African Organic Agriculture Training Manual

A Resource Manual for Trainers

4 PESTS, DISEASES AND WEEDS

Draft Version 1.0
June 2011

Ready for field testing

FiBL

IMPRINT

Publisher:
FiBL, Research Institute of Organic Agriculture, Switzerland, www.fibl.org

Collaboration:
- IFOAM, International Federation of Organic Agriculture Movements, Germany, www.ifoam.org
- NOGAMU, National Organic Agricultural Movement of Uganda, www.nogamu.org.ug
- FENAB, Senegal
- OPPAZ, Organic Producers and Processors Association of Zambia, www.oppaz.org.zm

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Draft version 1.0, September 2011.
This is an interim version. Comments and recommendations for improvement are welcome.

All materials resulting from the Africa Organic Agriculture Training Manual project are available free of charge in the internet under www.organic-africa.net

The production of this manual was funded by the Bill and Melinda Gates Foundation and the Syngenta Foundation for Sustainable Agriculture with the goal to promote organic farming in Africa.

Please cite this publication as follows:
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

ISBN 978-3-03736-197-9

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Learning targets for farmers:

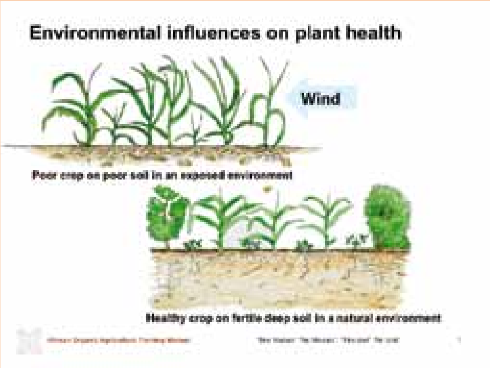
- Distinguish between beneficial organisms and pests, diseases and weeds
- Develop awareness of the most important organisms limiting production and storage of agricultural products
- Understand why management of pests, diseases and weeds should not be limited to spraying pesticides, but should consist of providing good growing conditions for the plants to enhance their resilience and resistance and encourage natural control mechanisms through promotion of natural enemies
- Recognize the tools of organic pest, disease and weed management and be able to combine them appropriately to limit pesticide applications

1 Introduction

From an ecological perspective all organisms are part of nature, irrespective of what they do. To a farmer, all organisms that reduce the yields of their crops are considered pests, diseases or weeds. Insects, birds or other animals are also pests whenever they cause damage to crops or stored produce. Fungi, bacteria and viruses are also recognized as disease causing organisms when they lead to conditions that interrupt or modify the vital functions of growing plants or stored produce. All unwanted plants that grow within crops and compete with them for nutrients, water and sunlight are considered weeds. Such plants can also be hosts for pests and diseases.

Presence of these organisms in crop fields is not a problem until their numbers increase beyond a level where they attack, and cause substantial reduction in field crop yields or quality of harvested and stored produce. Farmers, who wait until this moment, often depend on aggressive and very harmful methods to limit damage. However, since many African small-holder farmers neither have the access nor can afford such methods and products, yield and quality losses are often substantial. In general, challenges associated with pest, disease and weed management can be summarized as follows:

GENERAL CHALLENGES TO PEST, DISEASE AND WEED MANAGEMENT



- **Wide diversity of pests, diseases and weeds -** In sub-Saharan Africa a wide variety of pests, diseases and weeds occur because of the favourable, humid conditions nearly throughout the year. Because of this, many new pests, diseases and weeds evolve or are introduced, mostly accidentally, in the region. It, therefore, proves very challenging for farmers to recognize, distinguish and control the different pests, diseases and weeds.
- **Poor monitoring -** Many farmers lack knowledge on the cycles of specific pests, diseases and weeds and find it difficult to distinguish their specific characteristics. As a result, they cannot apply suitable preventive measures nor implement proper control measures.
- **Limited access to pesticides -** The great majority of African farmers lack the financial resources to buy chemical pesticides to control pests, diseases and weeds.
- **Limited knowledge on suitable pesticides -** There is a wide variety of pesticides available on the market, including ineffective ones. Since the majority of farmers cannot read and interpret the contents, prescriptions and other precautions, they cannot make proper choices on the best pesticides. They instead rely on recommendations from the pesticide retailers, who often lack the proper knowledge themselves and are often more motivated to make sales than advise farmers.
- **Lack of knowledge on proper storage and application of pesticides -** Farmers are exposed to high health risks in the case of improper application of pesticides; for example, the majority lack appropriate protective gear. In addition, synthetic pesticides and application equipment are usually stored inside homes, where food and children are exposed to them. Also, treated crops are sometimes harvested without proper observation of pre-harvest intervals, thereby exposing consumers to greater health risks.

