be dried quickly after harvest.
- Minimize re-infestation of the new harvest by cleaning out all residual pockets of infestation at the end of the storage season.
- Removing all dark corners, sealing off all potential entry points and clearing the surrounding spots where rodents are likely to hide.
- Periodic inspection and removal of all infested maize cobs or grain.
- To repel and kill maize weevils, use plant extracts, for example, crushed ripe, dry chilli pepper pods mixed with wood ashes, and with dried maize ready for storage.
- Use of natural enemies, for example, the predatory beetle *Teretrius nigrensis* has been used in many African countries in an attempt to control the larger grain borer.

Bt-maize is genetically engineered to resist stem borer. It has been created by adding the genes from the soil bacterium Bacillus thuringiensis to the maize seeds. Bt-maize produces a toxin that kills the African white stem borer (*Maliarpha separatella (Ragonot*). Apart from being expensive, farmers are not allowed to save or exchange Bt-maize seed. Stem borers quickly develop resistance to Bt-maize and pollen could transmit the Bt-gene to local maize varieties.

Reducing postharvest losses

Timely harvesting

Maize is harvested by hand on the cob in small-holder maize farming. Maize that is to be eaten green is ready for harvest when the grain hardens or when the silky flowering at the top of the cob turns black. At this full maturity stage the crop has a moisture content of about 30%. However, maize to be dried is left to partly dry in the field until all the leaves of the plants have turned brown. This bears the considerable risk of the grains spoiling by feeding birds. Many small-scale farmers wait too long to start harvesting because they lack suitable drying facilities.

Delayed harvesting can lead to rotting of the cobs, attacks by rodents, birds and weevils. It also allows fungal pathogens such as aflatoxins to spread, especially if the drying crop is rained on while still in the field. At harvest, the husks are removed from the cobs.

Drying

Quickly after harvest, the cobs should be dried under the sun before being shelled. If the grains are not well-dried, they will attract insect pests and mildew. To test whether the grains are dry enough, shake a handful of grains and half a handful of salt in a dry soda bottle for 2 or 3 minutes. If after the grains are allowed to settle, the salt sticks on the walls of the bottle, this means the grains still contain moisture. Grains should be dried again and tested repeatedly until no salt sticks to the bottle before being stored.

Drying should not be carried out on the bare ground, but on a cemented floor, on mats or tarpaulins on a raised structure like cribs or specially constructed drying sheds. This is to avoid the grains picking up moisture, dirt and insects. In case of open air drying, the grain should be protected from rain, night dew, domestic animals and birds.

Storage

After drying, maize should be stored in a clean and well-ventilated storage area, separating old from new grain stocks. There are different ways of storing maize.

- Maize is stored by hanging cobs, before shelling, on kitchen fire rafters to prevent insect damage. It is recommended to shell cobs immediately after drying to reduce weevil damage;
- Shelling of the grains should be done carefully, so that the grains do not get damaged. After shelling, the grains should be cleaned by removing any dirt and foreign matter, small and damaged seeds;
- Cleaned shelled grains are stored in small household storage metallic silos or packed in sacks (bags with perforations) and stored well on pallets in clean and well ventilated stores. Under such conditions, grain can be stored up to two years without significant reduction in terms of quantity and quality.

Farmers who do not have adequate storage capacity are advised to sell off the grain immediately to avoid incurring losses. Well-dried and shelled grain is ready for milling into flour and further processing into other products.

Marketing and organic certification

The majority of maize produced in Africa is consumed locally. Maize has also become a cash crop with local industries such as for the livestock sector and breweries, due to economic growth, urbanization and rising incomes. There are growing domestic and continental market opportunities for maize throughout sub-Saharan Africa. Organic farmers can exploit this potential to position organic maize at the national and continental levels.

However, the market for certified organic maize is still very small, or does not exist. Many small-scale farmers are already using some organic practices such as intercropping, they can easily learn and make use of full organic practices to establish sustainable and productive production systems for their families and take advantage of the local market opportunities without organic certification.

Millet

Millet can be grown as sole crop, mixed crop or intercrop. In traditional cropping systems, millet is commonly grown with other food crops. The reason lies in the numerous advantages associated with intercropping and mixed cropping, for instance, higher and more reliable yields, better use of resources, and cultural advantages such as better weed control and soil protection.

Most farmers pay little attention to the application of improved cultural practices in millet production, such as green manuring, crop rotation or animal manure. These practices are important to prevent further soil depletion, to improve soil fertility and to increase 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.

Plant description

Pearl or Candle millet (*Pennisetum glaucum* (*L.*) *R. Br.*) and Finger millet (*Eleusine coracana* (*L.*) (*Gaertn*) have a similar growth habit. Millet also includes Fonio (*Digitaria sp.*). Millet is a warm season crop, planted during the early rain season when the soil is still warm. Millet performs well on fertile, well drained soils. However, millet also performs well on sandy soils under acidic soil conditions, and when available soil moisture and fertility are low. This adaptation reflects the origin of pearl and finger millet in the Sahel region of Africa, where growing conditions are difficult. Millet appears to have fast root development, sending extensive roots both laterally and downward into the soil profile to take advantage of available moisture and nutrients. Millet tolerates low soil pH.

Organic production

Pearl millet can be grown effectively with organic methods for both human consumption and organic livestock feed. Using cover crops or manure to boost fertility, employing cultural weed control, and incorporating crop rotation can allow successful organic production.

Pest management

Downy mildew, smut, rust and ergot are common diseases where millet is grown. Stem borer, earworm and millet midge are the most problematic pests, but the crop may also be attacked by grasshoppers, locusts, white grubs and various butterflies.

Downy mildew (*Sclerospora graminicola*) is the most devastating disease. The disease is transmitted through soil, crop residues, contaminated seeds and tools. As a result of infection, inflorescences and glumes become twisted. 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 which are resistant to downy mildew.

Smut (*Tolyposporium penicillariae*) attacks millet plants during the flowering period after rainfall with air-borne spores. Infections are 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 millet cultivation. Preventive measures against bird attacks 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 such as nets is essential.

Coniesta igenfusalis is the stem-borer that most affects pearl millet. However, several natural enemies attack this pest at different stages of its cycle. Proper soil preparation and destruction of crop residues, or covering them with soil can help control stem-borers. Crop rotation breaks the pest's life cycle. Mixed cropping of millet with other species also confuses the pest and promotes natural enemies. In the control of cereal stem-borers the “push-pull method” can be applied. Neem application has been also found to be useful..

Millet midge (*Geiromiya penniseti*) is abundant during the rainy season. 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.

Harvest and post-harvest handling

Pearl millet varieties produce seeds ready for harvest before the plant is dried down. Although the seeds are not likely to shatter, it is desirable to harvest soon after seed maturity, as plant dry down allows avoiding unnecessary grain loss to birds. Millet can be stored at maximum moisture of 12-13%. Since the seed size is smaller than sorghum and corn, it is more difficult to force air through it in a grain drier.

Marketing and organic certification

Because pesticides are not applied, millet could be grown organically for the organic livestock feed market. Some pearl millet cultivars have also been developed for their grain and show potential as poultry and livestock feed.

Rice

Rice *(Oryza sativa)* production systems in Africa can be classified into rainfed upland, rainfed lowland (swamp), irrigated lowland and flood-prone (deep water) systems, based on the water availability for growth and the topography where rice is grown.

Challenges of rice production in Senegal and Mali

Due to prevailing challenges such as low soil fertility and low soil moisture, it has been difficult to achieve the full potential of the existing rice production systems in Africa. Challenges include:

- Limited access to good quality seeds;
- Decreasing soil fertility;
- Land shortage;
- Soil erosion;
- Water;
- Weeds;
- Pest and disease, including birds;
- High post-harvest losses;
- Low returns from rice production.

Selection of suitable varieties

- Decide whether to grow upland or lowland rice, determined by the type of land available (upland or lowland with available water).
- Consider locally adapted traditional or improved varieties which have been tested under local conditions by other farmers or research stations. It should be clear if the variety's growing period, weed tolerance, moisture and nutrient requirements are adaptable to local climatic stresses. It is also important to consider varieties that are in high demand on the market and varieties that are preferred by locals because of local cuisine preferences.
- Select varieties whose seeds can be selected, multiplied and re-used for the next crop. If brand new seeds are brought from another area, they should be tried and tested under local conditions before scaling up. When possible, select at least four varieties to create the genetic diversity necessary to satisfy different needs.

Seed selection

- Select healthy and superior plants (true-to-type) of that variety for seed to make sure that only the best seeds which are well adapted under local conditions are used.
- Before the final harvest, select that part of the farm where the plants are uniform, healthy, and disease-free with productive panicles.
- At full maturity, harvest the panicles and allow them to dry under a cool environment until the moisture content of the grain reaches about 14 to 15%. Thresh manually as the seeds could be contaminated with other varieties.
- From the harvested seeds, recycle 30 to 40kg to plant one hectare. The dry season harvest is a better source of good seeds because it has reached full maturity and, therefore, the lifespan of seeds is longer than seeds harvested during the wet season.
- Store the seeds in a cool, dry place in an airtight container like a pot or hang in the house to deter rodents and other pests. Sometimes, pest repelling materials may be added to keep away storage pests. For example, by mixing dried and crushed neem, castor leaves or any locally available herbal repellents.

Water management

Water supply is needed for optimum rice production in both upland and lowland systems. Water management depends on rice variety, rainfall patterns, soil properties, management practices and availability of water sources.

The water requirement in rainfed upland systems is met by making the most use of the available rainwater. Therefore, rice planting should be based on the cropping calendar, so that the stages of growth that need water most (from panicle initiation to heading) receive maximum rainfall. This will be complemented with reduced tillage practices, mulching and proper water harvesting channels on sloping lands. It is important to establish the time to sow in each season based on the long-term (15 years) daily rainfall pattern or actual trials on optimum sowing date.

Ideally, the water level in irrigated flooded rice needs to be maintained at about 2cm during most of the growing season, except during the ripening stage. However, it is possible only if access to water is assured whenever it is needed. In many situations this is not the case as the availability depends on rainfall patterns and irrigation is not accessible to many farmers.

Where resources permit, farmers should tap and conserve the available water more appropriately by creating bunds and channels to trap moving water from uphill into man-made ponds or dams. Such collected water can later be redistributed into the fields in seasons of low water availability.

Le Système de riziculture intensive (SRI)

Le SRI est une méthode pour augmenter la productivité du riz irrigué en modifiant la gestion des plantes, du sol, de l'eau et des nutriments. Le SRI, originaire de Madagascar, permet des plantes et des sols plus sains, des racines plus fortes et apporte une plus grande diversité des microorganismes présents dans le sol. Avec le SRI :

- Le sol n'a besoin d'être maintenu humide que pendant la période de croissance lorsque les talles et les feuilles sortent, avant la floraison et la production de graines. Pendant la phase de reproduction, une fine couche d'eau doit recouvrir le riz (1-2cm) à la surface du sol. Le champ ne doit pas recevoir plus d'eau pendant les 25 jours précédant la récolte.
- Transplanter des semis, généralement vieux de 8 à 12 jours, avec seulement deux petites feuilles. Cette opération doit être faite rapidement et avec soin pour ne pas perturber les racines, en mettant un semis par trou au lieu de trois pour réduire la compétition entre les racines. Espacer les plants pour favoriser une meilleure croissance des racines et de la canopée suivant le quadrillage d'une grille de 25 par 25cm ou d'une grille plus grande lorsque le sol est de bonne qualité.
- Le premier désherbage doit être effectué 10 jours après la transplantation et un second désherbage doit avoir lieu dans les deux semaines suivantes. Cela permettra de déterrer les herbes et de rajouter de l'oxygène au sol, ce qui est nécessaire pour les racines. Procéder à un ou deux désherbages complémentaires (3 ou 4 désherbages au total) apportera encore plus d'oxygène au sol. Un sarcloir mécanique très basique, appelé houe rotative, actionné à la main, a été conçu pour permettre aux agriculteurs d'éliminer les mauvaises herbes facilement, rapidement et plus tôt. Le travail fastidieux qui consiste à arracher les herbes une par une à la main une fois qu'elles ont poussé est considérablement allégé.
- Ajouter composte ou engrais lorsque c'est possible pour apporter des nutriments au champ.

Dans plus de 40 pays, le SRI a permis d'augmenter les rendements (de 50 à 100% et plus) et de réduire les semences nécessaires (jusqu'à 90%) ainsi que la consommation d'eau (50% et plus). Ceux qui utilisent le SRI ont également constaté une diminution des insectes nuisibles, des maladies, de l'égrenage prématuré, des grains échaudés et des verses. On constate d'autres avantages pour l'environnement, comme la réduction de l'utilisation des produits chimiques agricoles, de la consommation d'eau et des émissions de méthane qui contribuent au réchauffement climatique.

The System of Rice Intensification (SRI)

SRI is a methodology for increasing the productivity of irrigated rice by changing the management of plants, soil, water and nutrients. SRI, which originated in Madagascar, leads to healthier soil and plants supported by greater root growth as well as the nurturing of soil microbial abundance and diversity. In its simplest form, SRI involves:

- Soil only needs to be kept moist during the period of growth when the plant is putting out tillers and leaves, before it begins to flower and to produce grains. During this reproductive stage, the rice plants should be given a thin layer of water (1-2cm) on the surface of the soil. The field should not be supplied with extra water during the 25 days before harvest.

- Transplanting young seedlings, usually 8-12 days old, with just two small leaves. It must be done carefully and quickly to cause minimum trauma to the roots, putting only one seedling per hole instead of 3 to avoid root competition. Use wide spacing to encourage greater root and canopy growth in a square grid pattern, 25*25cm or wider in good quality soil.

- The first weeding should be within about 10 days after transplanting, and at least one more weeding should follow within two weeks. This will dig up weeds at the same time as it allows more air into the soil for the roots to utilize. Doing one or two additional weedings (3 or 4 total weedings) before the plants have completed their growth or begin flowering, will provide even more oxygen to the soil. A very simple hand powered mechanical weeder, called a rotating hoe, has been developed to enable farmers to eliminate weeds easily, quickly and early. It reduces the hard labour of pulling up individual weeds by hand once they emerge.

- Adding compost or manure whenever possible to add nutrients to the field.

The benefits of SRI, demonstrated in over 40 countries, include increased yield (50 to 100% or more), a reduction in required seed (up to 90%) and water savings (50% or more). SRI users also report a reduction in pests, diseases, grain shattering, unfilled grains and lodging. Additional environmental benefits stem from the reduction of agricultural chemicals, water use and methane emissions that contribute to global warming.

Minimizing post-harvest losses

Proper post-harvest handling of organic rice aims at maximizing grain quality and minimizing losses and any contamination risks from extraneous materials and agents. In case of certified organic rice production, maximum separation of organic, in-conversion and conventional rice throughout the handling process is also important.

The post-harvest handling process starts with proper and timely harvesting, threshing, drying, milling, storage and secure packaging:

- *Harvesting.* Rice is ready for harvest when the grains are full-sized, hard and the panicles have bent down. The number of days from flowering to harvest is fixed for the varieties. This should be used to ensure timely harvest and reduce grain shattering. At this stage, most of the panicles have turned golden brown in colour. To prolong the shelf life, rice should be harvested only when it reaches full maturity. The date is chosen taking into consideration the stage of maturity, the shattering characteristics of the variety and the weather conditions (preferably during dry weather). Avoid mixing weed seeds with the harvested rice grains, so any weeds with fully matured seeds can be removed prior to harvesting. Harvesting by cutting the stem of the rice close to the ground with serrated sickles is much faster than harvesting using knives. The harvested paddy should be put on tarpaulins or similar materials to reduce contamination with foreign materials such as stones.
- *Drying.* Rice is harvested when it has high moisture content and, therefore, needs immediate drying. Delays in drying or uneven drying will result in qualitative and quantitative losses by discoloration of grains and molding, and will increase the risk of insect damage. The paddy should be spread evenly on the tarpaulin; if it is too thick it will develop heat and cause discoloration. Drying under a cool, dry environment is preferred to fast drying of the grains under a hot sunny environment, which may affect the quality of the grain and break during milling.
- *Threshing and Milling.* Threshing methods range from simply beating the rice sheaves on a stone or piece of wood to the fully mechanized combine harvesting. The rice husk and the bran are separated by milling to obtain the edible seed. If the rice was not dried well before threshing then it should be dried again to about 14% before milling. In the simple method, mostly used at the household or village level, rice is milled in a one-step process. However, proper milling facilities are required to achieve a higher percentage of whole grains for better quality and higher price. To fetch good prices, the milled rice must be made of whole grains and free of husks, weed seeds, stones and other foreign materials. Under certified organic production, the rice mill should be cleaned properly prior to milling organic rice. For example, five sacks of organic rice can be milled first to clean the mill and will be classified as conventional. Only the succeeding milled rice will be recognized as organic.
- *Storage.* Rice quality can be affected by temperature and air moisture. Different processed rice (wholegrain or white) require different storage conditions. For example, wholegrain rice can be stored for two years under airtight storage and moderate temperatures 10-35°C while white rice can be stored up to three years under the same conditions.

Marketing and organic certification

Organic certification of rice production is only reasonable if done as a market requirement, as there should be a market that demands it. As the organic markets continue to grow in Africa's domestic and export markets, more rice producers will need to verify and approve their farming systems as organic. Thus, certification is expected to become increasingly important. Interested farmers should be willing to adopt the general organic production requirements: eradicating the use of synthetic pesticides and fertilizers as well as treated and genetically modified seeds, and employing other sustainable production methods. Farmers should be willing to learn and apply new knowledge to find organic solutions to any existing challenges to rice production.

Other considerations include:

- Farmers should have a sizable amount of land to produce rice beyond the household requirement (commercial volumes) to be able to cover the extra costs of certification. The land should also be owned by producers or they should have assured a long-term lease on the land.
- The producers should have access to at least one processing facility (especially for milling and packing), where they can negotiate for preferential treatment of their harvests to minimize contamination. Eventually, as volumes increase, they can acquire their own processing facilities.
- A group of farmers of the same village with adjacent fields can form a producer organization of organic producers to minimize the risks of contamination from neighboring fields. For organic rice, it is also important to avoid any contamination with conventionally grown rice and other substances during processing. All post-harvest equipment used for handling conventional rice should be adequately cleaned before being used for organic rice. It is also very important to use clean sacks that have not been used for synthetic fertilizers or any chemicals, or sufficiently wash them before using them for harvested produce.

Sorghum

Grain sorghum (*Sorghum bicolor*) is the most important cereal crop grown after wheat, rice, corn and barley. Main producers of sorghum are Nigeria, Sudan, Burkina, Ethiopia, Mali and Egypt.

Sorghum is a vigorous perennial grass, mostly cultivated as an annual crop. It grows up to 4mt 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). Sorghum is grown in marginalized cereal production areas. The growing interest in sorghum in Africa is largely due to its drought tolerance.

Crop residues of sorghum grain 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 produce new green leaves for grazing as long as there is some moisture in the soil.

In Africa, where sorghum is grown for subsistence, yields are generally low, ranging from 500 to 900kg/ha, which is far below the potential of the crop. The low yields are due to inappropriate production practices, damage by insects and diseases, the Striga parasitic weed and drought.

Sorghum is well suited for subsistence or local market farming. However, 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.

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, soil borne diseases and weeds (Striga). A planned rotation also enhances soil fertility. Combining different complementary crops and diverse varieties within one crop improves yield security in case of rain failure and increases returns from the land.

Crop rotation

Repeated cultivation of sorghum on the same field is not recommended for most arable crops with a high nutrient demand. This practice increases the risk of a build-up of pests and diseases. Rotation (with cotton and soybean) reduces the abundance of soil borne pests, such as wireworm and white grubs as well as 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 (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 in the same place every 2 to 3 years.

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

Sorghum is rotated with cotton, groundnuts, sunflowers or sugarcane. Recommended rotations are:

- Groundnut – sorghum – pigeon pea/cowpea;
- Finger millet – field bean;
- Amaranth – castor – sorghum – chillies.

Intercropping
Commercial produced sorghum is usually grown as a pure stand. Intercropping in rows is more common in farming crop production. Sorghum can be intercropped with maize, millet, groundnut or cowpea. In rain-fed conditions, sorghum is 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 other legumes such as cowpea to improve the nutritional value of the fodder.

Selection of cultivars
The selection of appropriate cultivars is essential. Selected cultivars are adapted to the local growing conditions, show tolerance or resistance to major insect pests and diseases, are resistant to lodging and reduce vulnerability to pests, merit of their open panicles.

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 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 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 agro-ecological zone. 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 seeds 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. Forage or grass sorghums, such as Sudan grass, are best for grazing. 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. 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 seeds. If hybrid seeds are used in a certified organic farm, close attention must be paid to avoid the use of seeds that have received chemical treatment.

Pest 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, 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.

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 seeds 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*): 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 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 from being added to the soil. Natural fungicide applied as seed treatment or foliar spray provides further effective control.

Ergot (*Claviceps africana*): This fungal disease 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 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, wet weather during 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 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 insects feed on the leaves of seedlings; some bore into the stem giving a dead heart; many feed on the foliage during the vegetative stage and some suck the sap (also know as sap-sucking insects) developing within the glumes. 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 (*Tibolium castaneum*) and the grain moth (*Silotroga cerealella*).

Shoot fly (*Atherigona soccata*): 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 of the 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. Where plants are at risk of damage, spraying with neem can be found useful.

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 attacks 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, are used as a general insecticide.

Biological control of stem borers is possible with the wasp Cotesia flaviceps Cameron. Controlling stem borers in sorghum have found to be useful by adopting the “push-pull” method..

Rows of napier 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. Desmodium also supplies nitrogen to the soil and suppresses the parasitic Striga weed.

Sorghum midge (*Contarinia sorghicola*): Potentially the most destructive pest of sorghum grain, this pest occurs wherever the crop is grown. 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 morning. Extreme temperatures and very dry or wet conditions 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.

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.

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/ha. 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 2, tons to as little as 200kg/ha. Irrigated sorghum may yield double or more.

Farmers harvest sorghum by hand. The heads are either cut off, or the whole plant is removed and the head is cut off later on.

Post-harvest

Sorghum grains are more difficult to store than other grains. Proper handling after harvest is of major importance, to avoid significant losses. Sorghum grains are very susceptible to storage pests, and moist grains encourage the development of molds. Unfortunately, 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 winnowed.

Panicles are stored in granaries. Plastic bags should not be used as they retain moisture and will promote moulds development. 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 fled for grazing (pasture) after the harvest, the sorghum will grow back better if 10 to 15cm 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.

In Africa, conventional intensive vegetable production is characterized by extremely high input of pesticides and fertilizers. In many cases, intensive vegetable production does not apply wide crop rotations and large regions are specialized only in a few vegetables. Single-crop production leads to an over-exploitation of the land and increasing pest and disease pressure. Intensive use of pesticides and fertilizers contaminates water, air and soil. After cultivating the same crop year after year on the same land, the insects and diseases become resistant to the common pesticides. Therefore, farmers become dependent on costly external inputs, and suffer yield depressions due to loss of soil-fertility. This mechanism has caused farmers from an entire region to shift to different crops or give up their production. Furthermore, growers have suffered health problems due to contamination by agro-chemicals.

Organic vegetable production has gained major importance in many countries, because in vegetables, pesticide application is much more “visible” and closer to the final consumer than, for example, cereals or any other agricultural product that receives important post-harvest treatments and further processing. This is the reason why organic vegetables in many countries are the first products demanded by the consumers. Producers, processors, and traders recognized this opportunity and started programs of fresh and processed organic vegetables. Organic vegetables are the most important items in the organic food assortment.

Wheat

The two main cultivar groups are bread wheat (*Triticum aestivum*) and durum wheat (*Triticum durum*). The consumption of wheat is constantly increasing in many countries. The comparably high price of imports is a considerable burden on economies and provides an incentive for domestic wheat production.

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). 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.

Agro-ecological requirements

Wheat is essentially a crop of the temperate to subtropical climates. The dry season 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 4500mt. Compared to other cereal crops, wheat's soil and water requirements are quite specific. Bread wheat and durum wheat have somewhat different ecological requirements.