This is a clear indication that the management of pests, diseases and weeds is still very challenging to many farmers all over Africa. To avoid major crop losses, the farmers should be able to implement affordable and effective measures which should not substantially increase their production costs or harm beneficial organisms in the ecosystem.
Generally appropriate methods and products should be:
- Easy to apply at minimal extra cost.
- Applicable in the local situation and conditions.
- Safe to handle, with minimal or no residual effect.

Assessment of local challenges in pest, disease and weed management

Inquire among the farmers what the major challenges related to pest, disease and weed management are. Ask the following questions.
- Is pest, disease and weed management challenging?
- What makes it difficult to manage pests, diseases and weeds?
- Do the challenges match with the ones listed above?
- How do you try or plan to address them?

A HEALTHY SOIL IS THE BASIS FOR HEALTHY PLANTS

2 General approach to pest, disease and weed management

The organic approach to plant pest, plant disease and weed management makes reference to the four principles of organic agriculture: the principle of health, the principle of ecology, the principle of fairness, and the principle of care (see IFOAM principles of organic agriculture in the introduction to organic agriculture chapter). Generally, organic farmers aim at sustaining and enhancing the health of their soils, plants, animals, humankind and—in the widest sense—the planet. The health of individuals and communities cannot be separated from the health of ecosystems. Therefore, by providing healthy soils and a diversified natural environment, farmers are able to produce healthy crops that foster the health of animals and people.

Healthy plants are also able to resist and tolerate physiological disruption and damage from disease-causing organisms and pests. Thus, organic farmers aim at optimizing the growing conditions for their crops to make them strong and competitive. At the same time they encourage natural control mechanisms to prevent pests, diseases and weeds to develop in a way that they cannot damage the crops. They, therefore, give priority to preventive measures to prevent and limit the spread of infections, instead of relying on direct control measures. Direct control measures are mainly applied when pathogens have already developed.

Organic plant pest, plant disease and weed management is based on:

- Enhancement of a healthy, fertile soil and good growing conditions to promote healthy plants.
- Growing suitable varieties that are adapted to the local conditions and resistant to major pests and diseases.
- Proper monitoring of pests and diseases in order to encourage timely and effective intervention.
- Non-reliance on externally sourced and costly inputs.
- Minimizing the spread and multiplication of pests, diseases and weeds and thus reducing losses in the field and during storage.
- Enhancement of natural predators to encourage natural control mechanisms.
- Direct control tools that respect and protect the natural resources soil, water, air, and biodiversity. Negative impact on the environment is also avoided by not using synthetic fertilisers and pesticides.

THE BASICS OF ORGANIC PEST AND DISEASE MANAGEMENT

2.1 The three-step approach

Organic pest, disease and weed management can be seen as a three-step approach with multiple tools.

- Step 1: The first step consists of providing good growing conditions for plants to enhance their resilience and resistance.
- Step 2: The second step consists of encouraging natural control mechanisms through promotion of natural enemies.
- Step 3: The third step involves application of direct control measures to kill the pests, diseases or weeds in a way that has minimum residual effect to the ecosystem.

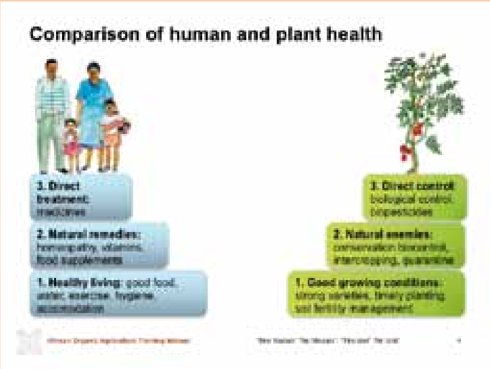
For a comparison, the three-step approach also applies to human health care management:

- 1st step measures: Provision of sufficient and healthy food and water and the preservation of a healthy environment to encourage human health. It also includes good behavioural practices to avoid illness by simple measures of hygiene (e.g. washing hands regularly and brushing teeth) and appropriate exercise to strengthen the body.
- 2nd step measures: Preventative intake of vitamins, antioxidants or probiotic agents and the use of natural medicine against illness (e.g. traditional medicine, medical herbs and homeopathy).
- 3rd step measures: Direct treatment using antibiotics and other medicines to kill off infections.

Each step of the three-step approach builds the foundation for the next step. The aim is to optimize steps 1 and 2 in order to encourage natural self-control of pathogens and to minimize the direct control measures (step 3). With proper and efficient application of steps 1 and 2, direct intervention is usually not needed. This saves on costs and prevents negative impacts of some direct control tools on the farm ecosystem.

Decades of practical experience from organic farmers and results of scientific research on organic pest, disease and weed management in the last 30 years have shown that the combination of indirect and direct control measures is more effective. As knowledge of the interaction of pest and disease pathogens and their natural enemies increases further, efficiency of this holistic approach

THREE STEPS OF HUMAN AND PLANT HEALTH CARE



also increases. Ideally, farmers will eventually be able to renounce any direct control measures and instead maximize the use of natural processes.

2.2 Plant pest and disease management

Organic methods can be very effective in the management of pests and disease, especially if applied well and on time. However, with certain devastative pest or disease outbreaks, more aggressive conventional means may be required in order to limit the spread of infections. In some cases, it may be a national regulatory requirement for all farmers to comply and thus individual farmers may have little or no control. Organic agriculture recognizes such situations and farmers should inform consumers or their certification bodies in order to find alternative remedial actions.

Steps and tools to pest and disease management - The organic pest and disease management toolbox

1st step: Crop management practices

These practices aim at providing good growing conditions to enhance plant health and prevention of introduction and spread of pests and diseases. This can be achieved through the following practices:

- Choice of appropriate crop varieties suitable for the location. Where possible, varieties tolerant or resistant to pests and diseases should be used.
- Using clean planting materials.
- Soil fertility improvement to encourage strong and vigorous growing plants, by using compost, animal manure, green manure and other organic materials.
- Intercropping and crop rotation to reduce the multiplication rate of pests.
- Other good management practices to ensure proper growth (e.g. timely planting, proper spacing, water conservation, pruning, shade management and timely harvesting).

2nd step: Habitat management practices

These practices aim at enhancing the proliferation of a variety of organisms (including natural enemies) around and within the crop fields. These include:

Discussion comparing human health with plant health

Invite the farmers to identify the similarities and differences between human health and plant health care. The functioning of plant health care can be elaborated on in groups and discussed in a plenary session.

ORGANIC PEST AND DISEASE MANAGEMENT TOOLBOX

- Planting hedges of indigenous plant species around fields to attract natural enemies. Allowing flowering plant species to grow within crops to provide nectar and pollen for natural enemies like ladybird beetles, hoverflies and parasitoids.
- Trap cropping to attract pests to non-crops or push away pests from the crops (e.g. push-pull strategy).
- Field hygiene, including timely weeding to remove alternative hosts, roguing infected plants and plant parts, proper disposal of infected plants and disinfecting tools used on infected plants/fields.

3rd step: Direct control
In situations of heavy infestations or very devastative pests and diseases, direct measures will be needed to minimize losses. These tools will only be fully effective when tools in the other two steps are applied properly.
These include:
- Biological control agents such as predatory insects and mites, insect parasitoids, viruses and bacteria.
- Approved or self-made insecticides or acaricides (against mites) of biological or mineral origin including plant extracts, plant oils, mineral oil, copper and sulphur.
- If available, insect pheromone traps may be used to disrupt mating of pests.
- Light, bait or colour traps may be used for mass-trapping pests.
- Hot water treatments of seeds to limit seed-borne diseases.