Diversification strategies

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 (foot and root rots) and leads to nutrient depletion and decreasing yields. A proper crop rotation underpins successful wheat cultivation.

It is recommended that a cereal crop should not be grown on a plot of land more than twice in succession. Wheat 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 in crop rotations are pulses or other legume crops. Legumes 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 tilt, 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.

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 (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, tine hoe, or rake mixes the seeds with the topsoil and improves their germination.

Disease management

Pest and disease management can be both direct and indirect. On average, diseases and pests 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.
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.

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. 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 seeds. Seedborne diseases can be difficult to control. To prevent their transmission, all seeds used should, wherever possible, be tested for seed-borne diseases and be certified disease free. The most efficient measure against seed-borne diseases remains 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 in Africa. 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 produce 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. Black spores develop at higher temperatures. 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, but 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, although temperatures above 20°C stop its growth. Losses occur due to a loss of active leaf surface, reduced root growth and increased water losses.

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. The lower leaves elongate and brown-black lesions that contrast sharply with the healthy leaf tissue appear after heading. The most visible symptom is a dark brown colored, sub-crown internode.

Other preventive measures are to avoid infested plots, grow resistant cultivars, mix resistant and susceptible cultivars and treat the seeds with microorganisms or plant extracts (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 a high nitrogen supply and dense stands with a close contact between the plants. Preventive measures include using resistant varieties and variety mixtures and avoiding very dense stands and over-fertilization.

Pest management

Field pests include various aphids (which may also transmit viruses), termites, grass, bugs, thrips, beetles, grubs, worms, maggots, miners, midges, sawflies, nematodes (of the roots and the grain) and birds. In Africa in particular, migratory locusts regularly destroy wheat crops. 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 thuringensis*, rotenone, soaps and the spraying of oils and Neem.

Aphids: 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.

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 rootknot nematodes (*Meloidogyne* spp.) and cyst nematodes (*Globodera* spp., *Heterodera* spp.). Most plant-parasitic nematodes live in the topsoil. Species can persist in the soil for several years (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.

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 south-western and south-central Asia, but losses occur mainly in central and western Asia.

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.

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; 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, thresh and winnow the grains all at once. However, most farmers 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. 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.

Storage

To ensure a good storage life and reduce losses, 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 molds. 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 molds. 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. Treatment of the grains in storage is rarely done in the tropics because it is too costly. Possible treatments include fumigation with CO_2 or N gas in closed containers, or treatment with siliceous stone powder.

Fonio

Introduction

Fonio (*Digitaria exilis*) is one of the oldest cultivated cereals in Africa, dating back to 5,000 BC. Fonio is the smallest species of millet.

In the mythology of the Dogon people in Mali, the creator made the universe by exploding a single grain of fonio, located inside the "egg of the world". The Dogon people of Mali believe the universe was created by exploding a single fonio grain.

Fonio is considered as a staple food in dry areas of several West African countries including Guinea, Gambia, Mali, Burkina Faso, Benin, Senegal, and Togo. Fonio plays a crucial role in food security in hungry seasons and critical periods when food reserves in the household are low. It grows in the Sahel belt, a semi–arid landscape located between the Sahara and tropical regions of central Africa that stretches from the Atlantic Ocean to the Horn of Africa. Fonio sustains millions of people early in the growing season, and therefore can be considered as a coping strategy for increased household food security.

The tiny seed is rich in two vital amino acids for humans’ consumption: methionine and cystine. Fonio is also regarded as a grain with medicinal and healing properties; it is recommended for lactating women and diabetic people and is often used in diets of sick people. Fonio is a small scale farmers’ crop and provides important income to the household; for example, the price of one kilo of cleaned fonio is about 1.5 to 2 times that of rice.

Fonio has potential to improve nutrition, boost food security, foster rural development and support sustainable land use. Despite the widespread cultivation of maize and other non-native cereals since
the 20th century, African farmers and consumers still value fonio highly because it is nutritious and extremely fast growing.

Best practices in Fonio cultivation

Fonio is a very hardy crop and grows well on poor shallow, sandy or rocky soils unsuitable for other cereals, but does not prosper in saline or heavy soils. It can even produce seed on soils with aluminum levels that are toxic to other crops and can be relied on in dry savannah lands, where rains are brief and unreliable.

Fonio requires little input in its cultivation and it is highly adapted to drought and low-fertility soils. Fonio is grown at sea level in Gambia, Guinea-Bissau and Sierra Leone, but more often it is cultivated at 600–1500 m altitude. The average temperature in the growing season ranges from 20ºC at higher altitudes to 25–30ºC near sea level.

Fonio is grown in areas with an average annual rainfall of 150–3000mm, but its cultivation is concentrated in regions with an average annual rainfall of 900–1000mm. It is not as drought resistant as pearl millet, but fast-maturing landraces reaching maturity in only 8 weeks are suited to areas with short and unreliable rains. In areas with very low rainfall it is grown in valleys benefiting from run-off water.

The entire fonio production in Africa is estimated at 250,000 to 300,000tons/year on more than 380,000 hectares. Fonio grains are used by African consumers in porridge and couscous, for bread, and for brewing beer. The tiny grains are gluten-free and rich in protein, and consumers outside Africa are beginning to recognize its flavour and nutritional qualities. Fonio is light and easy to digest and can be included in many different cereal-based recipes, making it an attractive ingredient for health food products for those with gluten intolerance, in poor health or for baby food.

Challenges in Fonio production

A major obstacle to increasing fonio production is the long and complex processing. The tiny grain makes dehusking and milling, traditionally done by women using a pestle and mortar, highly laborious.

Moreover, post-harvest activities are laborious and time-consuming. Meanwhile, urbanization and related changes leading to an increased demand of industrially produced and sophisticated foods induced a rapid shift of coarse grains to non-traditional grains. This resulted in a decreased consumption of fonio as traditional food, particularly in urban areas.

Also, to define quality criteria for precooked fonio, and determine consumer demand in Africa and Europe remains unsolved yet. As regards quality, sand (used for processing) in whitened (processed) fonio is still one of the main problems to be solved in order to produce quality fonio for sale in supermarkets and on the export market.

Moreover, it is difficult for small-holder farmers to increase their production volume without access to finance. Efforts are on their ways for Senegalese farmers growing fonio to exploring ways of improving local and export markets.

Research efforts at national and regional levels focus are currently focusing on:

- Genetic diversity and production. Germplasm of fonio is collected, characterized and conserved; promising cultivars are selected and released to farmers;

- Improvement of threshing and husking methods. Currently, a new husking machine has been developed (Sanoussi's husker). New threshing and husking practices are being tested;
- Improvement of the product quality. Techniques and methods to produce sandless fonio (premium fonio) are being developed.

Research institutes and development organizations in the sub region are now devoting more attention to the crop. The following results have been achieved:

- Through participatory approach, major limiting factors to the promotion of the crop was identified by farmers, processing units and research institutes;
- Five cultivars of early to medium growing cycle and with good yielding potential have been released to farmers;
- A husking machine has been locally developed and adopted;
- Other tools that have been introduced are being tested;
- Post harvest technologies to reduce grain losses are being experimented.

Vegetables

Cabbage

Cabbage (*Brassica oleracea L. convar. capitata var. capitata*) is one of the world's most important vegetables, especially in the temperate zone. Most processed cabbage goes for the production of sauerkraut.

Suitable varieties for organic production

Hybrid varieties are most dominant and suitable in organic farming. While both white and red cabbages exist, the white variety dominates the market. Farmers should carefully choose from the available varieties in the local market, depending on their resistance to heat and cold as well as a number of important diseases and physiological disorders. Growth period differs from 75 days for early varieties, 90 days for mid-season, to over 120 days for late large-headed varieties (from seed to maturity).

Field selection

With respect to the selection of an appropriate field before planting cabbage, farmers should consider the following important factors, which affect a number of diseases such as club root and *Sclerotinia*:

- The field should have been free of crucifer crops or related weeds for at least 2 years, preferably 4. Crucifer crops include cabbage, cauliflower, broccoli, kale, kohlrabi, Chinese cabbage, mustards, turnips, rutabagas, radishes, etc. Cruciferous weeds include wild radish, shepherdspurse, wild mustards, etc. Crucifer plant waste should not be dumped on these fields.
- Fields with club root in the past needs strict control of soil pH (over 6.5). Application of lime some weeks before planting the cabbage seedlings is reported to reduce infection.

Harvest and post-harvest handling

Handling

Cabbage for processing should be delivered to the processor soon after harvesting. Heads should be harvested when firm and before they split or burst. In harvesting for fresh market, leave 4-6 wrapper leaves attached to the head. Wrapper leaves are removed when harvesting for kraut.

Storage

Store cabbage at 0°C and relative humidity of 98 to 100%. If stored under proper conditions, late harvested cabbages should keep for 5 to 6 months. Early-crop cabbage has a storage life of 3 to 6 weeks. Cabbage is held in common storage, where a fairly uniform inside air temperature of 0 to 1.6°C can be maintained. Cabbage wilts quickly if held under storage conditions that are too dry; hence, the humidity should be high enough to keep the leaves fresh and turgid. The storage life of late cabbage can be extended for several months if it is held in an atmosphere with 2.5 to 5% oxygen and 2.5 to 5% CO_2. Cabbage should be handled carefully from field to storage, and only solid heads with no yellowing, decay, or mechanical injuries should be stored. Before the heads are stored, all loose leaves should be trimmed away; only three to six tight wrapper leaves should be left on the head. Loose leaves interfere with ventilation between heads, and ventilation is essential for successful storage. Upon removal from storage, the heads should be trimmed again to remove loose and damaged leaves. Cabbage should not be stored with fruits emitting ethylene such as, for example, bananas, dates and mangoes.

Carrot

Carrots (*Daucus carota L. ssp. sativus*) are cool-season biennials that are grown for the thickened root it produces in its first growing season. Although carrots can endure summer heat in many areas, they grow best when planted in the cool season. Carrots are rich in carotene (the source of vitamin A) and high in fibre and sugar content.

Suitable varieties for organic production

It is important that season specific varieties for summer or winter are used.

Planting

Carrots are sown directly on the field. To achieve a high percentage of germinating seeds, the soil structure should be well prepared (no excessive tillage). Seeds need to be planted near to the surface and be covered lightly with 0.3-0.6cm of soil. Germination is slow and irregular.

Design of the rotation

Carrots may be rotated with alfalfa or other leguminous cover crops; such as small grains, onions and spinach. To reduce soil borne diseases, rotation with celery, parsley, beets and sesbania has to be avoided.

Harvest and post-harvest handling

Handling

Carrots harvested and handled in hot weather are more likely to decay, and care should be exercised in handling to prevent wilting. Mature carrots are well adapted for storage and are stored in large quantities during the fall and winter for both the fresh market and processing. Careful handling during and post-harvest helps to ensure safe storage by avoiding bruising, cutting and breakage.

Storage

Mature topped carrots can be stored up to 9 months between 0° and 1°C with very high relative humidity: from 98% to 100%. However, even under these optimum conditions, 10% to 20% of the carrots may show some decay after 7 months. Under commonly found commercial conditions (0° to 4°C) with 95% relative humidity, 5 to 6 months storage is a more realistic expectation. Prompt cooling to 4°C or below after harvest is essential for extended storage. Poorly pre-cooled roots decay more rapidly. Carrots lose moisture easily, resulting in wilting.

Humidity should be kept high. Carrots stored at 98% to 100% relative humidity develop less decay, lose less moisture, and remain crisper than those stored at 95% relative humidity. A temperature of –1°C to 1°C is essential if decay and sprouting are to be minimized. With storage at 4 to 10°C, considerable decay and sprouting may develop within 1 to 3 months. Many potential decay causing organisms are removed by washing. Also, clean, washed carrots allow better air circulation. Air circulation between crates of pallet boxes in which carrots are stored is desirable to remove respiratory heat, maintain uniform temperatures, and help prevent condensation.

Bitterness in carrots, which may develop in storage, is due to abnormal metabolism caused by ethylene. This gas is given off by apples, pears, and certain other fruits and vegetables and from decaying tissues. Bitterness can be prevented by storing carrots away from such products. Development of bitterness can be avoided by low-temperature storage, as it minimizes ethylene production. Some surface browning or oxidative discoloration often develops in stored carrots.

Onion

Onions (*Allium cepa L. var cepa*) originate from central Asia. Bulb-forming onions produce a single bulb in a season. There are two basic types of bulb-forming onions: storage onions and “sweet” onions. The difference between storage and fresh onions is that storage onions keep for a longer period of time.

Suitable varieties for organic production

It is recommendable to use fast growing varieties that will shorten the susceptible period for diseases. Onions can be grown from seeds, small dormant onions called “sets”, or onion transplants:

- Set onion: seeds 90kg per ha, row distance 20cm, 2 - 3cm deep. Harvesting when the set onions have a size of 15-20mm diameter. Store them dry until planting;
- Plantlets: 4-5 seeds/pot in 4cm cubes or tray with 20-50 cm3/pot; ready to plant with 3 leaves.

Planting

The size of the onion mainly depends on the sawing/planting distance. With low sawing or planting density, you will harvest big onions:

- Direct sawing: 4-6kg seeds per ha;
- Planting set onions: 800 - 1000kg per ha, with 5 to 7cm distance in the row.

Crop rotation

Organic onions are planted in a crop rotation schedule. It is not recommendable to plant onions in the same soil for more than one season. Onions can be planted only once within five years in the crop rotation. This is important to avoid diseases. Previous crops can be potatoes, crucifers and field beans, but not carrots or celery. Onions have a good effect as a preceding crop. Onion organic matter residue is about 1 ton per ha, which contains approximately 25kg of nitrogen, 10kg of phosphor and 35kg of potassium. Crops cultivated after onions in the same year include spinach.

Harvest and post-harvest handling

Handling
Onions can be stored for several weeks in a cool, dark place. They can be stored in the refrigerator, but not in plastic bags. This will inhibit air circulation and promote rotting of onions.

Storage
The ripe period for storage onions is reached when at least 75% of the crop populations have been laid down. Clearing too early can cause problems during storage. Clearing too late can cause the shell to drop away and induce sprouting. After the harvest, the onions will store better if they are dried outdoors for a week. Leave tops on bulbs during drying. After drying, cut tops within 3 cm of bulb. The onions can be picked up manually or with a full harvester. Onions are stored in dry and well ventilated stores. Storage temperatures should be below 30°C.

Salad/Lettuce

Lettuce (*Lactuca sativa L.*) is a seasonal herb. Varieties which form heads are called cabbage or head lettuce. Usually, it is eaten raw, notably in salads. The leaves are large, more or less crinkled, sometimes lobate and varying in color from pale green to purple. The rosettes of cabbage lettuce are sometimes very compact.

Suitable varieties for organic production

Although mostly adapted to colder climates, there are summer and winter varieties which can be used in each of the seasons.

Propagation and Nursery Management
Lettuce should be sown into seeding trays so that young plants may grow strong enough for the field. Transplanting occurs when plants have 4-6 leaves, usually after 25 – 30 days. To get stronger and bigger lettuces, seedlings can be covered with a fine layer of substrate during their growth on the trays. Because of the danger of soaking small plants, it is not advisable to irrigate the trays one day before transplanting occurs.

Raised beds are ideal for lettuce production. They help prevent damage from soil compaction and flooding. They also improve air flow around the plants resulting in reduced disease incidence.

Harvest and post-harvest handling

Handling
Because lettuce is so fragile, it is handled as little as possible. No lettuce is washed before it gets to the store, but some may be hydro cooled or hydro-vacuum cooled.

Lettuce and other leafy items must be kept clean, and free of soil and mud. A stronger, bitter taste and toughness develops if harvest is delayed, or if crop is over- mature; and then the product becomes unmarketable.

Lettuce is extremely perishable and needs to be handled delicately, and marketed rapidly. Lettuce may be held temporarily at 0°C and 90-95% relative humidity for several days.

Head lettuce is harvested when the heads are of good size, well formed and solid. If the plants are wet with rain or dew the leaves are more brittle and break easily. Leave three undamaged wrapper leaves on each head.

Put 24 heads in rigid cardboard containers in the field and avoid bruising. Grade heads according to size, pack in cartons for long shipments. Leaf, butterhead and cos types are cut, trimmed and tied into compact bundles before placing in cartons.

Tomato

Tomatoes (*Lycopersicon esculentum Mill*.) belong to the Solanaceae family and are related to egg plants, paprika, and potatoes.

Suitable varieties for organic production

Most traders, retailers and supermarkets prefer especially firm durable varieties to minimize losses due to all the handling along the logistic chain from the field to the shop. Traditional types of tomatoes have a durability of approximately of one week. There are new varieties for which traditional breeding (semi-longlife or longlife) and genetic engineering (“flavor savor”) have increased durability by four weeks. In organic agriculture, genetically manipulated tomatoes are not allowed. For organic growers, disease-resistance or tolerance is in many cases more important than other factors, such as durability. For example, “*Peretti*” tomatoes are more susceptible to rotten flowering than round tomatoes. Furthermore, local markets decide which varieties are in demand. Market demands, disease resistance, suitability to cropping systems and life storage period are factors that influence the selection of varieties in organic tomato production.

Two different growth forms of tomatoes can be found: plants with determinate growth (bush) and tomatoes with an indeterminate growth (vining). Tomatoes with determinate growth are still found in bush tomatoes and in the early varieties used for short period growing.

Design of rotation

Organic tomatoes are planted in a rotational system. Continuous production of tomatoes can be changed in the same year by producing lettuce, cucumber, leek, cauliflower, paprika or incorporating a cover crop. For farmers that dispose of only small vegetable plots, long rotations may be impractical. In such cases, soil building practices (green manure, compost) that improve soil microflora are important to promote natural disease suppressing conditions. Pastures and small grain crops that are grown in rotations to increase soil structure and organic matter should be ploughed down several months ahead of planting (problems of cutworm and wireworm).

Organic growers have had very good experiences with planting leguminous cover crops before the tomatoes, such as hairy vetch (*Vicia villosa*) and fields beans (*Vicia faba*). Tomatoes are planted in the field when the first flowers open. Different plant densities are used; for strong growing varieties, a plant density of 2-2.2 plants per sqm; for slow growing varieties, plant to a density of 2.7-3 plants per sqm. Organic growers prefer lower density to guarantee ventilation and reduce disease infections.

Pest and disease management

Tomatoes are susceptible to physiological disturbances, diseases and pests. Priorities in organic tomato production have all the management methods to prevent such pests and diseases:

- Optimal site selection;
- Selection of pest and disease resistant varieties;
- Wide rotation (in case of soil borne diseases four years should be free of tomato-production);
- Creation of semi-natural habitats and ecological compensation areas;
- Improvement of soil fertility and activation of soil microbial life;
- Balanced nutrient supply.

With such measures, non parasitic damages and physiological disturbances, as well as nutrient deficiencies can be reduced. In addition, organic preparations are applied; however, they often are less effective than synthetic products and therefore only a combination of preventive and curative methods leads to successful organic tomato production.

Harvest and post-harvest handling

Handling

Harvesting tomatoes is labor intensive. For storage and shipping, the tomatoes can be picked at the initial stage of maturity- when the blossom end turns pink. Tomatoes can be harvested 2-3 times per week, preferably in the morning. Temperature-management is critical to maintain quality. The tomatoes should be stored at 10-13°C. The flavor will be reduced if tomatoes are stored at low temperatures, while high temperatures accelerate fruit ripening. In comparison to conventional production of tomatoes, the yield of organic grown tomatoes is comparable if all measures were managed correctly during the growing period.

Roots and Tubers

Cassava

Cassava (*Manihot esculenta*) is a commonly produced tuber crop in Africa. It can be used as food, as a cash crop, as feed for animals and as a source of industrial raw material. In sub-Saharan Africa, cassava is mostly used for human consumption in various forms ranging from boiling the fresh tuber to processing it into cassava flour. Cassava tubers are an important source of carbohydrates, while the leaves, eaten as a vegetable, are a good source of protein and vitamins.

Challenges facing cassava production in Africa

- Low productivity. Although cassava is an important crop with multiple uses, it does not receive the much needed attention during its production. Farmers normally plant it on very poor soils, where other crops like maize have failed. Sometimes cassava is grown as an insurance intercrop with other nutrient-demanding crops like maize or sorghum, just in case the main crop fails. Cassava is predominantly a crop for small-holder farmers, who basically grow for subsistence, using rudimentary tools and operating on small and fragmented plots. Crop yields are further reduced by infections by the cassava leaf mosaic disease, the cassava brown streak disease and the cassava mealy bugs and scales.
- High post-harvest losses. Poor post-harvest handling leads to uneven quality of the processed cassava and results in contamination by fungi. Poor and inadequate facilities for milling and storage; and poor access to roads, which are vital for adding value, further increase the postharvest handling challenges.

Cassava remains easy to produce, adaptable to many environments, with minimal labour requirements and less susceptible to pests and diseases. However, there is need to address increased productivity, marketing opportunities and profitability of cassava production. The following organic practices can contribute to achieving these goals.

Establishment of the cassava garden

In organic farming, crop management begins by giving the plants good growing conditions through improving soil fertility, and healthy planting material. This allows the crop to grow healthier, and produce higher yields.

Suitable varieties for organic production

Cassava varieties differ with regard to yield potential, flesh color (white or yellow-fleshed), diameter and length of the tubers, disease and pest resistance levels, time from planting to harvest, cooking quality and taste. Some cultivars require 18 months or more from planting to harvest, while others are ready to harvest in 9 months. Most cultivars have been selected by farmers under their growing conditions based on yields and cultural tendencies. Each growing region has its own special cultivars with farmers, often growing several different cultivars in the field at the same time.

Recommendations to farmers for selecting suitable cultivars
The best cassava varieties are those preferred by consumers. They grow fast, give good yields, store well in the soil and are tolerant to major pests and diseases. The following criteria are useful for selecting cassava varieties for organic production:

- Good adaptation to local conditions. To adopt the right variety it is important to be aware of the general growing conditions for cassava including length of the rainy season, prevalent diseases, pests and weeds. Such information helps to determine what characteristics are needed by each variety to perform well.
- Varieties with high dry matter and good food quality. Cassava varieties with tubers with dry matter content of more than 30% are said to produce good quality products and are more profitable for processing.
- Adaptability to different uses. The selected cassava variety should be adapted to multiple uses such as food, animal feed or industrial processing. Varieties that are commonly preferred are with tubers that are tasty for home consumption, can store well for processing purposes and produce enough foliage for animals.
- Ability to bulk early. Varieties that show early bulking, meaning the swelling of the root tubers, are better able to compete with weeds, than late maturing varieties, and are suitable for drier areas with short rains.
- Ability to store well in the ground. Varieties that keep the tubers in good condition for a long time after reaching maturity are preferred. Good ground storability leaves more time for harvesting, thus reducing the duration of post-harvest storage problems of fresh roots.
- Resistance to local weeds, pests and diseases. Varieties that can tolerate the prevalent diseases and pests in the area are most preferable.

<u>Selection of an appropriate planting site</u>

Cassava is drought tolerant, can grow on most soils, and gives some yields even on poor soils where most other crops fail. However, high yields are obtained in areas with well-drained, loamy soils, well-distributed annual rainfall of 1,000 to 1,500mm, and warm and moist climatic conditions only. The best site for planting cassava is flat or gently sloping land. Steep slopes are susceptible to erosion and are, therefore, not very suitable areas for growing cassava. Valleys and depression areas are also not recommended because they are prone to water logging. Cassava is sensitive to water logging and heavy soils do not allow the crop's roots to proliferate and develop.

<u>Land and seedbed preparation</u>

In cassava cultivation, it is important to till the land to loosen up the soil, improve soil drainage and make it easy for roots to develop. The level of tillage required for the cassava field mainly depends on the soil type and the drainage at the selected site. In places with shallow soils or poorly drained clayey soils, it is important to make mounds or ridges onto which the cassava is planted, as it encourages better root development and yields. In sandy soils, only minimum tillage is necessary and the cassava can be planted flat into the soil, as the soil is sufficiently loose to allow root development.