2.3 Weed management

A weed is a plant growing in a place where it is not wanted by humans. In agriculture, weeds may damage crops when growing in fields or poison domesticated animals when growing on pasture land. They can roughly be grouped into annual and perennial plant species.

Annual weeds are plants that normally take advantage of temporarily bare soil to produce another generation of seeds before the soil is covered again by crops.

Perennial weeds are plants that grow for many seasons. They propagate either by seeds or by the spread of vegetative parts, such as roots or tubers. Re-

THE ORGANIC WEED MANAGEMENT TOOLBOX

generation by vegetative means is a unique characteristic to perennial weeds, meaning even the smallest root or stem can reproduce an entire plant.

Steps and tools to weed management - The organic weed management toolbox

1st step: Crop management practices

These practices aim at limiting the introduction and multiplication of weeds. These include:

- Use of crop seeds free of weed seeds.
- Appropriate land preparation, adapted to either annual or perennial weeds. Perennial weeds should be removed as much as possible before planting or covered with an aggressive green manure plant, otherwise they are difficult to control after planting the main crop.

2nd step: Habitat management

These practices aim at reducing the impact of weeds on the growing plants:

- Intercropping or cover cropping to rapidly cover the soil before weeds emerge.
- Mulching to suppress weed growth.

3rd step: Direct control

On top of the practices in the 2nd step, direct control practices may be applied to completely eliminate the weeds. These practices include:

- Mechanical control by hand, animal traction or appropriate machines to remove weeds.
- Use of biological control agents, meaning the use of specific plant diseases or plant pests against weeds.
- Thermal weed control (flame weeding).

2.4 Monitoring of pests, diseases and weeds

Study the pests, diseases and weeds

Regular monitoring of pests, diseases and weeds is the basis for effective management. To be able to manage pests, diseases and weeds, information is needed on the specific pests, diseases and weeds present in the region, village or crop fields and the associated damage they cause.

Typical signs of pest attacks on crop plants

Most crop pests belong to the insects, mites and nematodes. However, in Africa, mammals (like elephants, monkeys or voles), and birds (like sparrows, starlings and crows) can also damage crops. Pest damage is obvious and easy to identify.

Insect damage can be categorized by biting and chewing (e.g. caterpillars, weevils), piercing and sucking (e.g. aphids, psyllids) and boring (e.g. borer, leaf miner) species. Some are slow moving (e.g. caterpillars), fast moving (e.g. fruit flies), hidden (e.g. stem borer), or easy to observe (e.g. caterpillars, weevils).

Pest damage is often species-specific: leaves with holes or missing parts is an indication of caterpillar or weevil damage; curled leaves is an indication of aphids; damaged or rotten fruits are often caused by larvae of fruit flies; withering plants can also be caused by larvae of noctuids or the stem borer; and branches or trunks with holes may be an attack by lignivorous insects.

Mites are very small and cannot be seen with the naked eye. However, some mite species (spider mites) weave a typical tissue on attacked plant parts and can, therefore, easily be detected. If mites are present on plants, leaves and fruits become yellowish.

Nematodes are also very small and therefore, they are not easy to observe with the naked eye. They mostly attack plant roots; plants become yellow, wither and die.

Typical signs of disease attacks on crop plants

Most crop diseases are caused by fungi, bacteria or viruses.

Fungi cause the great majority, estimated at two-thirds, of infectious plant diseases. They include all white and true rusts, smuts, needle casts, leaf curls, mildew, sooty moulds and anthracnose. In addition, they are responsible for most leaf, fruit, and flower spots, cankers, blights, wilts, scabs, and root, stem, fruit, wood rots among many others. Parts of plants or the total crop plant can wither and die.