<u>Preparing good quality planting material</u>

Cassava is propagated by planting pieces of the stem (stem cuttings). The development of cassava and amount of yields depends on the quality of stem cuttings. There are several cassava pests and diseases, which are stem-borne. Selecting healthy stem cuttings reduces the spread and damage caused by pests and diseases.

Recommendations to farmers in selecting good cassava stem cuttings

- Select planting material from healthy growing, high-yielding, 8 and 18-month old cassava plants. Healthy cassava plants have robust stems and branches, lush foliage, and minimal stem and leaf damage caused by pests and diseases.
- From each plant, select the middle, brown-skinned portion of stems as stem cuttings. The stems should be 2 to 4cm thick. These parts sprout and ensure plant vigour better than the top green stem portions. Stem cuttings taken from the top green portions or extreme top and bottom portions of stems are unsuitable. They will dehydrate quickly, produce unhealthy sprouts, and are easily damaged by pests and diseases.
- Tie the stems in bundles and wait for at least 10 days before planting them. The harvested stems can be stored for over 2 months in dry, well-ventilated, shaded areas away from direct sunlight until it is time for planting. One simple method of storing stems consists of arranging them vertically under a shady tree, with the oldest part of the stem buried in the soil. The soil should be moist to keep the stems 'alive' as leaves will form on the upper part of the stems. After storage, discard the top and basal parts of the stems, and use the middle part as cuttings. Another method, mainly used under cold conditions, consists of storing the stems in underground tunnels, which are protected from water. The stems are placed inside the tunnel on top of a layer of dry straw, and then covered with another layer of straw and soil.

Planting

To get the best sprouting and growth from cassava stem cuttings, the following considerations are recommended:

- *Selection of suitable planting dates.* Planting cassava early, at the beginning of the rainy season, ensures healthy sprouting and good plant establishment. This enables the plant to withstand attack by diseases and pests later in the season.
- *Preparation and handling of stem cuttings.* When cutting up cassava stems into pieces for planting, each cutting should be between 20 and 30cm long and have about 5 to 8 nodes, where roots and shoots originate. The interval between cutting of the stems and planting into the ground should be as short as possible to avoid dehydration and poor performance. Soaking the stem cuttings before planting in warm water (50°C) by mixing equal volumes of boiling and cold water for 10 minutes just before planting prevents stem-borne pest attacks.
- *Adopt suitable planting mode according to the type of soil.* Cassava cuttings can be planted by hand vertically, at an angle (inclined) or horizontally, depending on soil types. The drier the soil, the bigger the part of stem placed in the soil. The vertical planting method is best suitable in sandy soils and consists of planting the cuttings vertically with two-thirds of the length of the cutting below the soil. Planting at an angle is most suitable in loamy soils and consists of planting the stem cuttings vertically and with an angle ranging from slightly above horizontal to about 45°. Horizontal planting is recommended for dry climates and consists of placing the entire stem cutting horizontally in the soil at a depth of about 5 to 10cm. The spacing between the cassava plants depends on several factors such as the variety used, the soil type, soil fertility and water availability and on whether cassava is grown alone (mono crop) or with other crops (intercrop). If cassava is grown alone, a distance of

1mt between the plants should be considered. If cassava is grown as an intercrop, the distance between the crops should range from 1 to 4mt depending on the branching habit of both the cassava and other crops to make sure there is enough space for the plants.

Intercropping

Due to the fact that cassava has a slow initial development, intercropping during early crop development is feasible, and helps reduce soil erosion. However, farmers should consider that cassava is a poor competitor and can easily be shaded out by tall intercrops like maize. For this reason, it is important to consider the branching habit of both the cassava and the other crops in the intercropping system and make sure there is enough space for both crops. Furthermore, cassava can suffer from nutrient and/or water competition from intercrops. Therefore, attention must be given to the intercropping species that have different root systems and nutrient requirements.

Farmers usually intercrop cassava in simple or complex mixed cropping systems with vegetables such as amaranth and okra, plantation crops such as coconut, coffee, maize or legumes, and pulses such as cowpea and groundnuts. The intercropping pattern depends on the environmental conditions, food preferences and market conditions of the region.

Simple mixtures consist of the intercropping of only two crops, in which farmers select arable crops on the basis of differences in growth habit and time of maturity. For example, cassava, which is a long-duration crop with 9 to 18 months to maturity, is often intercropped with short-duration crops with 2 to 5 months of maturity process, such as maize, cowpeas, groundnut, okra and melon. These crops mature when the cassava is just attaining its maximum leaf area development and thus is able to expand its root tubers without competition. In complex mixtures consisting of three or four crops, good yields have been obtained with the following combinations:

- Maize - Cassava - Melon
- Maize - Groundnuts - Cassava
- Maize - Cassava - Okra - Cowpea
- Maize - Yam - Cassava
- Maize - Beans - Cassava

Complex mixtures improve weed suppression, reduce soil temperature, retain soil moisture in the topsoil, and produce more organic matter than single cropping or simple mixtures. Nutrient loss from erosion in complex mixtures is less than in single cropping.

Crop rotation

The continuous planting of cassava in the same field year after year leads to increased disease and pest levels, reduced yields and crop failure. To avoid such development, organic farmers should wait for at least 2 years before planting cassava on the same field again and develop a crop rotation system. A rotation system generally improves soil fertility, reduces soil erosion and helps to control diseases and pests. The suitable crop rotation depends on several factors such as the climatic conditions, the market requirements and the skills and objectives of the farmer. However, within a pattern of crop rotation, cassava is often grown in sub-Saharan Africa at the end of the sequence, as it can still produce relatively well at lower fertility levels, where other crops would not grow well.

This practice leads to lower cassava yields. It is important to establish a balanced crop rotation, which maintains or improves soil fertility, and to give cassava a place in the rotation that corresponds to farmer expectations. Cassava is a good crop to follow such crops as pumpkin, squashes, maize, sorghum or improved fallow. A 3-season rotation example that can be used in organic cassava production is maize-beans / cassava / groundnuts.

Reducing post-harvest losses

Post-harvest handling of organic cassava aims at maximizing tuber quality by minimizing any damage or cuts on the tubers during harvesting and transportation of the tubers. Young leaves and shoots of cassava are also harvested to be consumed as vegetables and may be as important as tubers for generating income. However, excessive harvesting of the leaves can have a negative effect on the yield of tubers.

Timely harvesting

Early-maturing cassava varieties are ready for harvesting at 7 months, while late-maturing varieties are ready 12 months after planting. The proper stage for harvesting is when the leaves turn yellow and fall down and the roots are mature. It is advisable to harvest cassava once it is mature. If the tubers are left in the ground over long periods, they lose quality and become woody due to hydrolysis of starch to sugars. Care should be taken to avoid damage to the tubers during harvesting. Damaged roots are highly susceptible to fungal attacks and decay.

Harvesting cassava tubers is labor-intensive and done by hand. It is easy if the soil is sandy or during the rainy season, but in heavier soils or during the dry season, harvesting usually requires digging around the tubers to free them of the covering soil and then lifting/pulling the plant. The day before harvest, the plants are normally ‘topped’; the stalks are cut off 40 to 60cm above ground and piled at the side of the field. From this material, the stalks for the next planting are selected. Excess soil is then scraped off from the tubers by hand. This should be done carefully so as not to peel or damage the outer protective skin of the tubers.

Transportation

The first thing to be done after the harvest is to transport the tubers from the production and harvest field to the processing and utilization site. This is because fresh cassava is highly perishable (within 2 to 3 days after harvesting). Transportation of cassava tubers should also be done carefully to avoid bruising and dehydrating the cassava tubers, especially if it is meant for fresh consumption.

Preservation

Since cassava roots can remain in the soil for up to 18 months after reaching maturity, the simplest preservation technique is to delay the harvest until the crop is needed. However, this method has the following disadvantages:
Cassava roots increasingly lose starch, the constituent defining its value. Also, they become fibrous and woody with prolonged in-ground storage. Furthermore, the longer the

roots remain in the ground, the longer they become exposed to insect, disease, or rodent attacks. Lastly, the land may be needed to plant other crops. Freshly harvested tubers can be preserved by the following methods:

- Cassava buried in straw-lined trenches and protected from seepage of ground water can hold for periods of up to 12 months. A shade is needed around the trenches; therefore, it is better to put several trenches under the same shade (roof).
- Storage in tightly woven bags such as rice or cocoa sacks. With this technique, storage times of 7 to 10 days are achievable.
- In a clamp storage system, a conical pile of 300 to 500kg of fresh cassava roots is seated on a circular bed of straw and covered with more straw. The whole unit is covered with soil to a thickness of 10 to 15cm, the soil being dug from around the clamp so as to form a drainage ditch. With this storage system, minimal losses up to 20% may be expected for periods of up to 2 months.
- Storage of tubers in wooden crates containing absorbent material such as damp sawdust. However, if the sawdust is too moist, it may promote fungal growth and if it is too dry, the roots deteriorate quickly. Lining the crates with perforated plastic prevents dehydration of the sawdust, resulting in a storage period of about 1 to 2 months.
- Cold storage by keeping the cassava tubers below 4°C. This system greatly reduces cassava deterioration and may be practicable for high-value markets. Alternatively, roots, or more commonly pieces of root can be stored frozen. This is a satisfactory method to conserve the tubers. It must be noted that, although the flavor is preserved, freezing changes the structure of cassava tubers, making them spongier.

Marketing and organic certification

Much of the cassava production is used at household food consumption level. It is also increasingly becoming a raw material for industrial production, especially for starch production. Organic certification of cassava production is only reasonable as a market requirement if there is a market that demands it. In such a case, interested farmers should be willing to adopt general organic production requirements, like not using synthetic pesticides and fertilizers, and applying other sustainable production methods.

Other considerations include:

- Farmers should have enough land to produce cassava beyond the household requirement (commercial volumes), to be able to cover the extra costs of certification.
- For successful marketing, farmers may need to work as group to increase production volumes needed to justify the cost of certification.

Specific national or international organic standards may define additional requirements for production and post-harvest handling of cassava. Farmers should consult the national organic movement or organic certification body operating within the region or country.

Potato/Sweet potato

Botanically speaking, the underground part of the sweet potato (*Ipomoea batatas* L.) is classified as a storage root, rather than a tuber, as is the white (Irish) potato (*Solanum tuberosum*).

Site selection and planting

Sweet potatoes should not be grown on the same land more often than once every 3 years. Farmers should avoid fields with a history of difficult to control perennial weeds. Sweet potatoes do best on light, deep, friable loams (sandy loam) with high fertility. Propagation results from vine cuttings, which are referred to as "slips". Ten to 12 bushels of disease-free sweet potatoes should be bedded to produce enough slips for one acre.

Sweet potatoes are usually bedded about 7 weeks before field setting time. Sweet potatoes are cold-sensitive. Providing an even supply of water during the first 40 days after planting is especially important for quality root development. An uneven water supply can result in growth cracks; drought conditions may reduce yields; and excess moisture may injure roots. Additionally, watering during this critical period can help plants survive water-related stresses later on.

Pest management

The main insect pests are those that feed on the roots, such as wireworms, flea beetle larvae, and sweet potato weevils. Diseases include black rot and scurf, Fusarium wilt, root knot nematodes, and post-harvest rots. Resistant cultivars, crop rotations, sanitation, and weed management are important tools in disease and insect management.

Harvest and post-harvest handling

Sweet potatoes should be harvested once they reach the weigh of at least 300grams. A good practice is to clip the vines before harvesting so they do not get in the way during harvest, resulting in less damage to the potatoes. A turn plough can be used to expose the roots with the least possible injury. Potatoes are graded in the field and then placed in containers that are to be put into storage.

Following harvest, sweet potatoes need to undergo a curing process to promote the healing of wounds (for example, from digging). Curing protects roots from many storage diseases and increases the post-storage lifetime of the root. Additionally, curing improves root flavor and texture. Curing is best accomplished at a temperature of 30°C and relative humidity of 80% to 90%. After curing, sweet potatoes may be stored for 4 to 7 months under the proper conditions, including ventilation. Sweet potatoes are cleaned, either by brushing or washing, and then sometimes waxed before packing into boxes, crates or baskets for market.

Fruits

Mango

The mango fruit tree (*Mangifera indica L.*) is the most important tropical fruit after the banana. Nonetheless, due to its sensitivity to bruising, in terms of numbers, fresh mango plays only a small role in world trade. Mango has been disseminated for many years, and is cultivated in all warm countries down to the sub-tropics.

Uses and contents

Mango has many uses. Young fruits whose tegument have not yet hardened are used in Asiatic countries as a vegetable, fresh or pickled. Ripened fruits are eaten fresh everywhere, can be made into juice or marmalade, or dried and made into candy. All remnants from the fruits can be used as animal feed; most commonly for pigs. The young leaves are very good as cattle feed, because they have a protein content of 8-9% as well as a high Ca content. The bark and leaves of mango trees can also be used as a dye for cloth. The wood of the trees is highly suitable for making charcoal.

Diversification strategies

In Africa, mangoes are planted in the mixed crop systems of the house gardens in small farm holdings, or on extensively cultivated meadows and marginal ground, where relatively acceptable harvests can be achieved.

On organic farms, mango trees should be integrated into a mixed crop system. This will reduce the risk of pests through a large population of useful insects.

Annual plants such as maize and beans can be planted during the early growth period, according to site conditions. If the soil and climatic conditions allow, more demanding crops such as papaya (a culture with a 3-5 year vegetation period), bananas (20 years and longer) as well as avocado, mangosteen (*Rheedia ssp.*), corossol (*Anona muricata*), coconut, lemons, nutmeg and many more can also be planted along with mango.

The following criteria should be heeded when choosing plants to include in a cultivation system with mango:

- Intercropping plants as well as green cover crops cannot be watered for a 2-month phase during the dry period or the mangoes will form an insufficient amount of blossoms.
- The bottom crops should not contain a high percentage of legumes, because the accumulation of nitrogen would otherwise inhibit the growth of the Mango tree, which then limits the production of fruit.

Harvest and post-harvest handling

Treatment

With hundreds of varieties, mangoes are differentiated by:

- Weight (250g to 2kg);
- Shape (oval, pear or kidney-shaped);
- Color of the skin (green, yellow, orange-yellow, orange-red);

- Taste (more or less aromatically sweet).

The flesh is yellow to yellow-orange, juicy, and has varying fiber content according to variety. Fruits with high fiber content are generally not sold as fresh fruit, but are processed to remove fibers. Mangoes have many different uses. Ripe fruits can be eaten fresh, or processed into juice, pulp, concentrate, candied fruits, jams, chutneys, canned fruits or dried.

If the mangoes are to be sold as fresh fruits, they must be treated with warm bath water to remove any dirt or fungi from the peel. It is recommendable to place them in a 55°C water bath for 5 minutes and then let them cool down slowly. Afterwards, they are dried, sorted, classified, packed and stored before shipment.

Harvesting
A mango plantation will supply its first commercially marketable amount of fruit around 4-5 years after being planted. At the end of the fruit's development period, the peel will turn leathery. The fruit is ripe for harvesting when the skin has turned from green to red, or yellow.

Some farmers wait to harvest until the first fruits have fallen to the ground. Yet, because the fruits fail to ripen at the same time, the color change must nevertheless be checked regularly. The fruits are harvested by breaking them off or with a pair of scissors. A pair of steps or a cherry-picker will be needed for tall trees. With medium tall trees (up to 4 m), the fruits can be picked individually with the help of a harvesting rod. Too many fruits should not be placed into one sack in order to avoid bruising them. Such fruits will not keep for long, and cannot be sold as fresh. Any damaged fruits should be separated during harvesting to prevent the spread of fungus infections.

Post harvest treatment
Usually, post harvest handling is not required. For safety reasons, treatment with warm water is recommended and is absolutely necessary in cases of anthracnose infection.

The fruits are packed into sturdy cases. They are sorted visually, because machine sorting is expensive and complicated. For export to Europe, sizes from 270g to 335g are preferable. The fruits are generally packed in untreated wood wool, free from harmful substances, to prevent them lying too close to one another.

The cases must also be well aerated. Cartons which hold 5kg of fruit have become standard for export to Europe, as this size is also easily managed in the retail business.

Packaging and storage

Packaging
The regulations concerning carton labeling were dealt with in the following section of the "UN/ECE standard FFV – 45 for mangoes".

Storage

- Mangoes that are not fully ripened and are to be shipped by sea should be stored at a relative humidity of 90% and not under 12°C.

- Fully ripened mangoes that are to be shipped by sea should be stored at a relative humidity of 90% and at a temperature of 10°C.

Product specifications and quality standards
The "UN/ECE standard FFV – 45" defines the quality requirements for trading with fresh mangoes. These do not necessarily have to be adhered to, but rather serve as recommended guidelines. Mangoes intended for export are not included.

Different minimum and maximum values can be agreed upon between importers and exporters, providing they do not clash with official regulations.

<u>The following is an excerpt from "UN/ECE standard FFV – 45 for mangoes"</u>
(I) Defining Terms
These standards apply to mangoes *Mangifera indica L*., which are delivered fresh to consumers.

(II) Quality Characteristics Regulations
a. Minimum Requirements
The mangoes must be as follows:
Fresh and healthy
- Clean, practically free of visible foreign substances;
- Practically free of pests and damage caused by them;
- Free of fungus;
- Free of bruising and frost-damage;
- Free of strange taste or smell;
- Well developed, ripe.

b. Classifications
Mangoes are sold in three categories:
- Class Extra. Mangoes in this class must be of the highest quality. They must possess the characteristics typical of their variety and/or trading type. The fruits must be unblemished, with the exception of very light surface flaws that do not detract from the fruit's general appearance, quality, the time it will keep.
- Class 1. Mangoes in this class must be of good quality. They must possess the characteristics typical of their variety and/or trading type. The following blemishes are permissible, providing they do not detract from the fruit's general appearance, quality, the time it will keep and the presentation of the bunch or cluster in its packaging:
  - Slightly misshapen
  - Light flaws in the skin caused by friction or by other means, providing the area does not exceed 3, 4 or 5 cm2 of the total surface area of the appropriate size class A, B, or C.
- Class 2. This class is composed of those mangoes that cannot be placed in the upper classes, yet which fulfil the definitions of minimum requirements. The following faults are allowed, providing the mangoes retain their essential characteristics in terms of quality, preservation and presentation:
  - Shape defects,

- Skin flaws, caused by scratches, friction or other means, providing the area does not exceed 5, 6 or 7 cm2 of the total surface area of the appropriate size class A, B, or C.

(III) Size Classification Regulations
Mangoes are sorted according to their weight. The fruits must weigh at least 200 grams.

Size Classes	*Weight*	*Maximum Differences in Weight within a Class*
A	200 - 350g	75g
B	351 - 550g	100g
C	551 - 800g	125g

(IV) Presentation Regulations
a. Uniformity
- The contents of a carton must be uniform, and may only contain mangoes of identical origin, variety and/or trade type, and quality.
- The visible part of the carton must be representative of the entire contents.

b. Packaging
- The mangoes must be packed in a way that ensures they are sufficiently protected.
- Packing material used inside the carton must be new, clean, and so shaped that it cannot cause any damage to either the inside or outside of the fruit. The usage of materials such as papers and stickers with company details on them is permitted providing the no toxic inks, dyes or glues have been used.
- The packaging must be free of all other materials.

(V) Regulations of Carton Labeling
Each carton must display the following details in unbroken, legible, permanent letters visible from the outside:

a. Identification
- Name and address of the exporter and packer.

b. Type of Product
- “Mangoes”, when the contents are not visible.
- Name of the variety.

c. Origin of Product
- Country of origin, and optionally, national, regional or local description.

d. Commercial Characteristics
- Class.
- Size (expressed in min. and max. weight).
- Size code (optional).
- Number of fruits.

Watermelon

Watermelon *(Citrullus lanatis)*.

Suitable varieties for organic production

Best market varieties fulfill characteristics such as strong rind for better transportation, small mesocarp (the white part between the rind and the fruit flesh) and sweet and juicy flesh. Seedless varieties also exist, but cause higher seed costs (and needs to be explained to the consumer as fruits are not 100% free of seeds). In general, the selection of the right variety depends on different factors such as site conditions, local availability, market demands and resistances (in case of water melons some varieties are resistant against Fusarium, Anthracnose, etc.).

Propagation and Nursery Management

Direct sowing is possible but not recommendable when dealing with seedless varieties or less than ideal site conditions. The latter would increase the germination time and delayed development in the plant. Watermelon vines require space; therefore, the following practices are suggested:

- Plant seeds 3cm deep in hills spaced 2m apart.
- Allow 2-3m between rows.
- After seedlings are established, plant single transplants 60-90cm apart in the rows, with an optimum maximum of three plants per hill.
- To replace failures, it is best to prepare seedlings inside. Start the seeds 3 weeks before they are to be set out in the field. Plant 2 or 3 seeds in pellets, pots or cell packs and thin to the best one or two plants.

For expensive seedless types, plant one seed to a pot or cell and discard those that do not germinate. Do not start too early - large watermelon seedlings transplant poorly. If you grow seedless melons, you must plant a standard seeded variety alongside. The seedless melon varieties do not have the fertile pollen necessary to pollinate and set the fruit.

Harvest and post-harvest handling

Handling

Harvest generally begins about 30 days after full bloom and continues for several weeks with 3 to 4 cuttings at 3-to-5-day intervals. Ripeness in watermelon is difficult to determine because the fruit remains attached to the vine, rather than “slipping” off. The flesh of a typical red-fleshed watermelon changes from immature pink to red-ripe, and then to overripe within a 10-to-14 days harvest window. Overripe fruits have a watery, mushy texture and lower sugars. Rind color changes indicating maturity, if any, are specific to cultivars. The “Golden Midget” variety turns yellow as it ripens, and “Sugar Baby” becomes dark green and loses its stripes. Generally, however, the only indication of ripeness is that the tendrils of the leaf closest to the fruit attachment become dry.

Additional ripeness indicators include a change in ground spot color from greenish-white to pale yellow. The rind becomes hard to pierce with the fingernail and the blossom end “fills out”. When ripe, there is also a “bloom” or powdery coating giving the fruit a duller appearance and a rough feel. Although researchers are experimenting with various non-destructive gauges of fruit soluble sugars, the usual method for timing the start of watermelon harvest is to cut open a few representative melons in the field.

If the field has received abundant water, the watermelons may crack open, especially if harvested in the morning when they are full of water (turgid). The risk of cracking can be reduced by harvesting in the afternoon and by cutting the stem rather than pulling the fruit off. Stacking watermelons on their side, rather than on their end, also reduces the risk of cracking.

Cut watermelons must be shaded to minimize additional heat build-up and because direct sunlight after harvest (especially on the ground-spot) reduces watermelon quality. If plants are not too turgid, field heat can also be minimized by harvesting in the morning. Watermelons should be dry when loaded, however, rather than dew-covered. They are either bulk loaded into straw-padded trucks, or placed in multi-walled corrugated fiberboard bins holding 60 to 80 melons and weighing 500 to 550kg when fully loaded (which corresponds to an average weight of 7.5kg per melon). Transit temperatures should be 7 to 10°C. Watermelons are stored at higher temperatures and lower humidity than muskmelons (10° to 13°C, 90 percent relative humidity). Storage for prolonged periods below 10°C can lead to chilling injury; one week at 0°C can cause pitting, color loss and off flavors. At 10° to 13°C, they can be kept 2 to 3 weeks after harvest. Even within this range, however, the red color is gradually lost.

Although watermelons do not ripen off the vine, flavor and color in seeded watermelons will improve over a 7 day holding period at room temperature.

Banana production

Introduction

Bananas constitute the fourth most important global food commodity (after rice, wheat and maize) grown in more than 100 countries over a harvested area of approximately 10 million hectares, with an annual production of 88 million tonnes (Frison and Sharrock, 1999).

The term banana refers to all types of bananas including cooking bananas. Bananas with all its species, varieties or hybrids belong to the genus *Musa*, order *Zingiberales*, family *Musaceae*. The genus *Musa* contains up to 40 species, with all wild species and native to South East Asia (Stover and Simmonds, 1987).

Banana (*Musa species x Paradisiaca*) is an important crop in sub-Saharan Africa, where besides consumption as food, bananas have cultural and medicinal values. There are many types of bananas grown in Africa, but depending on how bananas are utilised, they can be broadly grouped, as follows:

- Dessert bananas include Cavendish, Red Bananas, Apple bananas and Gros Michel. These are consumed as ripe fruits (table bananas). Most cultivars are susceptible to nematodes; Sigatoka leaf spots and Fusarium wilt although they are generally tolerant to weevil attack. Cavendish cultivars are the most popular and valuable of the dessert bananas and are traded worldwide.

- Cooking bananas include the East African highland bananas (EAHB) and many other types of plantains consumed as cooked or roasted bananas. The EAHB are said to be endemic to the East African region and grow comfortably at higher altitudes (above 1000m asl). Also, most plantains are lowland varieties and are very susceptible to weevil attack.
- Beer bananas cultivars are used mostly for production of banana juice which is directly consumed or used for making banana beer, wine or spirits.
- Multipurpose bananas include a number of improved cultivars such as the FHIA hybrids. These have multiple uses from being used as dessert bananas to juice production. They are also tolerant to nematodes.

Botany

Edible bananas contain no seeds. Reproduction is carried out via its subterranean rhizome, the shoots of which regularly form fruitful buds. The banana plant possesses a so-called pseudo-stem, which is created by the leaf sheathes. Inflorescence usually begins around 7-9 months after planting, depending on climatic conditions and type of soil.

Bananas are reproduced vegetatively. In accordance with availability, required amounts and transport possibilities, the following are suitable:

- Whole rhizomes; and
- Rhizome pieces;
- Shoots with inflorescence in the pseudo-stem; and
- Shoots lacking inflorescence in the pseudo-stem.

Using whole rhizomes is laborious. It requires a large amount of starting material and generates high transport costs. Rhizome pieces and shoots lacking inflorescence in the pseudo-stem are less expensive.

It is very important that the shoots are undamaged, and originate from nematode-free plantations. Prior to planting, the roots and any damaged spots should be removed with a sharp knife.

Methods of planting

Bananas are a perennial tropical and subtropical crop, which grow in a wide range of environments. However, the banana production systems can be divided into three broad categories depending on the number of cultivars grown and the intensity of management.

a. Backyard garden system

Banana is grown in a highly integrated system especially in peri-urban areas where land is limited. Bananas are grown mainly for food in combination with other enterprises like zero grazed animals or vegetable gardens to supplement nutritional or peri-urban market needs. This is a low input system and normally no proper pest and disease management is performed.

b. Perennial agroforestry system

Bananas are intercropped with perennial crops like coffee, vanilla, cocoa or fruit trees. Bananas serve as a middle storey shade crop, but also provide food for household needs. Any surplus is sold to the market. Different cultivars are normally grown together depending on the location and the intended use of the bananas. The plants are not replaced until they die of senescence or pests and diseases. This is a low input system and many pests and diseases are either partially controlled or not controlled at all, making banana production highly vulnerable. However, it is the most common production system in most banana producing areas in Africa.

c. Commercial plantation
This is performed as “single cultivar” monoculture system, comprising dessert banana cultivars which have good export potential. Management of these plantations is characterized by careful selection of cultivars/varieties and very often intensive use of synthetic fertilizers and pesticides. Well-defined crop cycles usually last 2 to 5 years after which all plants are uprooted and replaced.

Challenges to banana production in Africa

Production of bananas in Africa is, however, threatened by many challenges, including:

- Pests and diseases are the main threat to banana production. Traditional banana cultivars have been severely damaged by a wide range of pests and diseases, resulting in heavy yield losses. For example, bacterial wilt and Fusarium wilt are serious threats in many sub-Saharan African countries leading to 100% losses. Nematodes, banana weevils, Sigatoka leaf spots and banana bunchy top virus disease have also caused immense damage to plantations. Most farmers lack information on proper management of these infections so they continue to spread them unknowingly.
- Low productivity is mainly due to poor soil fertility management, water conservation and husbandry practices. In highland areas, banana plantations are not terraced and yet many trees are cut out of the garden. Running water from uphill washes down the topsoil and mulch. Bananas require good soil moisture. Many suckers are left per banana stool, pruning and removal of male buds is either done late or not at all. Crop cycles are not regulated whereby the same garden of bananas is left for a long time without rotation or replanting. Suckers for establishing new gardens are carried with all their roots from one village to another, thereby spreading pests and diseases.
- Hailstorm and wind damage can affect bananas production. Bananas have shallow spreading roots, weak stems and leaves. This makes them very susceptible to strong winds and hailstorms especially during the fruit bearing stage. This is a common problem in monoculture banana plantations where trees are cut for other purposes and in highland areas.

Discussion with farmers: assessment of the local situation.

- Inquire about the local practices in banana production and the common challenges faced in banana production:
- What challenges farmers experience?
- How do farmers tried to address them?

Improving management of banana pests and diseases

Bananas are susceptible to a wide range of pests and diseases. Some of these pests and diseases are highly destructive and very contagious (easily spread), and once introduced they are persistent and difficult to eradicate.

The severity and occurrence of pest outbreaks and plant damage depends on the prevailing environmental conditions, specific banana cultivars, and the specific disease or pest. However, most of these can be managed and controlled by implementing organic production practices.

The main approach in organic pest and disease management in banana production is prevention and proper management of infections to restrict spread and multiplication. With proper implementation of cultural practices (e.g. soil fertility improvement, crop rotation, use of resistant varieties and clean planting materials, proper sanitation in the field and rouging of infected plants) many of these pests and diseases can be effectively managed. This is also necessary because most the destructive diseases cannot be eradicated by direct control methods.

Establishing a new banana garden

A site with deep, well-drained and fertile soils, preferably rich in organic matter is good for banana production. It will encourage the development of strong plants that can tolerate infections. A newly opened land without signs or history of nematodes or the devastating Fusarium wilt and bacterial wilt diseases is preferred.

If the site has been used for production of bananas in the last two years, it is highly recommended to remove all remaining banana plants and corms. Normally such remnants harbor a lot of pests and diseases. The remnants should be transferred into another field (not of bananas), chopped and spread to dry or composted.

The land should then be planted with a legume crop (like beans) or left to fallow with a legume green manure cover crop for 1 to 2 years. This will ensure that any remaining pest or disease infections are completely removed before introducing new banana plants.

All perennial weeds should also be removed and destroyed before planting because bananas are very susceptible to weed competition. Some of the existing trees at the selected site should be left during land clearing in order to protect the young banana plants from wind and strong direct sunshine.

Selection and preparation of planting material

Sound management of banana pests and diseases begins with a careful selection and handling of pest and disease free and, where possible, resistant planting materials. The right cultivars and varieties should be selected with respect to the disease problems prevalent in a given location.

Some cultivars are resistant to certain diseases like Cavendish and highland cooking bananas, and varieties like FHIA 17 (*Cavendish variety*), FHIA 23 (*Gros Michel variety*) are resistant to the devastating Fusarium wilt (*Panama*) disease. Clean planting materials of superior banana cultivars that are resistant to diseases exist, and can be obtained through local extension officers and research stations. It is advisable to plant different cultivars and/or varieties in the banana plantation. In case a variety or cultivar is attacked by certain pests or diseases, then the whole field will not be wiped out.

Bananas are propagated using suckers or corms from the mother plant. Generally, well treated suckers/corms are highly recommended because they are free of pests and diseases. Suckers for planting should be carefully selected and prepared to minimise spread of pests and diseases. They must be obtained from pest and disease free plantations. Sword suckers are preferred because they are usually less infected with nematodes and weevils than bigger suckers.

Recommendations to farmers for preparing planting seedlings

Planting materials should be prepared in the field from where they are being obtained to limit the transfer of infections into new fields.

- Remove all leaves, outer leaf sheaths, roots, dead parts of the plant and pare the corm (trim off part of the corm) to eliminate weevils, weevil eggs and nematodes. Any brown and black spots that may appear on the corms should also be removed until only white corm tissue remains.
- It is recommended to treat the suckers to clean them of any infections. This is done by soaking the suckers in soapy water over night to eliminate weevil eggs and nymphs. Alternatively, the suckers can be treated by soaking the base of the plant in hot water (about 60°C) for 10 minutes. This will kill all nematodes in the outer layers of the sucker. A 10% household bleach solution (100ml of solution in 1lt of water) is also useful for disinfesting corms. Submerge the base of the suckers into the solution for about 20 minutes. Treated suckers should be planted within one week to avoid being re-infected.

Recommendations to farmers for planting a banana garden

Farmers should be advised on how to set up a banana garden by following these simple guidelines as:

- Mark out rows with a spacing of 3m*3m (10f*10f) to get the proper plant population of 450 plants/acre. This helps to avoid competition between banana plants and limits spread of pests and diseases from one plant to another.

- Dig out planting holes 60cm*60cm*60cm (2f*2f*2f) while placing the top soil and subsoil on separate sides of the planting hole. This ensures that during planting, the top soil mixed with manure/compost will be used for refilling the hole.
- Plant bananas at the beginning of the rainy season so newly planted plants receive enough water for quick establishment. When planting, do not completely fill the planting hole. Leave a shallow basin of about 1ft to enhance harvesting water for the young plant. Later during growth, this also provides a conducive environment for producing new suckers away from the mother plant.

Routine management practices

Some management practices are helpful in both strengthening the growing banana plants and in minimizing the spread of pests and diseases. However, these practices need to be routinely applied together as a package as leaving one practice may undermine the benefits achieved from the others.

a. De-suckering

Competition between suckers depletes soil fertility very fast and results in weak plants which are very susceptible to infections. About 3 to 4 suckers should be maintained per stool in order to ensure strong plants and good yields. Any extra suckers should be removed when they are still young. Suckers at different growth stages (mother, daughter and granddaughter) on the opposite side of the mother plant, should be chosen, also to avoid competition for light. De-suckering should be done well, so that pruned suckers do not grow up again. The sucker pseudostem should be cut off near its corm and the sharp point of the knife twisted into the growing point to kill off the sucker permanently. During this operation, care must be taken not to harm other daughter plants.

In the course of time, the banana plants tend to grow away from the original space whereby the gaps between the plants become smaller. At this point, it is necessary to remove the plants that stand close to each other. If the original pattern of the banana plantation becomes completely distorted, then the plantation should be cleared and newly planted.-

b. De-leafing

Old leaves and sheaths are susceptible to infections and can host infections if not removed in time. Removal of old leaves helps in management of the Sigatoka leaf spots, limiting its spread to young leaves and plants, while the removal of old sheaths eliminates hiding places for adult banana weevils. In addition, old leaves that hang downwards shield the young plants from sunlight. It is recommended to remove all old leaves and sheaths that have attained natural senescence and use them as mulch.

It is, however, important that enough leaves are left on the plant to produce a good quality bunch. The average number of leaves per banana plant should be 8 to 10 leaves at flowering and 4 at harvest. Complete de-leafing of the plant prior to harvesting is not recommended as this starts the ripening process, before the plant is actually ready.

c. Cutting off male buds

Removing the male buds early also helps reduce the spread of diseases like the banana bacterial wilt, which can be transmitted by bees collecting nectar from the banana male buds. Care should be taken not to damage the hands of the bunch while removing the male buds. Male bud removal also encourages quicker development of the young bunch.

Management of specific pests and diseases

Banana weevils and nematodes are the most important pests of bananas, attacking nearly all banana cultivars. On the other hand, banana has a multitude of diseases which can cause significant yield losses if not well managed.

For example, the black sigatoka, bunchy top disease, streak virus disease, and the highly devastative bacterial wilt and Fusarium wilt (panama) diseases.

a. Banana weevil (*Cosmopolites sordidus*)

The Banana weevil is a very damaging banana root borer. The larvae bore into corms, suckers, and roots and lead to extensive root destruction. This leads to stunted plant growth and eventually premature toppling of the plants and plant death.

Recommendations to farmers for management of the banana weevil

- Use clean planting materials for planting new banana plantations;
- In heavily infested gardens, crop rotation is highly recommended. Progressively destroy the garden and remove all banana plants and their corms. Chop them to dry or compost them and plant other crops in the field for 1 to 2 years. Make sure all corms/roots are destroyed;
- Ensure field hygiene. It is a common practice to split the pseudostem after every harvest. The stem is split open and the sheaths are spread out to dry so that weevil eggs and larvae are destroyed. The sheaths should, however, be laid about 2ft away from the banana stool, like any other mulching material in a banana plantation. Do not move banana residue material (pseudostems, corms, sheaths) from one field to another to limit transmission of weevils;
- Trap the weevils. Laying traps to catch banana weevils and killing the weevils collected from traps can be an effective method of controlling weevils especially in small gardens. The weevils are mobile at night and can be trapped by baiting the field with slices of banana pseudostems. Traps should be cleared every 3 days so that they do not become a breeding ground for the weevils. All trapped weevils should be picked from the baits and destroyed or fed to poultry.
- Keep the banana stool clean. Mulching materials or any debris should not be put close or within the stool to deny weevils a hiding place. Also, any banana plant remains from infected gardens should not be used as mulch in clean banana gardens.
- Use natural pesticides, such as wood ash, tephrosia leaf dust, chilli preparations with animal urine, tithonia leaf extract, and neem oil. These materials should be applied at the base of the plants around the stool and around infected pseudostems. However, it is important for certified organic farmers to check with their certification body before using any factory-made products for weevil control.

Also, it would be useful to have working groups on field identification of banana pests and diseases. Extensionists can organize field visit with farmers to different banana fields and identify any observable signs of pest or disease problems. Ask the farmers to analyze the signs of infection and identify the pests or diseases.

b. Nematodes

Radopholus similis and *Pratylenchus goodeyi* are the most damaging nematode species on bananas. Nematodes are microscopic (not visible with the naked eye) pests, which feed on banana roots. They destroy the roots and reduce uptake of water and nutrients. With damage to the roots, plants will lose stability and topple down.

It is, however, hard for farmers to distinguish between damage caused by the nematodes and the banana weevils. Nematode attack will cause the plant to topple down with all the roots exposed (the whole plant is uprooted) while weevils will cause the plant to break from the base at the soil level. New fields become infested with nematodes when suckers from infected fields are used; nearly all suckers will be infected with nematodes in an infected field. Cooking bananas and plantains are particularly susceptible to nematodes.

Recommendations to farmers for management of the banana nematodes

- Use clean planting materials to ensure that no infections are introduced into the new fields;
- Crop rotation is highly recommended;
- Increase soil fertility by adding of compost in planting holes, top-dressing with organic manures and mulching with organic materials increases soil life activity and has a negative effect on soil pests like nematodes. It encourages establishment of stronger plants that are less susceptible to toppling as a result of nematode infestation.
- Field hygiene. Besides planting materials, nematodes can also be spread through soil carried on farm tools, farmers shoes/feet and banana residues, mainly corms. Therefore, ensure that cleaning is done of all tools and farmers shoes/feet before entering a healthy garden. Banana corms should not be shared between gardens to limit the spread of nematode infections.

Disease management

a. Bacterial wilt

Bacterial wilt is the most destructive banana disease, attacking all types of bananas. It is caused by *Xanthomonas campestris pv. Musacearum*. Infected plants show premature ripening and staining of fruits, yellowing of leaves, the male bud dries prematurely and a pus-like liquid flows when the stem is cut. The infection is spread when farm tools and infected plant parts are moved from infected to healthy gardens. It is also spread by pollinating bees visiting male buds of infected plants and passing the infection to male buds of healthy plants.

To effectively manage the bacterial wilt disease, participatory and community action is normally necessary. Local leaders, NGOs, extension and research staff can be very helpful in mobilizing communities to implement strict quarantine practices.

Recommendations to farmers for management of the banana bacterial wilt

The disease can also be managed by employing the following measures:

- Destroy all plants showing symptoms of bacterial wilt. At the very first show of any signs. Cut the entire plant and heap to rot or bury, to limit the spread of the disease.

All tools must be disinfected by flaming them over fire or by cleaning them with Sodium hypochlorite or any other bleach solution.

- Use clean planting materials. Use tissue materials or treat banana suckers to ensure that no infections are introduced into the new fields.
- Crop rotation. After uprooting all banana material from the infected plot; grow other crops for a period of at least 2 years, followed by re-cultivation with pest-free banana planting materials.

b. Fusarium wilt

Fusarium wilt is caused by the soil borne fungus, *Fusarium oxysporum f.sp cubense (Foc)*. It spreads mostly through infected suckers, soil attached to plants, tools and shoes/feet. As the disease disrupts the plant's water vessels, leaves become yellow progressing from old to young leaves. The leaves then collapse at the petiole forming a skirt around the plant. Vascular tissues (pseudostems, corm leaf stalks), will also show discoloration to yellow, pale and dark red lines (i.e. infected vessels).

Gros Michel and apple bananas are highly susceptible to Fusarium wilt. The fungus can survive in the soil for many years (up to 30 years) and is thus very difficult to control. Fusarium wilt can be distinguished from Bacterial wilt by the absence of symptoms in young suckers of less than 4 to 5 months of age.

Recommendations to farmers on management of the banana Fusarium wilt

- Always use resistant cultivars or varieties - This is the most cost-effective and sustainable method of controlling the Fusarium wilt in the field. Resistant varieties include: Cavendish, FHIA 17, FHIA 23 and other hybrids.
- Field hygiene. It is recommended to destroy infected gardens; remove all banana plants and their corms. Chop them to dry or compost them to limit the spread of infection. Plant the field with other non-susceptible banana cultivars (cooking bananas, Cavendish, or other hybrids). Select new clean fields for replanting with clean banana planting materials. Ensure that proper cleaning is done of all tools and farmers shoes/feet (dipping in a 10% Sodium hypochlorite solution) before entering a healthy garden. Banana corms should not be shared between gardens to limit the spread of nematode infections.

c. Black sigatoka

Black sigatoka is also called Black leaf streak (caused by fungus *Mycosphaerella fijiensis*). It is the most important leaf disease that reduces yields. The disease causes severe discolouration and leaf necrosis, reducing the effective photosynthetic area dramatically and leading to poor fruit formation and small fingers.

As the pathogen can be spread by wind or water, it becomes difficult to control.

Recommendations to farmers for management of the Sigatoka leaf spots

Sigatoka leaf spots can be managed by applying the following cultural practices to improve host resistance and minimize the spread of infection:

- Improve soil fertility - Enhancing plant nutrition has been found to reduce leaf spot impact. A fertile soil encourages quick growth of the banana plant before significant leaf tissue is destroyed by the pathogen.
- Maintain proper spacing. As banana trees grow and produce suckers, there is a possibility of the space between neighbouring plants to reduce. It is important for the farmer to regulate the space between plants such that plant leaves from adjacent plants do not touch and rub against each other. This will limit the spread of sigatoka leaf spots.
- Ensure field hygiene. Remove old leaves and mulch them in non-banana gardens to limit infecting young leaves and plants and banana leaves and stalksshould not be shared between gardens to limit spread of infections.

Find out the most problematic pests and diseases in the area asking the following questions:

- Which banana pests and diseases are common in the area?
- How do you prevent the introduction or spread of these pests or diseases?
- What do you do when an infection is identified in the banana plantation?

Improving the productivity of the banana plantation

Intercropping

During the first two years of banana establishment, a good amount of space exists between the rows of bananas. This space should be planted with seasonal crops that do not compete with bananas in order to protect the soil from erosion, but also to provide extra harvest for the farmer.

Using leguminous intercrops also contributes to soil fertility improvement directly by fixing nitrogen or indirectly by providing mulching material. Common intercrops include legumes like beans, groundnuts and soybean or vegetables like cabbage and tomatoes.

Bananas can also be intercropped with coffee, vanilla, cocoa, avocado, passion fruits, pineapples, or paw-paws. A minimum distance of 60cm should be maintained between the banana plants and the intercrops.

Trees are also needed in a banana plantation for providing shade and for protection from strong winds. Strong winds shred banana leaves and can lead to serious toppling, especially in tall cultivars. In areas with strong winds, it is important to establish windbreaks long before planting bananas. Such trees will need regular pruning to avoid too much shading during early growth. New planting of shade trees can also be done at the same time as planting of bananas.

In either case, trees should combine well with other crops to form a banana agroforestry (multistorey) system.

However, shade in the banana plantation needs to be regulated; too much shade causes elongation of the plants and results in small bunches. Shade trees should be pruned regularly, especially at the beginning of the rainy season to reduce overhead shading.

Banana agroforestry (multi-storey) system

The banana garden should be established in a mixture of tall and short crops to form a multi-storey system. Multi-storey means that there are different layers of plants growing to different heights in the system. Three levels (storeys) are important in a banana agroforestry plantation:

a. Crops of the upper storey (shade)

- Shade trees protect the plants against strong winds and hailstorms. Common tree species that can be used as shade trees include *Grevelia robusta*, *Ficus natalensis*, *Albizia coriaria*, *Mesiopsis eminii*, *Cordial africana*, *Acacia* or *Erythrina spp*. Fruit trees such as mango, avocado or jackfruit can also be included at intervals.

b. Crops of the middle storey

- Depending on the needs of the farmer, fruit trees (e.g. citrus, paw paws), coffee, cocoa or vanilla can be integrated as middle storey crops. However, these should be included at a much wider spacing since bananas themselves feed at this level. Multipurpose leguminous trees can also be planted within the garden or along the boundaries (*Leucaena diversifola*, *Calliandra calothyrsus*, *Sesbania sesban*, *Gliricidia sepium*). They fix nitrogen into the soil and also provide mulch for the field when pruned. *Glyricidia sepium* and *Leucaena leucocephala*, should always be cut back at the banana plant's height once a year, so that around 15% of their leaves remain.

c. Crops of the under-storey

- The under-storey will com prise the annual crops that will be intercropped with bananas during early growth. As the plants grow bigger, the ground cover will then be replaced with green manure legumes. Legume ground covers are preferred as under-storey crops, for example, jack bean (*Canavalia ensi formis*), or Lablab (*Lablab purpureus*). Any other perennial non-climbing species can also be used but they should be regularly pruned.

Improving soil fertility

Healthy soil provides the foundation for a healthy banana crop and sustainable production. There are two approaches to building a fertile soil in a banana garden.

First is to prevent soil, organic matter and water loss. Second is to grow crops that feed the soil or directly add organic manures, compost and other organic amendments to improve the soil organic matter content and nutrients.

Soil and water conservation measures

Water stress affects banana yields by influencing the size of the bunch and the fingers. It is, therefore, important that banana farmers make all possible efforts to conserve as much water as possible in the banana fields.

Making soil bunds or terraces depending on sloping terrain is needed in order to trap runoff water. The terraces should further be stabilized with grass and legume shrubs. Shade trees also assist in conserving moisture within the plantation.

Mulching is very important in a banana plantation. It conserves soil moisture, improves soil structure, limits weed growth and controls soil erosion. When mulching, lay mulch across the slope and place it about 2ft away from the banana stool. Mulching too close to the stool provides hiding places for weevils and encourages bananas to produce suckers too close to the mother plant.

The mulch should be maintained because banana roots develop just below the mulch where there is good moisture. Such roots will dry off under strong sunshine when there is less mulch. It is highly recommended for banana farmers to grow their own mulch close to the banana plantation or along soil bunds and partitions within the banana plantation. This is the best way to ensure a constant cheap supply of mulching materials. Common sources of mulch used in bananas include

Elephant grass (*Pennisetum purpureum*), Guatemala grass (*Tripsacum laxurn*) and wild sunflower (*Tithonia spp*). Crop residues such as coffee husks, bean husks, maize stover and sorghum stover can also be used for mulching bananas.

Leguminous cover crops such as jack beans (*Canavalia ensiformis*), velvet beans (*Mucuna pruriens*) or Lablab (*Lablab purpureus*) also provide a source of mulching in the understorey. They suppress weeds, fix nitro gen and control soil erosion. However, cover crops should be pruned regularly so that they do not compete with the banana plants.