Bacteria cause any of the four following main problems. Some bacteria produce enzymes that breakdown the cell walls of plants anywhere in the plant. This causes parts of the plant to start rotting (known as 'rot'). Some bacteria produce toxins that are generally damaging to plant tissues, usually causing early death of the plant. Others produce large amounts of very sticky sugars; as they travel through the plant, they block the narrow channels preventing water getting from the plant roots up to the shoots and leaves, again causing rapid death of the plant. Finally, other bacteria produce proteins that mimic plant hormones. These lead to overgrowth of plant tissue and form tumours.

Viruses mostly cause systemic diseases. Generally, leaves show chlorosis or change in colour of leaves and other green parts. Light green or yellow patches of various shades, shapes and sizes appear in affected leaves. These patches may form characteristic mosaic patterns, resulting in general reduction in growth and vigour of the plant.

Before managing any particular pests, diseases and weeds, the farmer should know how it behaves in relation to the concerned crop.

Guiding criteria for understanding pests, diseases and weeds

Pests

- At what stage of the lifecycle is it a pest: larvae, caterpillar or adult?
- At what stage of plant growth does it attack: seedling, growing or mature plant?
- Which part of the plant does it attack: leaves, roots, stem, fruits, seeds or the entire plant?
- What kind of damage does it cause: chewing, sucking or the death of the plant?
- When does it attack: dry season or wet season?

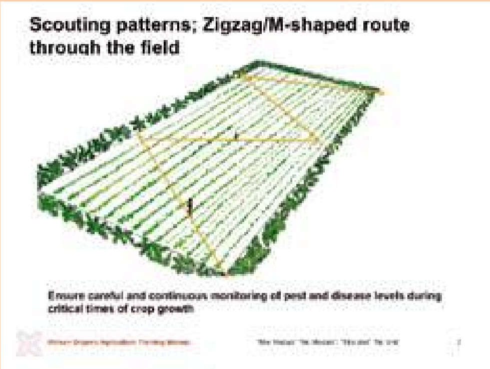
Diseases

- What is the cause of the disease: virus, bacteria or fungus?
- How is the disease transmitted: by seeds, through the soil, by air or by insects?
- At what stage of plant growth does it attack: seedling, growing or mature plant?
- Which plant part is attacked: leaves, roots, stem, fruits, seeds or the entire plant?
- What kind of damage does it cause: rotting, chlorosis, wilting, spots, etc.?
- When does it attack: in the dry season or the wet season?

Field visit or exercise to identify pest and disease causing organisms

Collect plant samples showing different pest and disease damage, and invite the farmers to categorise the symptoms into fungal, bacterial or viral infections.

SCOUTING PATTERNS



Weeds
- Is the weed perennial or annual?
- How is it spread: by seeds, rhizomes, etc.?
- Which conditions promote its growth?

Field scouting for pests and diseases

Careful and continuous monitoring of pest and disease levels during critical times of growth of a crop is the key to successful management. This can be done through regular scouting of the field by the farmer. It helps the farmer to intervene early enough before the pest and/or disease cause significant damage. Scouting avoids unnecessary use of natural plant extracts. Limited use of these substances (e.g. pyrethrum, derris and tobacco) and oils is important as they also have negative effects on beneficial insects. If the application of these substances is not regulated, many pest predators and parasitoids may be killed as well. Over application of these substances may also lead to pests developing resistance.

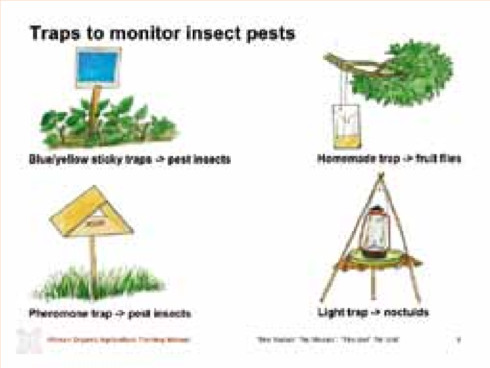
Therefore, scouting should be planned and done in an organised way. It is important to get a random sample that will be representative of the overall situation in the crop garden. Therefore, the scout (farmer) needs to observe and record any of the findings for better decision making. The most common pattern in pest and disease scouting programs involves walking along a predetermined zigzag or M-shaped route through a field. This pattern is commonly used because it is easy to teach, convenient to use, and ensures that all regions of the field are visited.