Organic manures and compost

The majority of banana varieties cultivated for export purposes require a high soil quality. In natural forest ecosystems, they appear towards the beginning of the new growth, and must be replaced by other species about every 10-15 years. If this is not carried out on the plantation, then sooner or later a crisis will occur, which can only be solved in the short term by applying fertilizers and pesticides.

Regular application of organic material gained from cutting work helps to maintain a layer of humus and activity in the soil. This includes adding dead leaves and pseudo-stems grown on the plantation as mulching material. It is important that the material is spread evenly throughout the entire plantation.

Organic manure should only be seen as an additional fertilizer, and not as the main source of nutrients for the bananas. These measures will suffice to maintain the fertility of the soil on sites suited to growing bananas, despite continual harvests.

Beside adding organic materials, compost and animal manures should also be applied. Compost is best applied in the planting holes of young banana seedlings while animal manures should be added, whenever available, as a top-dressing but most importantly close to the flowering stage to improve growth and productivity.

Poultry manure is preferred because it is particularly rich in nitrogen (N). There are also a variety of other local amendments that have been used to improve banana yields:

- Wood ash from the kitchen is also a good source of potassium (K);
- Animal urine (including human urine), is a good nitrogen source and if mixed with hot chilli, has also proved effective in weevil control.

A group work on soil fertility management in banana plantations can organise a field visit to selected banana plantations. Farmers can examine the soil and make recommendations on how soil fertility can be improved in the different plantations.

Weed management

Banana trees are highly susceptible to weed competition especially during the first year of establishment. Therefore, timely weeding is necessary to achieve good yields. Weed management can be achieved by mulching, cover cropping or mechanical means.

During early growth (up to one year), when annual crops are still intercropped within the young banana plants, mechanical weeding is feasible. After 1 to 2 years, usually no weeding activities are necessary. At this stage, digging/tillage in the banana plantation is not recommended to avoid damaging banana roots. Usually, most banana roots do not go deep (less than 30cm depth), but they spread out widely forming a mat of up to 1.5m in width. Damaging the roots through tillage reduces their capacity to take up nutrients and water.

Mulching and zero tillage are recommended practices in a banana plantation. Mulching limits weed growth while zero tillage improves soil structure and minimizes damage to banana roots.

A useful tool would be a discussion with farmers on how improving productivity of banana plantations. Extensionists can ask farmers to give examples of local species of trees that can be grown with bananas. Also, what other benefits do these trees provide and how should these trees be managed within a banana plantation?

Post-harvest handling

Under the weight of a maturing banana bunch, stems are likely to break under the weight of heavy bunches. Although this may be more common among tall cultivars than shorter ones, it is important to provide support to banana stems when bearing fruits. As the weight of the bunch increases, the pseudostem should be supported with a wooden pole to prevent it from breaking under the weight of the fruit. Forked poles are normally used to keep the stems upright and support the weight of the bunch.

Bananas are harvested throughout the year. With a good de-suckering plan, it is possible for a farmer to harvest 3 to 4 times a year from each stool, depending on the variety and cultivar of the banana. Whilst still green, the fruits have a distinctly edged appearance, which gradually becomes almost round as they ripen.

The cooking bananas are harvested green and dessert bananas should also preferably be harvested while still green. Normally the duration of transport to the market determines in which stage of ripeness the fruit should be picked. While harvesting, care should be taken to see that bunches do not fall to the ground. Hitting the ground causes bruises which reduce the quality and can be starting points for rotting. Harvested bunches should be kept under the shade and should not be heaped together without sufficient ventilation. Piling up bananas without good air flow quickens ripening.

Harvesting the banana bunches is usually spread evenly throughout the whole year. A slowing down in production, or even cessation, only generally occurs at sites which experience either a noticeable drop in temperature during the winter months, or distinctive dry periods.

Whilst still green, the fruits have a distinctly edged appearance, which gradually becomes almost round as they ripen. The fruits of a bunch do not ripen at the same pace. If some fruits have begun to turn yellow on the plant, then it is already too late to transport them any great distance, as they quickly become too soft and burst.
The bananas must therefore be harvested while still green. The optimal cutting stage is established by the diameter of individual fruits. To simplify the harvest, the bushes are marked with different colored bands as the fruits appear.

The workers will then only cut bananas of a particular color, which are now ripe enough. Terms which characterize the thickness of the fruit, such as “three-quarters”, “light full three-quarters”, “full three quarters” and “full”, are also used. The duration of a proposed transport determines in which stage a fruit destined for export is judged to be ripe.

To achieve a uniform ripeness during shipping, the maturity stage of an entire bunch should be as consistent as possible. Harvests are therefore usually carried out at one to two week intervals.

The bunches are harvested by cutting them away from the plant just above where the fruit begins. The tall varieties must also be freed of their pseudo-stems, which are bent back and cut off, in order for the bunches to become visible.

Thereby, it is very important that the bunches do not fall, or are otherwise bumped during shipping, as this causes them to blacken and rot.

It is advisable to leave behind a ca. 2 m high stub (depending on the variety) of the pseudo-stem, because nutrients and water are still transported to the remaining shoots for several weeks, and thereby encouraged in their development. The cut away part of the pseudo-stem is lain with the cut side facing downwards directly next to the neighboring trees. This type of mulching prevents a damaging anaerobe oxidation by butyric acid bacteria inside the stalk, and encourages an intensive stimulation of the soil flora.

The remains of the stalk are then cut off at the base during the next bout of maintenance work, and also lain on the ground. The large surface of the banana leaves should be trimmed away along the petiole and chopped up so that the secondary vegetation is allowed to develop.

Increasing returns from banana production

Although banana production in most areas in Africa targets household food security, banana production can also be made more commercially beneficial to the farmer. For farmers to achieve this goal, the following have to be considered:

- The first consideration is to increase output from existing banana plantations. As discussed in the previous sections, this can be done by improving the soil fertility, better husbandry practices in the banana plantation and by managing pests and diseases better. Together, these practices will allow for more yields to be obtained from the same piece of land.
- The farmer can further expand the acreage under banana production, coupled with good management; the yields will be higher and hence the farmer gets excess production for sale to get income.
- Organic banana production also emphasizes use of locally available and, as much as possible, on-farm inputs for planting materials, soil fertility and pest and disease management. This helps the farmer be more self-reliant and spend less on off-farm inputs and hence money is saved. Through diversification by growing different crops along with bananas, the farmer gets consistent extra income from the intercrops like coffee, cocoa or vanilla.

Depending on the location, climatic conditions and growth stage of the banana plantation, banana trees can be grown together with other crops which can benefit the farmer:

- Intercropping. In the first 2 years of banana production, short term crops (e.g. beans, maize or cassava) or long term crops such as bananas, cocoa, vanilla, can be grown in the space between the plants. Such crops will provide extra income to the farmer, and yet their management costs will be greatly reduced.
- Fruit trees. Fruit trees can be included in the banana as shade or wind break trees. Fruit trees such as mangoes, jackfruit and avocados are commonly used. Fruit harvests can be eaten by the household to diversify their nutritional needs and extra harvests sold to earn extra income.
- Timber trees. Some species of shade and windbreak trees can serve as sources of timber in the longer term. This is a long term investment for the farmer for future income needs. Tree species like *Grevelia robusta*, *Albizia coriaria*, *Mesiopsis eminii* and *Cordia africana* grow very well in the banana agroforestry system and provide good timber.

Marketing and organic certification of banana production

Most banana production in sub-Saharan Africa is consumed domestically within production locations and urban areas. Some bananas are exported as fresh, dried or frozen pulp and here banana products of organic quality are demanded.

However, organic certification comes with costs. So it will only be rewarding, if the cultivars of banana being grown can be marketed with an organic surplus to the regular price that pays off for the certification costs. To reduce certification costs an individual farmer may join an existing collective certification scheme or work with other farmers in the form of a farmer group. This will minimize the certification cost per farmer as well as making it possible to mobilize enough volumes that may be required by the market.

General requirements on organic certification of banana production:

- During production of bananas, no use of synthetic pesticides including herbicides, and fertilizers or genetically modified planting materials is allowed. Any pesticide contamination from neighboring conventional banana gardens through soil erosion or wind drift should also be avoided.
- During post-harvest handling of bananas, use of fungicides in treatment of bananas to increase shelf life is not allowed.

Specific national or international organic standards may define additional requirements for production and post-harvest handling of bananas. Farmers should therefore consult the national organic movement or organic certification body operating within the region or country.

Annex: Quality Requirements

The “EU quality standard for bananas” clearly defines the quality requirements placed upon trade with fresh bananas. The regulations must be strictly adhered to until the fruit reaches the ripening plants.

The following is an excerpt from the “EU quality standard for bananas” as:
(I) Definition
The standards apply to bananas of the following listed varieties of the genus *Musa (AAA) ssp.*, subgroups Cavendish and Gros Michel, to be transported in a fresh state to consumers. Flour bananas and Fig bananas, as well as bananas intended for industrial processing are not included.

(II) Quality Characteristics Regulations
The standard regulates the quality characteristics that green, unripe bananas must exhibit after packing and processing.

a. Minimum Characteristics
Subject to the pertinent regulations and tolerances for each class, the bananas in all quality classes must be configured as follows:

- green, unripe;
- whole, firm;
- clean, practically free of visible foreign matter;
- practically free of pests and the damage caused by them with a unbroken, intact stalk which is not dried out and is free of fungus;
- the fruit must not be misshapen, and not abnormally bent: free of bruising and frost damage; free of strange smells and/or taste.

Furthermore, the bunches or clusters must also have:

- a sufficient, healthy length of normally-colored coronet, free of fungus;
- a clean cut of the coronet, without evidence of nicks or tearing.

The development and ripeness of the fruit must be so that fruit can withstand handling and transporting, are in a satisfactory condition when they arrive at the port, and will achieve a reasonable state of ripeness after ripening has taken place.

b. Classifications

- Class Extra. Bananas in this class must be of the highest quality. They must possess the characteristics typical of their variety and/or trading type. The fruits must be unblemished, with the exception of very light surface flaws that cover less than 1 cm2 of the fruit's surface, and providing this does not detract from the fruit's general appearance, quality, the time it will keep and the presentation of the bunch or cluster in its packaging.
- Class 1. Bananas in this class must be of good quality. They must possess the characteristics typical of their variety and/or trading type. The following blemishes are permissible, providing they do not detract from the fruit's general appearance, quality, the time it will keep and the presentation of the bunch or cluster in its packaging:
  - Slightly misshapen
  - Light flaws in the skin caused by friction or by other means, providing the area does not exceed 2 cm2 of the total surface area of the fruit.
- Class 2. This class is composed of those bananas that cannot be placed in the upper classes, yet fulfill the definitions of minimum requirements. The following faults are allowed, providing the bananas retain their essential characteristics in terms of quality, preserve ability and presentation:
  - Shape defects,
  - Skin flaws, caused by scratches, friction or other means, providing the less than 4sqcm of the total surface is affected. The flaws are not permitted to affect the fruit's pulp.

(III) Size Classification Regulations
Size classification is performed according to:

- The length of the fruit in cm measured along the outer curve from the stem to the blossom end.
- The thickness in mm, measured as the diameter of the middle, cutting across its longitudinal axis.

Size classification of a reference fruit is carried out by measuring the length and thickness

- Of the outer, middle fruit of a bunch
- Of the first fruit of a outer row of a cluster, next to the cut that separated the bunch.
- The length must be at least 14cm and the thickness at least 27mm.

Deviations to the previous paragraph are allowed in the following regions: Madeira, Azores, Algarve, Crete and Laconia, where bananas measuring less than 14cm may still be marketed within the union, providing they are classified as class II fruits.

(V) Presentation Regulations
a. Uniformity

The contents of a carton must be uniform, and may only contain bananas of identical origin, variety and/or trade type, and quality. The visible part of the carton must be representative of the entire contents.

b. Packaging
The bananas must be packed in a way that ensures sufficient protection
Packing material used inside the carton must be new, clean, and so shaped that it cannot cause any damage to either the inside or outside of the fruit. The usage of materials such as papers and stickers with company details on them is permitted providing the no toxic inks, dyes or glues have been used.

The packaging must be free of all other materials.
c. Presentation
Presentation is in bunches comprising at least 4 fruits. Clusters with a maximum of two fruits missing are permitted when the stalks have been cleanly cut off, and not torn, leaving the other fruits unharmed. A maximum of one cluster with three fingers is permitted in each row, providing it conforms to the characteristics of the other fruits in the carton.

(VI) Regulations Of Carton Labeling
Each carton must display the following details in unbroken, legible, permanent letters visible from the outside:

a. Identification
Name and address of the packer

b. Type of Product
“Bananas”, when the contents are not visible
Name of the variety

c. Origin of Product
Country of origin, and optionally, national, regional or local description

d. Commercial Characteristics
- Class;
- Net weight;
- Size, depicted as the minimum and (optionally) maximum length

e. Official Stamp
(optional)

Discussion on improving returns from banana production. Evaluate the participants' perception of banana production in terms of returns by asking the following questions:

- Do farmers consider banana production a profitable venture?
- How do farmers estimate the returns from banana production?
- Try to estimate the costs and returns from banana, and discuss potentials for saving costs and increasing returns.

Discussion on assessment of local banana marketing and certification

- Inquire among the farmers about their knowledge on potential for marketing and certification by asking the following questions:
- Who are the main buyers of bananas in the area?
- Are there any certified organic banana farmers?
- Are there any companies that require certified organic bananas?
- What are their requirements on production and quality?

Pulses

Cowpea Bean

Cowpea (*Vigna unguiculata (L.)* is one of the most ancient human food sources.

Varieties and cultivars

Cowpea cultivars have a vining growth habit; however, modern plant breeding has also led to more upright, bush-type cultivars. The vining type is preferred for forage or cover crop use, while the bush type is better suited for direct combining. The extreme variability of the species has led to a number of commercial cultivars grouped by the variance in bean shape, size and color.

- Black-eyed or pink-eyed/purple hull peas. The seeds are white with a black eye round the hilum. The “eye” can be other colors: pink, purple or shades of red being common. Upon drying, the eye color darkens to a dark purple. The pods are purple-like on the pink-eyed/purple hull type. The seeds are not tightly packed or crowded in the pod and are kidney-shaped or oblong.
- Brown-eyed peas. Pods range in color from green to lavender and in length. The immature seeds, when cooked, are a medium to dark brown, very tender and have a delicate flavor.
- Crowder peas. Seeds are black, speckled, and brown or brown-eyed. The seeds are “crowded” in the pod and also tend to be globular in shape.
- Cream. Seeds are cream colored and not crowded in the pods. This is an intermediate between the black-eyed and Crowder types.
- White acre type. Seeds are kidney-shaped with a blunt end, semi-crowded and generally tan in color. Pods are stiff with small seeds.

Other cultivation practices

Inoculants should be applied on cowpea seeds. Inoculants are marketed in liquid and powder forms for seed inoculation or in granular form for soil inoculation. Powder and granular formulations can consist of clay or peat carriers. *Rhizobium inoculant* is sensitive to some fungicide seed treatments and fertilizers. Seed-applied inoculant must be applied to the seed just before planting. Large populations of this introduced *rhizobia bacteria* must survive in the harsh soil environment for 2 to 3 weeks to effectively form nodules on the roots of pulse crop seedlings. In dryland cropping regions, granular inoculant is preferred because it is more reliable in dry seedbed conditions.

Harvest

Cowpeas vary in growth habit. Erect or semi-erect types with short (<100 days) growth duration are grown mostly for grain. Semi-erect types and trailing plants have longer (>120 days) duration in and are grown primarily for forage. At maturity, leaves dry down but may not drop off completely. Cowpeas need to be harvested when seed moisture content is 14 to18%, depending on the consumer’s requirement. In cowpeas grown for vegetable purposes, the leaves are picked 4 weeks after planting, and this continues until the plants start to flower.

Harvesting method
Cowpea can be harvested using a harvester or by hand. The upright cultivars are easy to harvest by machine. Cowpea grown as a dried seed product can be directly combined, using a platform head or a row crop head. Adjustments to combine settings and sieve sizes should be made for the cowpea seed. Because the pods are relatively long, some will touch the ground or be close to it, making it important to run the grain table close to the ground. In the case of cowpeas grown for vegetable purposes, young leaves are mainly picked by hand; older leaves accumulate dust or get spattered with mud from raindrops if not harvested. In most cases, harvesting of cowpea should coincide with the onset of dry season when the dry pods can await harvesting for a week without spoilage. However, to avoid field weathering or shattering, dry pods should not be left in the field longer than 2 weeks after full pod maturity. Harvesting can be carried out manually (hand harvesting) or by using a combine harvester in the case of large-scale production.

Post-harvest handling

Sorting
Seed quality is important. Care in harvest and post-harvest handling allows to avoid cracked or split seed as such seeds which were allowed to dry on plant are harvested to ensure full maturity. Sorting is done to separate the broken seeds from full seeds.

Post-harvest handling
The leaves are dried to store for the dry season. Usually they are first steamed or boded, but not in all places. Sun-drying requires 1 to 3 days; storage is possible for up to a year because dried cooked leaves are not damaged by insects to the same extent as dried seeds. Excessive losses of P-carotene, vitamin C, and the amino acid lysine often occur in sun-dried leaves; however, these can be reduced by minimal cooking followed by drying in the shade.

Grading
The youngest leaves or tender shoots are gathered while in the distinctive green colour phase of new growth. Young leaves are tender, usually higher in protein, and, lacking insect damage, often look more appealing. Older leaves accumulate dust or get spattered with mud from raindrops, while younger leaves would not need so much washing.

Packing
Buyers want the seeds cleaned and bagged, while others will take the grain in bulk form and clean it themselves. In case of sun drying, package in sacks and put into electrical dryers or spread on a concrete slab in order to reduce the moisture content to about 12%.

Storage
Insect pests can devastate cowpea during storage. There are storage insects that cause damage to the seed; it is therefore important to store seed in a protected place. A serious insect pest during storage is the cowpea weevil *Callosobruchus maculatus*, (*Coleoptera: bruchidae*). The rising popularity of organic produce lines has created interest in nonchemical disinfestation treatments; as the use of chemicals in controlling these insects is becoming a problem.

The storage life of cowpea depends on its moisture content before storage. The lower the moisture content, the better the quality of seeds in storage. The grain can be stored short term at around 12% moisture or less, with 8 to 9% recommended for long-term storage. Cowpea leaves are dried to store them for the dry season. Sun-dried leaves may store for up to a year because dried, cooked leaves are not damaged as much by insects as dried seeds.

Groundnut

The peanut (*Arachis hypogaea L.*) is a herbaceous, annual type of plant that grows to a height of 20-60cm. Depending on the species, the plants may grow upright and sideways with their sideward shoots to a breadth of 30-80cm. The main stem usually remains upright. The taproots penetrate to a depth of 90-120cm, creating branches within the upper soil levels that are populated by rhizobia and mycorhiza.

Soil requirements

Peanuts grow best in a weakly acidic pH value (6.0-6.5); a pH value of 5.5-7.0 is still acceptable, and local can adapt themselves to pH values up to 7.8. Peanuts are sensitive to a high salt content in the soil (max. 4mS/cm).

Cultivation systems and diversification possibilities

Crop rotation
Peanuts should only be planted in a three year crop rotation, at least. Otherwise, soil-borne diseases can accumulate, and humus is lost due to excessive soil loosening during the harvest.

Nevertheless, peanuts possess good soil enrichment potential for a non-legume, and act as an excellent crop prior to planting grain. The previous crop should leave little weeds behind, and be harvested early; to allow plenty of time to work over the soil to permit early sowing to take place. The previous crop should be allowed to largely go to seed. Suitable crop partners include grain, sorghum, pearl barley, maize, rice, and also: sesame, saffron, cotton, sweet potatoes and grain legumes such as mung beans (*Vigna mungo*) or cowpea (*Vigna unguiculata*).

Mixed crops

Planting peanuts in mixed crop systems is very widely spread and is more the rule than the exception on small farm units. Some advantages are:

- Greater total production per area (despite the losses caused by overshadowing of the peanuts as opposed to monoculture);
- Reduction of transpiration especially in alley-cropping;
- Greater diversity of diet;
- Regulation of erosion and weeds;
- Reduced susceptibility to pests.

Due to their tolerance of shading, peanuts are especially suited to mixed cultivation together with tall-growing crops such as pearl barley, sorgo, maize, cotton, hibiscus (*Hibiscus sabdariffa*), manioc and sunflowers; and as an under-sown crop together with such other crops as bananas, pigeon peas (*Cajanus cajan*), *Gliricidia sepium*, castor beans (*Ricinus communis*), sugar cane or permanent crops such as coconut palms, oil palms, rubber and cocoa.

When their vegetation periods are similar in length, other crops cultivated together with peanuts will benefit by a gain in yield (in contrast to monoculture sites, peanut and pearl barley). Even greater increases in yield have been observed for other crops such as cotton –which has a vegetation period which is up to 3 months longer. The success of cultivating in a mixed system, or in agro-forestry systems, is dependent largely upon choosing site appropriate crops, the way the combination gels and from the correct placement of the peanut in the chronological order of the various species. For example, cultivation in an agro-forestry system must always be at the beginning of a cycle (planting within the first 3 years may be possible – according to which other crops are grown), because the plant's natural attributes preclude it from being planted.

Diseases

The most important ways of avoiding diseases are:

- Crop rotation;
- Choosing the right variety;
- Sufficient supply of nutrients;
- Uprooting infesting plants to stop the disease spreading;
- Destruction of any infested plant parts after the harvest.

Harvest and post-harvest handling

Time of harvesting

Because the leaves are still green when the pods are already ripe, occasional uprooting must be performed to ascertain the optimum harvesting date. Bush varieties mature in 110-130 days after sowing, branching varieties in 130-150 days. The individual seeds are ripe when:

- The structure of the pods is easily recognizable;
- These have been largely filled by the seeds within;
- The inner walls of the pods have taken on a darker color (brown). The testae have then attained the typical color for their variety.

As soon as 60-70% of the pods are ripe, any further delays in harvesting will result in losses. The optimum period for harvesting is very short. If this is not kept to, and harvesting is begun either 5-10 days before this time or after it then up to 25-50% of the production may be lost. Harvesting too late especially in hard and dry soils, results in pegs breaking off as they will already have become too brittle.

Harvesting methods

The pods from freshly harvested plants still have a moisture content of around 35-50%, and need to be rapidly dried to a moisture content of around 20-25% so they may be easily separated from the plants. The best method is to pre-dry them in windrows for 2-3 days. After the tap roots have been cut away, the plants are stacked on their leaves with the pods facing downwards. The advantages are:

- Rapid drying;

- Avoidance of contact with the soil;
- A reduction of attacks by insects and the risk of infestation by Aspergillus spp.

The quicker the pods are dried after being uprooted, the less aflatoxin is created. Nevertheless, care must be taken not to dry them too quickly, as this could result in a weakening of the testa, which protects the seeds from decay.

Manual harvesting is still widely practiced in many countries where it is more profitable, because fewer pods are left in the soil, and they are also less likely to be damaged. Planting on ridges, in hard soils, can make the harvest easier. The plants can be extracted by hand with a hoe; this can be made easier still by cutting below all of the rows with special uprooting blades (pulled either by tractor or animals). In light soils, harvesting machines, similar to those used for potato crops can be used. For heavy soils, use special peanut uprooters. Purely mechanical harvesting is also often carried out in two stages, initially drying the peanut plants in windrows to reduce the amount of drying necessary in the artificial drying processes. The first machine uproots the plants, shakes off the soil and lays them on the ground upside-down, similarly to manual harvesting. In the second stage, a threshing machine picks up the pre-dried windrows.

Post harvest treatment

Making hay

Foliage from peanut plants provides excellent, protein-rich fodder, with similar nutritional values as lucerne (*alfalfa*), and is therefore also harvested. It can be cut down just before the uprooting takes place and dried into hay. One method of carefully drying after the whole plant has been harvested is to dry the foliage on hay racks, or upright poles, after it has been left to wilt for a short while on a windrow. Otherwise, the valuable leaf parts can get lost.

Threshing

After being dried out in the field, the pods are separated from the plants. The best results are gained when the moisture content is between 20-25%, because then the pods can be separated easily and completely. If the content is lower, then the pods and seeds will be more susceptible to damage. The best method is to separate them by hand. Sometimes, the pods are carefully beaten off with a stick, or stationary threshing and pick-up threshing machines are used.

Drying

Directly after being threshed, the pods are dried, either artificially or in the sun, until they attain a moisture content of 6-7%. Delays must be avoided at all costs to reduce the risk of infestation by *Aspergillus flavus*, which rapidly increases. Under 9%, the creation of aflatoxin is retarded, but protection against storage pests, whose activities create aflatoxins, is only attained at levels under 7%. For this reason, a moisture content of 6-7% is necessary. Problems can often occur when the harvest is carried out during wet weather, and the produce isn't sufficiently dried afterwards. Only at less than 6% will the seeds become damaged (they break during shelling).

In cases of extreme sunshine and heat, it may be advisable to carry out the drying process under a roof. The weight loss during drying is compensated for by an increase in quality and a reduction of the risks involved. In regions where insufficient sunshine is available to dry out the seeds after harvesting, conditions need to be created to artificially dry the produce, to reduce any post-harvest losses and the risk of toxicity (mobile dryers).

Sorting
Because usually only a few seeds are infected with aflatoxin, sorting is an effective and important preventative measure after the harvest. Strongly infected pods and seeds are either highly discolored, or will have shrunk. They can either be sorted manually or mechanically; electronic color sorting has made it possible to sort out practically all of the aflatoxin infected and bad seeds.

Storage
The main factors which need to be observed in storing are; a low moisture content of the seeds (see: drying) and low ambient temperatures. High seed and/or room moisture content, coupled with high temperatures, are the main reasons for the creation of aflatoxins. Prevention is achieved by:

- Sufficient air circulation;
- Regulation of the relative air humidity;
- Suitable cooling;
- Sorting out the damaged and discolored pods before they are stored.

Unshelled peanuts are far easier to store than shelled, because the protective testa remains intact. If they are not to be sold in the pods, they should be shelled only immediately before being sold.

Storage pests: Most storage pests reach the seeds through a broken pod or testa, which means that careful sorting provides good protection. One exception to this rule is *Attagenus fasciatus*, one of the few storage pests that bore into the pods. Some varieties have formed a special resistance against storage pests due to protective substances in their pods and testa. Adding clay powder helps against *Corcyra cephalonica*. Most storage pests cease their activities when moisture content of the seeds is below 7% and 20% air humidity.

The aflatoxin problem
Peanuts are extremely susceptible to infection by the fungi *Aspergillus flavus*. The poison aflatoxin is created by fungi of the species Aspergillus flavus and Aspergillus parasiticus, which are widely disseminated in tropical and subtropical soils. All cultivation measures should be well-planned, to take this aspect into consideration. Aflatoxin in food can affect the health of both man and animal. Importing countries have set maximum tolerance values for the presence of aflatoxin in foodstuffs; to protect consumers.

For consumers in the producing countries, the risks due to the poison are more difficult to ascertain, because the larger part of the peanut harvest is consumed or sold on local markets. Thereby, there are also no “dilution” effects caused by large quantities, meaning that both humans and animals can be subjected to high doses of aflatoxin. Additionally, malnutrition leads to immune systems being weakened. By heeding the preventative measures outlined, economic or health problems regarding an aflatoxin infection should not even arise.

Infection before the harvest
The fungus penetrates the pods during the growth period whilst still in the soil and it takes place in two ways:

A) Infection through invisible damage to the pods or seeds
Mechanically damaged or bitten pods will quickly be infected by the fungus, which feeds primarily on dead and dying tissue. Hot, dry soil conditions abet attacks by termites, which are vectors for the fungi's spores. Alternating phases of rain and drought causes the pods to split open, and producing high aflatoxin values in the seeds.

B) Invisible infections of the pods
Many pods are infected after the pegs have been pushed down into the soil. Yet when the plant enjoys good growing conditions, the fungi may remain inactive and no significant amounts of aflatoxin are produced; this is because peanut plants have a natural protection mechanism: The growing plant produces immune substances (phytoalexin), which have an anti-microbe and fungus-suppressing effect (arachidin). All cultivation measures that encourage healthy, natural growth in effect support this protection mechanism.

The production of phytoalexins decreases towards maturity, as a result of water deficiency, and ceases altogether if a drought continues. In contrast, the fungi *A. flavus* is still able to proliferate and create aflatoxin at much drier conditions, before it also finally ceases all activity. It is encouraged at average temperatures of 26-30°C in the upper 5cm of the soil. In dry periods, the peanut plant folds its leaves together, meaning that the ground receives even less shade, resulting in sudden increases of soil temperatures. In hot, dry conditions, *A. flavus* grows very rapidly, possibly due to its enemies dying off, for they breed best in hot, humid conditions, when they can keep *A. flavus* under control.

Sufficient irrigation is an effective way prevent the production of aflatoxin (especially during the final 4-6 weeks of the vegetative period), even when the soil temperatures are perfect for A. flavus, and 50% of the pods are infested.

Production of aflatoxin after harvesting
When the fungus has actually penetrated, it can create aflatoxin during the drying, transport and storage processes. Humidity and temperature are the two main factors. Even manufactured goods, such as peanut flour, are at risk. Although detoxification methods exist, the best approach is always prevention.

Quality requirements

These quality requirements for peanuts, with their minimum and maximum values, are generally issued by the authorities or importers. Yet agreements may be reached between individual manufacturers and importers upon different values, providing they still conform to official requirements.

Quality requirements	Minimum and Maximum values
Appearance	Specific according to Quality grade
Taste and smell	Variety-specific, fresh, not mouldy
Purity	Free of foreign substances (sand, stones, shell rests, insects etc.)
Water	Max. 5.0%
Peroxide units	Max. 1.0 milli-equivalent peroxide per kg fat
Free fatty acids	Max. 0.5%
Residues	
Pesticide	Not measurable
Bromide and ethylene oxide	Not measurable
Heavy metals	
Lead (Pb)	Max. 0.50mg/kg
Cadmium (Cd)	Max. 0.10mg/kg
Mercury (Hg)	Max. 0.03mg/kg
Micro-organisms	
Total organisms	Max. 10,000/g
Yeasts and mold fungi	Max. 500/g
Enterobacteriaceae	Max. 10/g
Coliform	Max. 10/g
Escherichia coli	Not measurable
Staphylococcus aureus	Max. 100/g
Salmonella	Not measurable in 25g
Mycotoxins	
Aflatoxin B1	Max. 2 Zg/kg
Σ Aflatoxins B1, B2, G1, G2	Max. 4 Zg/kg

Nuts

Cashew nuts

The cashew tree (*Anacardium occidentale*) originates from South and Central America. Cashew nuts consist of 35-45% seeds and around 55-65% shells. The shells contain 15-30% oil. A ton of nuts contains around 200kg seeds and 180kg oil. Cashew nut oil or Cashew Nut Shell Liquid (CNSL) is used as oil in industry. Cashew nuts are dried before being sold. The cashew apple can be sold fresh as soon as they have been picked, and then used as a culinary ingredient, or further processed into drinks (juice, wine), marmalade or vinegar. In India, rubber is sometimes harvested from the trunk, and used instead of rubber arabicum.

Diversification strategies

Due to the wide variety of ecological sites for cashew trees, general recommendations can be offered for diversification. It is possible to develop a multitude of combination possibilities for each and every site, which include local tree and bush species for agroforestry systems.

Crops such as hibiscus, peanut, dry rice, sesame, beans and soya beans, as well as various vegetable crops can also be planted. *Ricinus* (*Ricinus communis*) is also possible, whereby this plant can be integrated as a green fertilizer.

Pineapple can be included among the crops mentioned above, as a secondary plant among the bottom crops.

Mangoes, as fruit trees, are suitable partners in a cashew garden. It should be noted that both grow to roughly the same height and also have widely-spreading crowns, therefore, they need to be planted at a sufficient distance from one-another. Crops that could be planted as middle crops include *Annonaceae ssp.* (*Annona squamosa L.*), as well as guavas (*Psidium guajava L.*), as they thrive in the shade of cashew nut trees.

Arable fruits can also be planted between the rows, especially in young cashew gardens. Intensity, species and crop rotation are dependent on the specific site conditions and the market access for each crop. In West Africa, good results have been gained from using peanuts and soya beans as bottom crops. Grains and arable fodder crops are also possibilities. The bottom crops need to be integrated within a crop rotation system.

Under no circumstances should the system lack palm trees. The wide variety of different regional species on the planet makes it slightly difficult to offer any recommendations here. Even when no commercially viable varieties are available within the region, palm trees are generally excellent suppliers of building materials and fuel.

Crop cultivation and maintenance

Young cashew trees should be trimmed in the first 3-4 years to develop enough fruits growing laterally to the main stem. Afterwards, no further trimming is necessary. When branches reach down to the ground, or older trees are too widely spread, then a regeneration cutting should be performed. Dead branches should be regularly removed. In order to ease harvest work, tree grids with a diameter of 2-4m should be previously covered with mulching material.

Harvest and post-harvest handling

Harvest

If the cashew tree apple is to be used, the ripened fruits need to be harvested twice a week. The fruits are taken to the processing site, where the nuts are separated from the rest of the fruit. If the apples are not to be used, then picking up the fallen nuts once per week is sufficient. The apple parts are then cut away from the nuts and left out on the site.

Post harvest treatment

The processing method used depends on the amount of nuts harvested: if fewer than 10 tons of raw nuts have been harvested, then no special equipment is needed to roast them, and the nuts can be shelled by hand.

Between 10-50tons, the nuts can be processed with simple tools. The nuts can either be dry-roasted, or in a bath of CNSL.

Quality requirements

The following is a list of quality characteristics with minimum and maximum values for cashew nuts that are usually required officially or by importers. Different minimum and maximum values can be agreed between importers and exporters, providing these do not clash with official regulations.

Quality characteristics	Minimum and maximum values
Appearance	Specific, according to the quality
Taste and smell	According to the variety, fresh, not rancid, not stale
Purity	Free of foreign matter (sand, stones, shell parts, insects etc).
Water content	Max. 5.0%
Peroxide value	Max. 1.0milli-equivalent of peroxide per kg fat
Free fatty acids	Max. 0.7%
Residues	
Pesticides	Not measurable
Bromide and ethylene oxide	Not measurable
Heavy metals	
Lead (Pb)	Max. 0.50mg/kg
Cadmium (Cd)	Max. 0.05mg/kg
Mercury (Hg)	Max. 0.03mg/kg
Micro-organisms	
Total number of parts	Max. 10.000/g
Yeasts and fungus	Max. 500/g
Enterobacteria	Max. 10/g
Coliforms	Max. 10/g
Escherichia coli	Not measurable
Staphylococcus aureus	Max. 100/g
Salmonella	Not measurable in 25g
Mycotoxins	
Aflatoxin B1	Max. 2 Vg/kg
Total aflatoxins B1, B2, G1, G2	Max. 4 Vg/kg

To have quality requirements and no contamination of the cashew nuts, preparation should take place under clean, hygienic and ideal conditions, such as:

- Equipment (tubs, knives etc.), as well as working and drying surfaces (racks, mats etc.) and preparing and storage rooms, should be cleaned regularly.
- Personnel should be healthy, and have the possibility to wash themselves or at least their hands (washrooms, toilets) and wear clean, washable clothes.
- Water used for cleansing purposes must be free from faeces and other contaminants.
- Animals or animal faeces must not come into contact with the product.

Fibers

Cotton

Organic cotton (*Gossypium herbaceum*) occupies a tiny niche of far less than 1% of global cotton production. In Africa, organic cotton cultivation is reported in Benin, Burkina Faso, Egypt, Mali, Mozambique, Senegal, Tanzania, Togo, Uganda, Zambia, and Zimbabwe.

There are a number of reasons to grow cotton organically. The negative impacts of conventional cotton farming on the environment and health are obvious and well known. Given that 60% of the cotton weight harvest is cotton seed that is processed to edible oil and cattle feed, farmers realize that the bigger part of cotton production enters the human food chain. Pesticides sprayed on cotton do not only affect the target pest. Beneficial insects and other animals are killed, too, so that pests that formerly were of minor importance now have become a major problem (for example, whitefly and aphids).

Marketing and organic certification

Farmers planning to sell their produce as "organic" in domestic or export markets need to be certified as organic. Farmers need to strictly follow national regulations and organic standards of their respective target country. A premium price is possible only if there is mutual trust between producers and consumers. The organic farmer also needs to be protected against unfair competition from other farmers who use the term "organic" in a fraudulent way.

Organic standards define the minimum criteria to be fulfilled.

ORGANIC STANDARDS IN COTTON FARMING
No application of any synthetic fertilizer such as UREA, NPK, DAP, etc
No application of synthetic pesticides (including herbicides, insecticides, fungicides) or growth promoters
No use of genetically modified organisms (GMOs) such as Bt-cotton varieties
Crop rotation (no cotton after cotton in the same field in two subsequent farming seasons) and/or intercropping
Prevent spray drift from neighboring conventional fields, e g. growing border crops
Maintain records and documents for inspection and certification

REQUIREMENTS OF COTTON CROP
Climatic conditions
• High temperature (30°)
• Long vegetation period
• Ample sunshine
• Dry climate
• Minimum 500mm rainfall or irrigation
Soil conditions
• Deep soils
• Heavy clay soils, ideally black cotton soils (vertisols)
• No waterlogging
Crop development
• Strong root growth in the first two weeks
• Natural bud shedding (only approximately 1/3 flowers develop bolls)
• Plant compensates for damage through increased growth

Soil fertility management

Organic cotton has to be grown in rotation with other crops. Rotation helps to improve and maintain soil fertility and ensures balanced nutrient contents in the soil. If cotton is grown continually on the same field, yields are likely to decrease.

Depending on the 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. Choosing the most suitable rotation pattern for a particular farm depends on a number of factors: soil, irrigation facilities, crop prices, market access, and the farmer's skills and preferences.

On organic farms, cotton should not be grown in the same field two years in a row. If cotton is repeatedly grown in the same field, the soil nutrients get depleted, pest populations increase and there is a risk for soil-borne diseases. At least for one year, but preferably for two years, another crop should be grown between two cotton crops. If the size of the land restricts farmers to repeat the crop, they should use an intercrop (moong bean, cowpea, or chickpea, for harvesting) or a green manure crop (sun hemp or cowpea, to be cut and ploughed back into the soil before flowering).

Good yields are achieved when cotton is grown after pulses (soy bean, chickpea, pigeon pea, groundnut etc.), horticultural crops like chillies or vegetables, and after sugar-cane and wheat. Organic farmers in particular should take care to include pulses in the rotation, as they increase the nitrogen content in the soil by fixing nitrogen from the air.

Natural pesticides

There are a number of natural pesticides that can be used in organic cotton cultivation, and organic farmers continuously try out new ones. However, little scientific research has been done on the efficiency of most of the locally prepared formulations. Therefore, farmers are encouraged to do their own experiments and trials to find out which natural pesticides are most suitable for their farms. Natural pesticides also affect beneficial insect populations and should be used only when necessary. Some plant extracts are also toxic to humans and animals and should be used carefully.

Neem (*Azadirachta indica*)
Ingredients: Neem kernel extract, containing azadirachtin
Target pests: Sucking pests, jassids, bollworms, thrips
Preparation: Farm-made: Pound 30g neem kernels (that is the seed from which the seed coat has been removed) and mix with 1litre of water. Leave overnight. The next morning, filter the solution through a fine cloth and use immediately for spraying. It should not be further diluted.
Remarks: Sprays from neem seed or leaf extract do not kill the insects but reduce their feeding, moving and multiplying rates. Therefore, the effect is not noticeable until after few days. The main advantage of using neem is that it is not harmful to most beneficial insects. To a limited extent, neem's active substance is also absorbed by the plants and thus affects the pest when they feed on the crop.

Pyrethrum
Ingredients: Powdered flower heads or liquid extracts of a daisy-like chrysanthemum
Target pests: Red cotton bug, cutworms, grasshoppers
Remarks: Pyrethrum causes immediate paralysis or death to most insects, but also affects beneficial insects.

Harvest and post-harvest handling

Quality issues in cotton picking
The quality of the cotton harvest depends on the length of the fiber (staple length), on the degree of contamination with non-fiber material such as leaves or dust, and on the portion of fiber damaged by pest or disease infestation.

Good-quality raw material helps to produce yarns and garments of high quality, and thus eventually contributes to the market success of the organic cotton project. When cotton buyers fix prices, they usually take into consideration the quality of the cotton seed.

Measures taken to improve the quality of the harvest that directly pay off for the farmers:
- Allow the cotton bolls to fully ripen and open.
- Pick the cotton after the morning dews have dried up, so that the cotton is dry and less prone to fungus when being stored.
- Pick the cotton into clean cotton cloth material, never into nylon or other synthetics (foreign fibers).
- Remove leaves, capsules and damaged bolls from the cotton harvest.
- Keep cotton of lesser quality separate with the help of a second, smaller picking bag.
- Picking delays can cause reduction of fiber quality, as the opened bolls are exposed to dew, dust and honeydew from insects longer.
- No unripe cotton is picked, as it will not absorb the dye well enough and thus is priced lower.

A major cost factor in cotton production is the labor required for cotton picking. The following suggestions might help to increase the efficiency of cotton picking, and to ensure a high quality harvest:

- Use a long sack so that the weight rests on the ground;
- Keep the sack permanently open with a ring of flexible wood;
- Pick two rows at a time;
- Keep a separate, smaller bag for second-grade cotton.

Storage

If farmers store the harvested cotton before selling it, they should take care to prevent contamination from dust or chemicals, especially fertilizers, pesticides, and petroleum. Never use any storage pest control (DDT) on the harvested cotton! No foreign fibre material (from clothes, human hair etc.) shall get into the cotton, as it can affect the quality of the yarn.

The storage place needs to be clean and dry. Damp conditions can lead to the growth of fungus, with significant loss of cotton quality. When organic harvest is stored in the same facilities with conventional cotton (in ginneries), care must be taken to clearly separate the organic, in-conversion and non-organic produce, and to avoid any mixing.

Strategies in cotton production

Farmers' income from a crop depends on the yields, the costs of production, and the price gotten on the market, and the production risk involved. Thus, there are four ways farmers can earn a better and more sustainable income through organic production:

- By increasing and sustaining crop yields through improved soil fertility;
- By reducing costs of production (for off-farm inputs);
- By getting a better price for their produce (organic premium, market access);
- By reducing the risks of production (droughts and pest damage).

Organic farmers get the maximum benefit when they manage to combine all these approaches.

With organic cotton, farmers follow one of two different strategies to achieve good profits:

- First strategy as “intensive organic”, aims at achieving high yields through optimum nutrient supply and crop care. Farmers following this strategy typically buy organic manures from outside (cow dung, oil cakes), irrigate their fields intensively and take a number of measures to protect their crops. This is a strategy typically followed by farmers with more resources (larger land holdings, good irrigation facilities, fertile soils).
- Second strategy as “low cost, low risk”, aims at reducing production costs and the risk of production, targeting medium yields. Farmers produce all inputs on the farm itself (compost, botanical pesticides, liquid manures etc.) and perform farming activities with family labor. This low external-input strategy can help to reduce risk in areas of frequent crop loss due to droughts, water-logging or theft, as farmers need to invest less money into the crop. It is not possible to draw a clear line between the two strategies. Still, this basic distinction can help farmers to make their farming more profitable, and extension services to adjust their services to the requirements of different farmers.

PESTICIDES: COMPOUNDS, USE AND HAZARDS

Introduction

Non-chemical (or ecologically friendly) methods of crop protection have been practised over the centuries, but the introduction of chemical pesticides a few decades ago seemed to make crop protection easier.

Products proved to be effective at first as it was thought that all pests could be eradicated. However, the pests were not eradicated, as they came back over and over again, every growing season. Many natural enemies were temporarily wiped out along with the pests, which gave pests the opportunity to multiply even more explosively than before.

It is necessary to spray several times per season in order to control even just one type of pest and ensure healthy crops. Eventually, some pesticides do not work anymore because pests develop a certain resistance to them. Initially, this happened with pesticides used against insects and mites (insecticides), but eventually some pesticides used to control diseases (fungicides and bactericides) and weeds (herbicides) also have become ineffective. Given that pests were becoming resistant to frequently used chemicals, there is a continuous need for new chemicals, chemical compounds and mixtures.

Moreover, some pesticides are extremely poisonous for the users. Farmers are expected to know how to handle chemicals safely, without incurring accidents.

Human health and pesticides

More than just to affect farmers directly, it has been shown that their is a correlation between the use of pesticides by farmers and birth defects of their children, in particular boys being born with genital defects:

- Gaspari L, Paris F, Jandel C, Kalfa N, Orsini M, Daurès JP, Sultan C. Prenatal environmental risk factors for genital malformations in a population of 1442 French male newborns: a nested case-control study. PubMed.gov. 26 November 2011. [Accessed 29 July 2012]
- Pesticides et malformations génitales des fils d'agriculteurs, 07.03.2005, http://www.novethic.fr/novethic/planete/environnement/agriculture/pesticides_et_malformations_genitales_fils_agriculteurs/89313.jsp
- Dans le Nordeste brésilien, des garçons au pénis atrophié pour cause de pesticides, Le Monde, 18.05.2012, http://www.lemonde.fr/sante/article/2012/05/18/au-bresil-des-garcons-au-penis-atrophie-pour-cause-de-pesticides_1703658_1651302.html

Consequences of changing to an organic crop protection system

It is not economically easy to compare the cost-effectiveness of chemical and organic crop protection systems. Especially if looking at one crop or one year alone, farmers tend to under-estimate the costs of chemical control and over-estimate the costs (especially the labor costs) of organic control. The costs of chemical control include not only the pesticides, but also equipment, protective clothing, safe storage and depreciation costs. Often, health costs have to be considered in case of accidents.

In addition, in remote areas, the local market price of the crop may not cover the costs of the pesticides.

Chemical pesticides are often effective against the target pests. However, if the pests become resistant to the pesticide, or if crops suffer unfavorable weather conditions, costs incur and there is no crop yield to pay for them.

Organic crop protection is often less effective than chemical crop protection, but it is usually less expensive, and is based on locally available inputs and interventions.

The undesired side effects of chemical pesticides make it difficult to combine them with many non-chemical methods.

Outline of the chapter

This chapter does not give farmers ready-to-use formulas on how to respond to pest X in crop A or to pest Y in crop B. It provides a more flexible way of thinking and working, which farmers can adapt to local conditions and to the crops cultivated.

Whether a farmer applies non-chemical crop protection methods or chemical pesticides, he or she must be able to recognize the most important pests that occur on the farm. It is also important to know more about their life cycles and how they are affected by local conditions.

The chapter summarizes the most important characteristics of pests and explains how farmers can learn to control them in a responsible way. The intention is not to eradicate pests, but to minimize their harmful effects.

Also, the chapter describes how farmers can organize their farming activities in such a way that pests have less chance of multiplying at an explosive rate. Many of these measures are effective for several years and help to control more than one type of pest.

Many measures to protect crops from pests are taken before or during cultivation. These measures are usually directed towards keeping down the numbers of a specific type of pest or category of pest organisms.

One example is the use of healthy seeds to prevent a crop from becoming diseased at an early stage of growth. Another example is sowing a crop in rows so that weeds can be removed using a hand tool. Yet another example is planting a Neem tree, which keeps many pest insects at bay.

Strengthening knowledge in farmers' communities

To apply the general principles of organic crop protection effectively, farmers need additional knowledge about their crops, pests, and how these interact under local conditions in a specific agro-ecological zone.

Farming communities often have a lot of valuable knowledge, but sometimes also have ideas and beliefs that are inaccurate or incomplete. For efficient production of healthy crops with zero pesticide use, it is important to strengthen and upgrade the technical knowledge in farming communities.

Farmers have to learn how to make decisions based on observation of crops and based on knowledge. Farmer Field Schools have proven to be excellent means of applying and improving non-chemical crop protection. Successes have been reported from many parts of the world.

Farmers in Ghana benefit from Farmer Field School
In the Kumasi region of Ghana, 250 farmers participated in the Farmer Field School program to increase yields by an average of over 50%/ha, rising seasonable profits by 30%, and reducing pesticide use by 95%.

With the increased income, farmers improved their housing conditions, paid school fees for their children, bought new clothes, and contributed to their churches. Some farmers expanded their farms and turned them into more business-oriented enterprises.

Participants from the savannah zone were able to produce enough crops to store food throughout the lean season. Farmers from more food-secure districts could afford more meat and fish in their diet.

Farmers valued the improvement of their health status due to reduced pesticide poisoning. Female participants who were trained as farmers or extension staff members felt that they have strengthened their organizational ability, leadership skills and self-esteem.

Farmers working together also pushed local authorities and agricultural district offices to put more effort into community development.

Pests and pest management

Crop pests are any organisms threatening the quality and yield of food and cash crops. Pests can be small mammals, such as rats and mice or birds. More often, these pests are small living organisms, such as insects, mites, nematodes (microscopically small worms) or snails. Microorganisms, such as fungi, bacteria and viruses, can also cause harmful plant diseases. Special mention goes to the higher plants, acting as weeds, which can also be classified as pests.

However, the mere presence of these organisms on the farm does not qualify them as pests. In principle, they are not pests as long as they do not reach a threshold. Plants can be especially bothersome in one situation, but quite useful in another. Plants growing wild on a field are often weeds, but in another situation they can be a useful source of animal feed or compost. Seeds, bulbs or roots left on a field after a crop has been harvested can grow into bothersome weeds for the following crop.

Not all plants and animals found on the farm can develop into pests. All potential crop pests share the following characteristics:

- Can damage individual plants in a crop;
- Under favorable conditions can multiply very rapidly;
- Harm the farmer because the damage they cause reduces the yield or quality of the harvested product, or can only be controlled at great expense.

Pests which damage individual plants in a crop

Pests differ in the way they damage crop plants. Three groups of pests are presented as: insects, micro-organisms and weeds.

Insects
Insect pests either feed on plants or plant parts, or they pierce the plants and feed on their juices.

Micro-organisms
Micro-organisms can be a pest as they cause plant diseases. These are called disease-causing or pathogenic organisms. The symptoms of such diseases can include malformation, spots on the plants' leaves, or rotting stems, fruit or roots.

Weeds
Most weeds are harmful as they compete with the crop plants for light, water and nutrients. This infestation slows down the crop's growth. Some plants are considered to be weeds as they are parasitic. They live on the roots of plants and through direct contact, they extract nutrients and water from the plant. Other plants are weeds as they host pest insects or disease-causing microorganisms.

A common weed in African farms is Striga (*Striga hermonthica*), a parasitic weed of grass cereals, specifically sorghum and finger millet.
Most commonly occurring on low nitrogen-fertility soils and under low rainfall ecologies, as few as three plants per square meter can completely inhibit grain production. Attaching to the host root and transpiring at three times the normal rate, water and nutrients are shunted to the parasite. *Striga* also alters the hormone balance of the host, stimulating the crop to reduce shoot growth and extend root growth. Producing as high as 20,000 seeds per plant, and remaining viable in the soil for up to 20 years, *Striga* infested soils loose their productivity and become characterized by masses of purple flowers.

Crop damage

The pest organisms in an infestation can eventually have an impact on the yield and quality of a crop. The damage is felt by a farmer in the form of a smaller crop yield or a lower-quality product that will have to be sold at a lower price.

To prevent such damage, the farmer can take measures to control pests. But these measures cost money, so it is not a good idea to implement them automatically. The decision as to whether or not to take action has to be based on regular inspections of the crop. Weekly inspections will be sufficient in most cases.

The purpose of the inspections is to identify which pests and how many are present in the crop, and to determine whether they are increasing in number.

Shifting to non-chemical methods

Crop protection through the use of big amounts of pesticides is primarily reactive; as soon as first individuals of a pest are sighted, or the population reaches a certain size, farmers start to consider what pesticide they can use to reduce the number of pest organisms.

The advantage of this method is that the desired result is achieved quickly and will continue for as long as the pesticide remains effective. However, in the past few decades, more and more pests have become resistant to chemical products. Furthermore, chemical pesticides often have a very broad impact, which means they kill not only pests but also useful organisms, and they are sometimes poisonous to humans as well.

For all these reasons, protecting crops through regular applications of chemical pesticides has become less and less effective. Protecting crops with little or no use of pesticides is possible, but it requires a way of thinking that takes into account the life cycle of pests.

Rather than choosing to eradicate a pest as soon as small number of individuals are noted in the field, farmers should ask themselves why the pest comes back every time a new crop is planted and how it reproduces itself so rapidly in that particular crop. It will soon become clear that pests take advantage of certain circumstances.

These circumstances may be related to the pest, to the crop, to environmental conditions, or to a combination of the three.

This knowledge forms the basis for a more pro-active (preventive) approach to crop protection. Being pro-active means that farmers accept the presence of pests on the farm, but are at the same time able to organize their farming activities and adjust their cultivation techniques so that pest populations do not become too large and that damage remains within acceptable limits. In the unusual event that of a population of a particular pest threatening to reach an unacceptable level, pesticides with the least unwanted effects can still be applied as the last resort.

Recognizing the most important pests

Farmers wanting to apply non-chemical crop protection must be able to recognize which pests are the most harmful for the crops: the key pests. Once understood under which conditions pests will cause most damage, farmers can take proactive action to prevent that damage. Measures should not be too expensive or require more labor than farmers can spare.

Planning, implementing and experimenting

Proactive pest management is not a recipe that works in the same way in any agro-ecological zone. It is a flexible approach which farmers need to adapt from time to time to the circumstances of their farms. Some measures are effective for several farming seasons and help control various types of pests. For example, farmers might want to make a planting schedule which will indicate the type and order of crops to be cultivated per field (crop rotation).

In practice, farmers will continuously make small improvements. It is recommended that farmers experiment on a limited scale, by planting a different variety or a different combination of crops on a small section of a field. By comparing the damage caused by a certain pest to an individual variety, or combinations of varieties, farmers can determine under what conditions the pest causes the least damage.

How farmers in Cameroon evaluate new crop protection techniques
Farmers in Cameroon are organized in small groups, in which they discuss challenges they have with pests, and traditional (local) methods to mitigate them. Farmers also consult a specialist from a local Research Center who knows about new methods of non-chemical crop protection. Together, they set up experiments to see how the new techniques work in local practice.

If a new method turns out to be an improvement, it is adopted and used on a wider scale. Efforts are focused on the use of plant extracts against insect pests.

Inspection

During the growing season, farmers have to inspect their crops weekly to observe the main pests and get an idea of how quickly the latter develop.

It is recommended to make drawings of the crops and the pests found several times per year. Then later, it can be seen which pests are to be expected and at which development stage of a crop.

For insect pests, it is also important to know how their natural enemies develop. If the pest develops much faster than its enemies, you may still be able to take corrective action. At the end of the season, one can evaluate the yield and quality of the crop.

Making a farm field less attractive to pests

Mono-cropping makes it easier to perform various tasks in the field, but it is also a major cause of the explosive growth of pest organisms. One large field of maize, for example, is a nearly inexhaustible source of food for pests. Often the same crop is cultivated year after year on the same land, enabling soil-borne pathogens and certain weed species to multiply unchecked.

Small farms are usually more diverse, with various crops planted side by side in the same field. Farmers have often developed their own methods to keep harmful pests, especially animals, away from their crops. These type of farms are also a lot less attractive to pests. Growing a variety of crops already leads farmers to a pro-active pest management framework.

The role of biodiversity

One of the main pillars of proactive pest management is making farms less attractive to pests. A key requirement for this is to create the greatest possible variety of plant and animal life above and below the ground. This variety of life forms the well-known biodiversity. Biodiversity severely hampers the growth of pests.

The main consequences of improving biodiversity are the following:

- Varied plant growth in and around the fields creates a favorable environment for the natural enemies of animal pests (insects and mites in particular). In many cases these natural enemies keep the pest populations from reaching a harmful level;
- Varied plant growth in and around the fields limits the spread of pathogenic fungi, bacteria and viruses, but also the spread of insects and mites;
- Varied plant growth in the fields can provide faster-growing and more widespread ground cover, which prevents weeds from germinating and growing;
- Multiple crops, which are cultivated at the same time or in rotation, stimulate a rich and varied soil life. This helps control the growth of soil-borne pathogens and weeds;
- A varied soil life, created in part by varied plant growth, is also good for the soil structure. Good soil structure and balanced fertilization ensure the optimal growth of crops that have maximum resistance to diseases and animal pests and that can compete successfully with weeds.

The measures listed above not only help control pests, but often have other positive effects as well, which is all the more reason to implement them. Additional advantages can include the following:

- Ground cover crops protect the soil from intense sunshine, avoiding evapo-transpiration;
- Keeping the ground covered with plants prevents soil erosion, caused by heavy rains or strong winds. This is particularly important on hilly terrain;
- Combining leguminous crops with other crops allows both to profit from the nitrogen fixation of the leguminous crops;
- Combining a shallow-rooted crop with a deeper-rooted crop makes better use of the applied manure or fertilizers;
- A well-balanced crop rotation also ensures that the fertilizer applications incorporated in the planting schedule are optimally utilized.

Improving biodiversity, Plant growth alongside fields and ditches

Vegetation borders along the edges of fields and ditches can serve to ward off pests arriving from elsewhere. A combination of tall-growing trees and bushes with an undergrowth of grasses and herbs is sufficient for this purpose. As pests are carried by the wind, it is important to plant borders along the edges of the fields to face the prevailing winds. Many natural enemies of insects depend for part of their life cycle on nectar and pollen. It is therefore also important to plant on the borders trees, bushes and herbs rich in flowers.

However, vegetation may also offer food and shelter for some crop pests; farmers may need to adapt it to make it more attractive to the natural enemies and less attractive to pests.

It is best to use plant species that grow well under local conditions. A permanent border composed of a mixture of grass seeds with annual and perennial herbs can be made. The border has to be maintained by cutting once or twice a year for the first two to three years, primarily to suppress the growth of undesirable plants. It is not advisable to fertilize the border because that would stimulate the growth of grasses, which would eventually take over. Herbs and spices are encouraged but weeding is required in the early growth stages, to avoid nutrients competition.

The push-pull effect protects maize from Stem borers and Striga
Stem borers (caterpillars of moths) are the major insect pests of cereal crops in eastern and southern Africa. Losses can reach as high as 80%, while those due to *Striga* range from 30 to 100% in most areas.

Researchers found a way to grow maize together with two other crops. One attracts stem borers. This is the "pull effect". The other intercrop repels the stem borers, causing the push effect. Together they effectively protect the maize crop from stem borers.

Both domestic and wild grasses can cause the pull effect. Napier grass is the most effective. It is planted in the border around the maize fields where invading adult moths are attracted to it. Instead of landing on the maize plants, insects are attracted to what appears to be a tastier meal. Napier grass has a particularly clever way of defending itself against the pest onslaught: once attacked by a borer larva, it secretes a sticky substance that physically traps the pest and effectively limits its damage. And so the natural enemies lurking among the grasses go into action.

The legume *Desmodium* repels stem borer moths and 'pushes' them away from the main crop (maize or sorghum). *Desmodium* is planted in between the rows of maize or sorghum. Being a low-growing plant, it does not interfere with the crops' growth and has the further advantage of maintaining soil stability and improving soil fertility through nitrogen fixation. It also serves as a highly nutritious animal feed. Other legumes have this effect as well, but *Desmodium* also effectively suppresses *Striga*.

Crop rotation

Crop rotation means that various crops are cultivated in successive planting seasons. Crop rotation plays an important role for soil fertility, but also for controlling various pests such as soil-borne diseases and perennial weeds. Ideally, farmers should rotate grain crops with vegetables and root crops.

Be careful not to grow two crops from the same family one right after the other, such as potato and tomato, or celery and carrot. It is possible, however, to grow a grain crop more frequently than others in a rotation, because soil-borne diseases do not thrive in grain crops. Regular food and cash crops have to be taken into consideration when planning a rotation.

Organic farmers in Benin successfully grow cotton without pesticides
Cotton attracts a large number of insect pest species. That is why conventional cotton growing is associated with intensive spraying with insecticides. Benin cotton farmers, associated in the NGO OBEPAB (*Organisation Béninoise pour la Promotion de l'Agriculture Biologique*) switched to a system of organic cotton production. No synthetic pesticides and no inorganic fertilizers are used. Another difference with conventional farming is that crop residues are recycled instead of burnt, to increase soil fertility.

Additional advantages are that organic farmers do not need to buy pesticides, and farmers get a better price for their cotton.

The basis for organic cotton is a three year crop rotation. The cotton crop in the first year is fertilized with cottonseed press cake and is grown on ridges of decomposing crop residues on the contour line. The cotton crop is followed by grain (maize, millet, sorghum) and oil plants (peanuts, sesame or safflower).

Other possibilities include spices and vegetables like chilli or onion. In the third year, pulses like pigeon pea, mung bean, chick pea and cowpea are grown. The following cotton crop (in year 4) profits from the nitrogen provided.

In longer periods between two growing seasons, the soil is not left bare, but cover crops are grown instead, to prevent soil erosion, to suppress weeds and to supply food and shelter for beneficial insects that control cotton pest insects.

Popular cover crops include alfalfa, sweet clover, red clover, white clover, vetch, cowpea, buckwheat and mustard. In addition, trap crops are grown on the edges of cotton fields. They attract pest insects from the cotton crop. Trap crops include sunflower, cowpea, alfalfa, okra and early sown cotton.

Prevention of damage, promoting natural enemies
The natural enemies of crop-damaging insects and mites are also farmers' allies. There are two groups of natural enemies: predators and parasites. Predators eat their prey. The most important predators are harmless to crops and people.

Well-known predators include spiders, predatory mites, lady beetles, ground beetles and hoverflies. The advantage of these predators is that they multiply just as rapidly as their prey. The most common parasites are wasps and flies. They lay eggs in the pest insect's larvae, and then their larvae eat the host from the inside out. Predators eat many different species of insects or mites, but parasites are often specialized in one type of pest insect. As adults, their diet consists entirely of pollen and nectar, often of wild flowers. If there is a sufficient number of natural enemies present at the start of the growing season, they will normally keep the pest insects and mites under an acceptable level, so crops can remain healthy.

The farmers can also take measures to help the natural enemies out a bit. Diverse vegetation around pieces of land offers shelter where they can survive between growing periods. Farmers can stimulate their growth even more by sowing flowering herbs around and in the fields where crops are grown. Farmers can also build additional housing for predator insects or parasites.

Preventing the spread of pests
Vegetation in and around crops does more than just supply shelter for natural enemies. High vegetation around fields keeps flying insects away, as well as mites transported by the wind. A second crop in a field can also serve as a physical barrier, in addition to the

advantages mentioned. Rows of specific crops can deter or attract pest insects with their smell: these are known as repellent crops and trap crops.

Crop rotation
In a crop rotation, farmers can alternate crops that are eaten by a certain pest with crops that are not eaten by that pest. Crop rotation is part of a multi-annual strategy to minimize the number of pest insects on a farm.

Short growing season
If farmers are mainly growing one crop, and crop rotation is not a viable option, it is especially important to extend the period between crops as long as possible. The number of pest insects will decrease during the crop-free period. Farmers can also enhance this decline by working the plant residues containing the pest insects deep into the soil, or by bringing the pests to the surface where they are vulnerable to attack from their natural enemies. It is recommended to keep the growing season short by sowing or planting over as short of a period as possible. The same is true for harvesting. It may also be better not to wait until the last plant can be harvested or the last fruit is ripe, because the longer you wait to harvest, the more surviving pest insects there will be when you plant the next crop.

Removing crop residues
If there are many pest insects left after harvesting, it is better to remove the crop residues together with the pest insect than to leave the residue in the field. However, if there are relatively few pest insects present on the crop residues and many natural enemies, it may be useful to leave the crop residue in the field.

Fertilizing
It is important to fertilize in a balanced way, with enough P and K and not too much N. Too much N makes the crop appetizing for insects, and leads to a dense crop, in which it is more difficult for pest insects' natural enemies to find them.

Control
Even with all the preventive measures mentioned above, the number of pest insects could become too high and threaten to cause unacceptable damage to the crops. It is important to inspect the crops every week in order to determine whether critical levels are being reached.

Information on critical levels (such as the number of pests per sqm or per metre of a row) should be available for the field. As soon as the number of pest organisms is too high, farmers can consider taking corrective action.

Catching by hand
If pests' population is not large, relatively big insects can be caught by hand and squashed.

Catching in traps
It is less labor intensive and less tedious to control these pests by luring them into traps. The most common types of traps give off light to attract night insects, are made of yellow strips covered with glue, or contain some kind of bait.

Biological control with beneficial insects and micro-organisms
If it appears that the natural enemies of the pest insects and mites are staying in the margins of the field rather than moving into the center, farmers can carry them by hand into the field. Sometimes natural enemies that are bred elsewhere are offered for sale. These can be predators or parasites, but also nematodes or disease- causing fungi, bacteria or viruses.

Nematodes are primarily used to combat soil insects. Viruses, bacteria and fungi are sprayed over the entire crop and work against the pest insects that are present on the plants.

Control using plant extracts
Many plant species, both cultivated and wild, contain substances that can kill insects. You can easily make a spraying liquid out of these plants yourself. Plant extracts have both advantages and disadvantages compared to chemical pesticides. The most important advantages are:

- Less expensive; and
- Decompose faster, so no residue is left on the crop.

Farmers in Cameroon select plant extracts with insecticidal properties

Various non-chemical crop protection methods and products have been tested under local conditions in Cameroon.

First, an inventory of traditional methods of pest control was conducted with small-scale farmers in the North-West, South-West and West provinces of Cameroon. Information was gathered from their answers and from literature, and a booklet was prepared for distribution. Farmers were trained in non-chemical crop protection methods for controlling pests on their farms. The training methodology was based on a participatory approach and Farmer Field School.

One of the promising preparations subjected to field-testing after this inventory was castor oil (Ricinus communis).

The preparation is as follows: 0.5kg shelled or 0.75kg fresh unshelled seeds are mashed and then heated for 10 minutes in 2 liters of water. 2 teaspoons of kerosene and a bit of soap are added. The solution is sifted (through a cloth) and diluted with 10 liters of cold water. The preparation is then ready for application on the leaves, to control leaf-eating caterpillars, aphids and true bugs on vegetable crops. Castor oil is poisonous for humans as well as for the natural enemies of pests.

Extracts from the Neem tree (Azadirachta indica) are also widely used. Neem extracts have an effect on nearly 400 species of insects, including major pests (moths, weevils, beetles and leaf miners). They do not kill insects directly, but effectively prevent their reproduction. Neem extracts can be prepared from leaves, but the seeds contain higher concentrations of insecticidal components. 75g of seeds (including the seed coat) should be used per liter of water.

The seeds should be at least between 3 and 8-10 months old. The pounded kernel powder is gathered in a muslin pouch and soaked overnight in water. The pouch is squeezed and the extract is filtered. Some soap is added to the filtrate (1 ml/lt of water) to help the extract stick to the leaf surface of crop plants.

Papaya leaves can also be used: 1kg of fresh leaves, shred and soaked in 10 liters of water, add 2 teaspoons of kerosene and a bit of soap, and leave it overnight. Sift the decoction through a cloth, and the spray is ready for application on the leaves of vegetables, against leaf-eating caterpillars, aphids and true bugs.

On the other hand, the main disadvantages of plant extracts are:

- That they often have a weaker effect than synthetic insecticides. Many insects survive or just become ill and then recover;
- The required dosage differs according to the insect species. As farmers manufacture the spray themselves, they will have to determine the optimal dosage through experimentation;
- Some extracts (such as tobacco juice that contains nicotine) are poisonous to humans and pets. Just as with chemical pesticides, farmers have to handle these extracts with care;
- Most plant extracts are toxic to natural predators or parasites of pest insects, so the 'natural balance' will be disturbed when using these bio-insecticides.

A Neem (*Azadirachta indica)* oil pesticide is a natural way to control pest and diseases affecting crops as well as plants or flowers. Neem oil has been used for hundreds of years due to its ability to repel bugs. African farmers are using neem as an organic alternative to toxic chemicals that pollute the soil, water supply, along with harming children, birds and good insects.

African farmers Most Neem Oil is good quality but check the label to see what has been added to it as some have been diluted more than others. You can find it in most health stores as Neem Oil or Neem Leaf extract and it should be organic.

Neem can be easily made at household level by following the instructions as:

- Container big enough to hold two quarts of warm water to mix it in.
- Add ½ teaspoon of a mild liquid soap like Castile and mix it up, and then add ½ ounce of Neem Oil slowly into the water while stirring it or slightly shaking it up.
- Now pour some into an old, clean spray bottle of some type or into a new one.
- You can double this recipe but it should be used within 8 hours or it will lose its potency.

Spray all of the leaves wholly with your homemade pesticide on the top and bottom and saturate the soil with it, too. Always spray early in the morning or early in the evening to avoid scaring off the good bugs and scorching the plant in the hot sun.

Make sure to shake it while spraying to keep it well mixed, and repeat the spraying once a week and more if it rains.

It will not instantly kill the insects until they bite into the leaf, but it will instantly repel them with its strong smell.

Neem Oil pesticide has been known to kill and control aphids, moth larvae, spider mites, whiteflies, and Japanese beetles. It will not harm insects that do not chew the leaves like butterflies, ladybugs and bees.

Pesticides
African farmers strive to achieve highest yield and the best quality product possible to ensure food security at the household level. Thus would be done with a minimum

investment of energy and resources, without being affected by all kinds of harmful organisms (pests) that threaten to reduce the quality and yield of crops. Protecting crops from pests is extremely important, but it is difficult to achieve maximum results with minimum effort. Farmers have to look not only at a measure's immediate effect, but also at its long-term effects.

In best practices for organic production, non-chemical protection measures are always to be preferred against any threat of pest infestation or diseases to crops.

However, major challenges still lie ahead. The risks and hazards related to the toxicity of pesticides remain as serious as ever, despite of programs for enhancing safety use and wide distribution of practical extension materials.

It is important for farmers to use pesticides, after being informed correctly. Moreover, farmers should combine their knowledge gained through experience with the information they receive on proper use of pesticides.

Pesticides classification
'Pesticide' is the name used to indicate agrochemicals used for food and cash crops protection. A pesticide is a substance intended to prevent, destroy, repel or control any animal pest or disease caused by micro-organisms, as well as unwanted weeds. Pesticides can affect harmful pest animals and micro-organisms through direct contact, feeding or other kinds of effective exposure during stages of growth.

Bio-pesticides can play an important role in pest management. These consist of beneficial micro-organisms, and can be bacteria, viruses, fungi and protozoa, beneficial nematodes or other safe, biologically based active ingredients. Benefits of bio-pesticides include effective control of insects, plant diseases and weeds, as well as human and environmental safety. In some areas, pesticide resistance and environmental concerns limit the use of chemical pesticide products.

Pesticide names
The full chemical name of a crop protection product is often difficult to pronounce as well as to remember. The coded name is referred to as *active ingredient* (abbreviated as a.i.). This is generally a shortened version of the full chemical name. The active ingredient is the compound used to control the harmful organism. Its ability to kill, harm or deter a certain pest or disease has been proven and its use is authorized through a national or international registration process.

Ways to categorize pesticides used in agriculture
Chemicals or agro-pesticides available can be classified according to type of pest or disease against which they are effective (Table 1).

Table 1: Agro-chemicals including pesticides (P) and their activity

Category	Activity
Algicide	Kills algae e.g. on wood
Anti-feedant	Prevents animals feeding on a crop or stored product
Attractant	Attracts pest animals
Bactericide (P)	Kills or inhibits bacteria growth
Fungicide (P)	Fungus disinfection
Fumigant (P)	Gas or smoke against pests or fungi in stored products
Herbicide	Kills or inhibits growth of weeds
Insect growth regulator	Modifies insect development stages or growth
Insecticide (aphicide) (P)	Kills or harms insects (e.g. aphids)
Miticide / acaricide (P)	Kills or harms mites (or spiders)
Molluscicide	Kills snails and slugs
Nematicide (P)	Kills nematodes
Repellent	Keeps away pest animals
Rodenticide	Kills rats, mice, rodents
Sterilizant	Sterilizes insects in chemical way
Termiticide (P)	Kills or harms termites

Products are effective against more than one biological class:

- Some insecticides also kill mites or nematodes;
- Some fungicides are also effective against bacterial diseases;
- A few pesticides kill nematodes, insects, fungi and weed seeds.

Chemical origin
Agro-pesticides can be divided into *inorganic compounds*, *synthetic organic chemicals* and *bio-pesticides.*

Inorganic compounds are chemicals used for pest control, such as application of sulphur, lead arsenate, copper and lime mixtures, borax and chlorates, and mercury compounds. Inorganic pesticides are based on chemical elements that do not break down, and therefore many of them have very severe environmental and toxicological effects in their use. For example, some accumulate in the soil; lead, arsenic and mercury are very toxic.

Most *synthetic organic chemicals* are chemically derived from mineral oil products. After the introduction of insecticides and herbicides in the 1940s, their use spread rapidly throughout the world and continued to increase during the 1950s and 1960s. Increasingly sensitive tools for chemical analysis of the residual effects on crop parts, the environment, and test animals were developed from 1960 to 1980, enabling detection of very small amounts of pesticide residues in food and the environment, down to less than one part per ten million. This exerted a strong influence on pesticide development, its use and regulation.

Bio-pesticides are substances derived from plants or animals. These can even be the organisms themselves, and include fungi, bacteria, viruses and nematodes, plant-derived chemical compounds and insect pheromones. Some biological pesticides, such as nicotine, can be very toxic and their use is as hazardous as many inorganic or synthetic pesticides. Less toxic to man are the flowers of *Pyrethrum,* a root extract of *Derris elliptica* (Rotenone) and leaves and flowers of the Neem tree (*Azadirachta* spp.), which have been used for generations as effective insecticides. Other naturally occurring substances that are used include cow's urine and garlic juice.

Pesticide manufacturers have now made synthetic versions of many naturally occurring botanical pesticides, by identifying the essential chemical mechanisms that kill harmful organisms for crop protection.

Effective application and aims of pesticide application
Farmers have to know how a pesticide affects the pest. Insecticides, for example, can kill through dermal (skin) contact, act as a stomach poison, inhibit growth or repel the insect, and thus prevent it from feeding on the crop or stored product.

Leaf-eating caterpillars become sufficiently contaminated with insecticide residues when they crawl and feed on leaves. Boring insects inside leaves and stems as well as certain sucking insects are more protected against direct contamination. They are, however, poisoned by feeding on sap and tissue inside plants that have been sprayed with systemic insecticides.

The aim of chemical control is to bring the toxic active ingredient in contact with the target pest or disease agent in such a way to kill them, or inhibit their growth and development. Application of a crop protection product is *effective* if the physical and chemical formulation of the active ingredient kills or harms an insect, fungus, bacteria or other harmful organism which causes crop damage. Effective application meets the following conditions:

- The right choice of crop protection product;
- Applied in the right dosage, at the right time and using an appropriate technique.

Correct dosage is not only dependent on pest level, but also on potential crop damage or expected harvest loss, as well as on economic costs and benefits of crop protection. Potential damage to the crop may justify the application of the pesticide, but this must always be done in accordance with the instructions on the label.

Application is economically efficient if the avoided damage and crop loss justifies application. Farmers should always estimate and compare the cost of applying pesticides with the rate of loss in yield or with the quality deemed acceptable.

Different aims of pesticide treatment: preventive or curative
Preventive pesticide treatment aims to protect crops or stored products beforehand against infection by diseases, infestation by animal pests or competition from harmful weeds.
Curative treatment aims to destroy or limit population development of harmful organisms.

Pesticides can be distinguished according to their effect:
Contact pesticides need to reach the harmful organisms directly to be effective. The finer the spray mist, the better it will penetrate the crop and thus kill the organism.

Systemic pesticides attach to and penetrate the plant surface, and then disperse through the whole plant. Pesticides that persist for some time in the soil and subsequently penetrate through contact with roots, are also systemic. In order to be effective, these products do not need to be dispersed in a fine mist like a contact pesticide. Bigger droplets, smaller in number, can thus be dispersed over the crop, making the treatment easier and less costly.

HERDING PRACTICES

A herder is a worker whose main activity consists of leading the cattle in areas where pasture is available for his animals. In the Saharan region, many herders are semi-nomadic or nomadic. The semi-nomadic herders lead their animals to food and water sources throughout the day and then return back to their fixed dwelling. They do not need to march excessively in order to have access to pasture and water because they live in areas where the rain falls on a rare but regular basis. Nomadic herders, on the other hand, are on the move a good part of the year following food and water sources, as available depending on seasons and the evolving climate. Typically, they have to walk for miles before finding water. Some herders are sedentary, as they live in areas where enough pastures are available to feed their cattle without traveling anywhere.

Access to water

Access to water constitutes a real problem to herders. Most of them are using wells which are generally free but the access to which is not easy. During the rainy season, water is abundant and they do not need to go far to find rivers. However, between December and June, the wells are dry and herders would either wake early to be among the first at the well, or walk kilometers to find water for their cattle. In some areas where the water is made accessible by national services (*Senegalaise des Eaux*), they just buy the water they give to their cattle, the price of the water depending on the size of the basin.
The main livestock rearing areas (except for the Delta and near rivers) are without permanent water points. The surface water there dries up rapidly after the onset of the dry season. The search for water consequently becomes a serious problem throughout the dry season for the herds and their owners. The dispersion of existing water points (permanent ponds, wells, shallow wells) and their distance from pastures exploitable in the dry season demands long journeys, which exhausts the animals. The available resources only suffice to cover basic needs. Herd productivity drops during this period. Diseases and lack of resources are the most severe limitations of livestock production systems.

Access to food

Nomadic stock rearing: Nomadic stock raising is characterized by frequent movements of the herders and their stock, without fixed camps, according to the availability of resources. The areas of nomadic stock-rearing are either distinct or confluent and the family groups are more or less separated. Production follows a seasonal cycle. This type of system, called pure pastoral system, is found in the sub-desert zones in the north of Senegal (Adrar, Azaouad, Azaouak and Tilemsi) and in those of the northern Sahel such as the Gourma and the Hodh and in Mali. The breeds raised in these regions are zebus (Moor and Tuareg) for cattle, Saharan sheep and goats for the small ruminants and camels. The products are milk, meat and wool. The milk provided by cattle, goats and camels is insufficient and is all consumed fresh or made into cheese. Meat is provided by goats and hair sheep. Long-haired sheep produce wool. There is no salable surplus of these products.

Agro-pastoral systems: These are systems where crop production and stock rearing cohabit. According to the predominance of one or the other component, a system where livestock predominate or where crops are more important can be distinguished.

Transhumant systems: It is characterized by back and forth movements between pastoral territories by pastoral groups or communities seeking land resources other than their own. This movement pattern, called transhumance is made according to fixed axes and for a given period of time. Transhumance is characteristic of the Sahel. It takes the herders from south to north at the onset of the rainy season to remove the herds from the agricultural areas or areas which are flooded (in the case of the Niger Delta). The return south is made according to the progressive drying up of watering points and the exhaustion of the northern pastures. It is in the dry season that resources available for the animals are more plentiful in the south (water in watercourses, pasture after floods recede, perennial grasses, crop by-products and residues).

Animal health

The situation of animal health in the Saharan area is worrying. Every year, there is at least one epidemic which devastates cattle. Generally, before the news gets to everybody, a lot of animals are dead. However, there is an effort from governments, attempting to launch a vaccination campaign against the most dangerous diseases every year. Nonetheless, due to the high price of vaccines, most of the herders prefer to turn to herbal cures for their cattle.

Nutrition and human health

Almost all nutritionists have agreed on the importance of meat consumption because of its calorie content. Meat eating is very important to the growth of children. It gives them energy and works for the quick rehabilitation after they are weakened by infections. It is the most important source of proteins, which are vital to the organism. Apart from the proteins, it offers valuable nutrients including iron, zinc and vitamins.
The body needs proteins to build healthy muscles, bones and skin, as well as producing hormones and synthesize vitamins. Meat provides you with heme-iron, a type of iron that is easier for the body to absorb than the type of iron found in non-meat sources such as vegetables and beans. Zinc helps the immune system function properly, while the vitamin B group helps regulate the nervous system and release energy.

Meat consumption and health

As in every Islamic area, the rate of meat consumption in the Saharan region is high. The average meat eating per week for a Senegalese family is one meal. That rate is good for both their health and the health of the environment, given that studies demonstrate that a reduction in the consumption of animal products would reduce human pressure on the environment. According to some research, lowering the meat consumption may free up one million square kilometers of crop-land and 27 million square kilometers of pasture that could be used to store large amounts of carbon as the vegetation regrows. Regular and well balanced meat also lowers the risk of obesity and heart attack due to an important rate of grease in the organism.

Useful studies

- Livestock and region market in the Sahel and West Africa
  http://www.oecd.org/dataoecd/10/8/41848366.pdf
- Human and animal health in nomadic pastoralist communities of Chad: zoonoses, morbidity and health services
  http://edoc.unibas.ch/57/1/DissB_6478.pdf
- Nicholson Sharon E., Sahel, West Africa, dweb.met.fsu.edu/people/nicholson/papers/sahel95.pdf, Florida State University, Academic Press, Inc., 1995.
- Richerson, Pastoral Socieities, UC Davis,
  http://www.des.ucdavis.edu/faculty/Richerson/BooksOnline/He5-95.pdf

FISHING PRACTICES

Going alongside the coastal areas of West Africa, it is inevitable that you will notice the canoe of artisanal fishermen. For many villages fishing is the only economic activity which can provide decent jobs and continues therefore to attract people looking for a decent living. Fishermen generally gather in a community because of their common interest, which is the main reason of the creation of traditional coastal villages.

Quality in regards to presence and health of fish

Lately, fish presence in coastal Sahel has decreased considerably. That situation combined with overfishing has had a bad impact on the health of the species. Some other species tend to disappear in the fishery of that region because of the industrialization and over-exploitation which have brought about new kinds of infections.

Overfishing and stock management

In order to preserve the marine ecosystem, fishermen must respect certain basic rules. For example, having too much fish in a basket but not knowing how to stock them for future use is counterproductive. Overfishing is one of the major problems in fishing villages which do not have the technology to freeze the unsold production.
To respond to the issue of conservation, women have developed techniques of processing it. In Senegal, the most famous technique consists of grilling the fish and then drying it under the sun for at least three days. The result is called “keccax” and can be conserved for three months without any problem. Another technique is known as “gejj” which consists of cleaning the fish, coating it with salt and drying it under the sun for two to three days. As with the “keccax”, the resulting product can be also used three months later.
However, the overfishing dilemma does not come from artisanal fishermen, but mostly from industrial vessels which are literally devastating the ecosystem. The damages are numerous and the worst is that these foreign boats are confiscating the fish of the local fishermen. As a consequence, artisanal fishermen are now obliged to fish in the high seas because the coast is no longer able to supply them with enough fish.

Fishing strategies

The industrialization of the fishing sector is causing many damages to the traditional fishermen who find it more and more difficult to supply their customers. However, the government of Senegal is trying to introduce new reforms to the sector of artisanal fishing for its survival and sustainability. To date, the sector has been little regulated, no taxes are being paid, and no permits are required. However, according to a BBC article[1] (following a four-day conference in Nigeria discussing the matter), the government of Senegal is trying solve part of the problem by introducing a system of taxation. Now, the government is trying to find ways of restricting the ever-growing canoe fleet although any declaration has yet to be made.

1http://news.bbc.co.uk/2/hi/business/4182972.stm

Nutrition / human health

The fishery is an important portion of our nutrition. Fish is the most consumed food in Sub-Saharan societies. Its use is linked to its availability, but also to the nutriments it gives to our organism. Fish are an excellent source of high quality protein. They are low in fat, particularly cholesterol and saturated fats. They are rich in calcium, particularly small fish eaten with bones. Canned fish are very rich in calcium due to the fact that during processing they soften up. Additionally, marine fish are good sources of iodine. Being low in sodium they are sufficiently rich in potassium.

Pollution absorption and mercury levels

The factories in the coasts are throwing their waste into the open sea and since the coast is no longer able to supply the market for sufficient fish, fishermen are obliged to go into the high seas to throw their nets. These factories are polluting the water and the fish will serve as vehicle to this waste which is transferred to people through the food chain. Nearly all fish contain traces of mercury from industrial smoke and accumulates in streams and oceans, subsequently being turned into methyl-mercury in the water. This transformation is dangerous to children. Fish absorb the methyl-mercury as they feed in these waters and it builds up in their bodies. It builds up more in some types of fish and shellfish than others, depending on what the fish eat.

Pregnant women and fish

For most people, the risk from mercury by eating fish is not a health concern. Yet, some fish contain higher levels of mercury that may harm babies and children who are developing their nervous system. The risks from mercury in fish depends on the amount consumed. That is why some types of fish are to be avoided by pregnant women. Because they contain a high level of mercury, Shark, Swordfish and Tilefish are not advisable to pregnant women.

BIBLIOGRAPHY

- AATF (2006). Empowering African farmers to eradicate Striga from maize croplands. The African Agricultural Technology Foundation. Nairobi, Kenya. [Accessed 12th June 2012]
- Baier, A., (2005). Organic Certification Process. National Sustainable Agriculture Information Service. [Accessed 21 March 2012]
- Benkimoun Paul, Dans le Nordeste brésilien, des garçons au pénis atrophié pour cause de pesticides, Le Monde, 18 May 2012, [Accessed 29 July 2012]
- Boland, J., Koomen, I., van Lidth de Jeude, J., Oudejans, J., Agromisa Foundation, Wageningen, 2004. Agrodok 29 Pesticides: compounds, use and hazards. [Accessed 12th June 2012]
- Brunella Christophe, Pesticides et malformations génitales des fils d'agriculteurs, Novethic, 7 March 2005, [Accessed 29 July 2012]
- Choudhury, K., Jansen, L. J. M., (1999). *Chapter 7. Land in an agricultural, pastoral and forestry context*. [Online] Available at: www.fao.org/DOCREP/005/X2038E/x2038e0b.htm. [Accessed 20 March 2012]
- Choudhury, K., Jansen, L. J. M., (1999). Chapter 7. Land in an agricultural, pastoral and forestry context. [Accessed 19 March 2012]
- De Groot, Inge, (2004). Agromisa Foundation, Wageningen, 2004. Agrodok 18. *Protection of stored cereal grains and pulses*. [Online] Available at: www.agromisa.org/displayblob.php?256. [Accessed 20 March 2012]
- De Groot, Inge, (2004). Agromisa Foundation, Wageningen, 2004. Agrodok 18. Protection of stored cereal grains and pulses. [Accessed 20 March 2012]
- Enda Pronat1 (2011). Food crops grown by organic cotton farmers in West Africa [Accessed 13 July 2012]
- Ensor, J. (2009). *Biodiverse agriculture for a changing climate.* Practical Action The Schumacher Centre for Technology and Development. [Accessed 19 March 2012]
- European Commission (2006). A project funded under the EU's Research Programme explores properties of the African cereal fonio as a healthy and cheap addition to European diets, while at the same time generating incomes for local producers. [Accessed 13 July 2012]
- Eyhorn, F, S.G. Ratter & M. Ramakrishnan (2005) Organic Cotton Crop Guide; a Manual for Practitioners in the Tropics. Research Institute for Organic Agriculture (FIBL), Frick, Switzerland, ISBN 3-906081-67-2.
- Fanou-Fogny N, Koreissi Y, Dossa RAM, Brouwer ID. Consumption of, and beliefs about fonio (Digitaria exilis) in urban area in Mali. AJFAND 2009; 9(9): 1927-1944 cited in Fonio (Digitaria exilis) as a staple food in Mali: an approach to upgrade nutritional value, Nadia M.L. Fanou-Fogny, Thesis 22 June 2012. [Accessed 13 July 2012]
- FAO, Glossary on Organic Agriculture
- FAO (2011). Save and grow. A policymaker's guide to the sustainable intensification of smallholder crop production. [Accessed 12th June 2012]
- FAO (2011) Produire plus avec moins. Guide à l'intention des décideurs sur l'intensification durable de l'agriculture paysanne, [Visité le 12 juillet 2012]
- FAO, (1985). *Intercropping*. FAO Soils Bulletin 55. [Online] Available at: www.fao.org/docrep/X5648E/x5648e0m.htm#glossary. [Accessed 20 March 2012]

- FAO, (1996). *Agro-ecological Zoning – Guidelines*. FAO Soils Bulletin 76. [Online] Available at: www.mpl.ird.fr/crea/taller-colombia/FAO/AGLL/pdfdocs/aeze.pdf. [Accessed 20 March 2012]
- FAO, (1999). *What is Agro-biodiversity?* [Online] Available at: www.fao.org/docrep/007/y5609e/y5609e01.htm. [Accessed 20 March 2012]
- FAO/WHO Food Standards Programme, (1999 and modifications). Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods. [Accessed 18 March 2012]
- FiBL, Research Institute of Organic Agriculture, Switzerland (2011). *African Organic Agriculture Training* Manual. *Soil Fertility Management.* [Online] Available at: www.organic-africa.net/fileadmin/documents-africamanual/training-manual/chapter-02/Africa_Manual_M02.pdf [Accessed 19 March 2012]
- FiBL, Research Institute of Organic Agriculture, Switzerland (2011). *African Organic Agriculture Training* Manual. *Conversion to Organic Farming.* [Online] Available at: www.organic-africa.net/fileadmin/documents-africamanual/training-manual/chapter-08/Africa_Manual_M08.pdf [Accessed 19 March 2012]
- FiBL, Research Institute of Organic Agriculture, Switzerland (2011). *African Organic Agriculture Training* Manual. *Crop Management.* [Online] Available at: www.organic-africa.net/1303.html [Accessed 19 March 2012]
- FiBL, Research Institute of Organic Agriculture, Switzerland (2005). *Organic Cotton Crop Guide.* Authors: Frank Eyhorn (FiBL), Saro G. Ratter (BioSim), Mahesh Ramakrishnan (ICCOA). [Online] Available at: www.fibl.net/fileadmin/documents/en/development-cooperation/production-systems/cotton-training-manual-text.pdf [Accessed 19 March 2012]
- FiBL (2011): African Organic Agriculture Training Manual. Version 1.0 June 2011. Edited by Gilles Weidmann and Lukas Kilcher. Research Institute of Organic Agriculture FiBL, Frick. [Accessed 12 July 2012]
- FiBL, Research Institute of Organic Agriculture, Switzerland (2011). African Organic Agriculture Training Manual. Soil Fertility Management. [Accessed 19 March 2012]
- Frison, E. and Sharrock, S. (1999). The economic, social and nutritional importance of banana in the world. In: Picq, C., Foure, E., Frison, E.A (Eds). Banana and Food Security International Symposium, Douala, Cameroon, 10-14 November, 1998. [Accessed 12 July 2012]
- Gaspari L, Sampaio DR, Paris F, Audran F, Orsini M, Neto JB, Sultan C., High prevalence of micropenis in 2710 male newborns from an intensive-use pesticide area of Northeastern Brazil, Int J Androl. 28 February 2012.
- Hayma, J., (2003). Agromisa Foundation, Wageningen, 2003. Agrodok 31. *The storage of tropical agricultural products*. [Online] Available at: journeytoforever.org/farm_library/AD31.pdf. [Accessed 19 March 2012]
- International Federation of Organic Agriculture Movements (IFOAM) (2007). *Development of a Regional Organic Agriculture Standard in East Africa 2005-2007*. [Accessed 19 March 2012]
- International Federation of Organic Agriculture Movements (IFOAM) (2009). *High Sequestration, Low Emission, Food Secure Farming. Organic Agriculture - a Guide to Climate Change & Food Security*. Authored by Robert Jordan, Adrian Müller and Anne Oudes. [Accessed 19 March 2012]
- James, B., Atcha-Ahowé, C., Godonou, I., Baimey, H., Goergen, H., Sikirou, R., and Toko, M. (2010). Integrated Pest Management in vegetable production: A guide

for extension workers in West Africa. International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria, 120 pp. [Accessed 12th June 2012]

- James, B., Atcha-Ahowé, C., Godonou, I., Baimey, H., Goergen, H., Sikirou, R., and Toko, M. (2010). Gestion intégrée des nuisibles en production maraîchère: Guide pour les agents de vulgarisation en Afrique de l'Ouest. Institut international d'agriculture tropicale (IITA) Ibadan, Nigeria, 125 pp. [Visité le 12 juillet 2012]
- Khan, Z., Amudavi, D., and Pickett, J. (2008). *Push-Pull Technology Transforms Small Farms in Kenya*. PAN North America Magazine Spring 2008. [Online] Available at: www.push-pull.net/panna.pdf. [Accessed 26 March 2012]
- Office québécois de la langue française, Le grand discionnaire terminologique (GDT)
- Scheepens, P., Hoevers, R., Agromisa Foundation and CTA, Wageningen (2007). Agromisa, Agrodok 30 Non-chemical crop protection. [Accessed 12th June 2012]
- Scheepens, P., Hoevers, R., Agromisa Foundation and CTA, Wageningen (2007) Agromisa, Agrodok 30, La protection non chimique des cultures, [Visité le12 juillet 2012]
- Shank Robert, UNDP Emergencies Unit for Ethiopia (1996). Striga: The parasitic weed and its relation to poverty. [Accessed 12th June 2012]
- Senegal (2010). Research information from infosysplus.org: Organisations and projects in Senegal. [Accessed 13 July 2012]
- Stover, R.H. and Simmonds, N.W. (1987) Bananas. Longman, London cited in Overview of Banana and Plantain (Musa spp.) Improvement in Africa: Past and Future. J. Lorenzen,, A. Tenkouano,, R. Bandyopadhyay, B. Vroh, D. Coyne and L. Tripathi, International Institute of Tropical Agriculture, P.O. Box 7878, Kampala, Uganda, International Institute of Tropical Agriculture, PMB 5320, Ibadan, Nigeria [Accessed 12 July 2012]
- UNCTAD (2003). Organic Fruit and Vegetables from theTropics. Market, Certification and Production Information for Producers and International Trading Companies. [Accessed 19 March 2012]
- UNCTAD (2008). *Certified organic export production. Implications for economic welfare and gender equity among small-holder farmers in tropical Africa*. [Online] Available at: www.unctad.org/en/docs/ditcted20077_en.pdf. [Accessed 19 March 2012]
- UNCTAD (2003). *Organic Fruit and Vegetables from the Tropics. Market, Certification and Production Information for Producers and International Trading Companies*. [Online] Available at: www.unctad.org/en/docs//ditccom20032_en.pdf. [Accessed 19 March 2012]
- UNEP (2007). *Organic Agriculture in Africa.* [Online] Available at: www.unep.org/training/programmes/Instructor %20Version/Part_2/Activities/Human_Societies/Agriculture/Supplemental/Organic_Agriculture_in_Africa.pdf. [Accessed 21 March 2012]
- UNEP (2007). Organic Agriculture in Africa. [Accessed 21 March 2012]
- USAID, Support For Accelerated Growth And Increased Competitiveness (2008). Chaîne de Valeur Fonio - Sénégal Analyse et Cadre Strategique d'Initiatives pour la Croissance de la Filière. [Accessed 13 July 2012]
- Vodouhe R.S., Achigan Dako G.E., Dansi A., Adoukonou-Sagbadja H. (2008). Fonio: A treasure for West Africa. Genetic Resources Multiplication And Utilization [Accessed 13 july 2012]

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