To monitor insect pests, different traps can also be used. The simple idea is to know more about the presence of the insect pests in the field especially the fast moving (mobile) insect pests (e.g. fruit flies, lepidopteran pests).
- Fruit flies can be captured using **bait traps.** For example, PE-bottles with small holes can be half-filled with water, some cattle urine, fruit flesh or a small dead fish and a drop of detergent or soapy water. These bottles are then hung in trees and checked every three days.
- **Yellow plastic cards** coated with adhesive are also good for trapping aphids and leafhopper. **Yellow-orange plastic boards** are appropriate for white flies, while blue cards are appropriate for thrips monitoring.

Group work for monitoring insect pests

Choose any crop fields in the neighbourhood for a trial scouting exercise for pests and disease infestations. Demonstrate how scouting is done, emphasizing the need to know what to look for and where to start looking.

TRAPS TO MONITOR INSECT PESTS



- **Light traps** are especially needed where noctuids (e.g. moths, cutworms, African armyworm, and cotton bollworm) are a problem. Within crops attacked by cutworms, visual checks of caterpillars have to be done by dawn.

3 Tools to manage pests and diseases

3.1 Cultural practices to manage pests and diseases (1st step tools)

Organic farmers aim at creating diverse and ecologically stable farming systems and enhancing the plants' natural defence mechanisms. The goal is a robust, healthy crop plant. They give first priority to prevention of pest and disease development instead of direct control measures. At the same time, this approach enhances biodiversity, protects natural resources and favours natural control mechanisms. This avoids costs for pesticides, residues on the crops, and negative impacts on the environment.

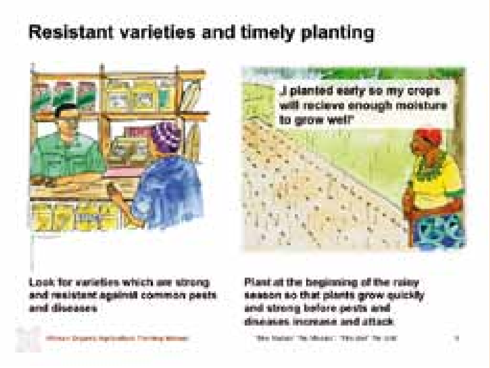
Tool 1: Choice of tolerant or resistant crops and varieties
The use of crops and varieties tolerant or even resistant against common pests and diseases is an effective measure to lower risks of pest and disease damage. In organic farming, the selection of varieties with partial resistance or field tolerance to pests is practical and even preferable to high-level resistance. There are more commercial varieties with disease resistance than are known for pest resistance. Therefore, for pest resistance, the local knowledge of farmers and advisers about the characteristics of traditional and local crop varieties is of high value. Even 'resistant' varieties need to be adapted under local climatic conditions for effective resistance.

Tool 2: Timely planting
Planting should be scheduled so that the most susceptible time of plant growth does not coincide with the life stage of pest or disease inoculum that damage the plant. Timing of seeding and planting is used to avoid invasion by migrants, or the oviposition period of particular pests, and the introduction of disease in the crop by insect vectors (like aphids and psyllids). In addition, it is used to synchronize the pest or disease attack with its natural enemies, with weather conditions that are adverse for the pest, disease pathogens or with the abundance

Plenary discussion on cultural practices for pest and disease management

Invite the farmers into a discussion about the different cultural practices that can enhance the health of a crop. Identify local examples and discuss how each mentioned practice prevents infections. Ask the farmers that have implemented such a practice to share their experiences in terms of its advantages and disadvantages. Alternatively, you may visit a farmer who practices already practicing these methods to share his/her knowledge.

RESISTANT VARIETIES AND TIMELY PLANTING



SOIL FERTILITY MANAGEMENT

of alternative hosts. This timing needs special knowledge of the pest or disease pathogen and when it is likely to attack.

Tool 3: Soil fertility management

The enhancement of soil fertility plays an important role in pest and disease control. A fertile soil enhances plant health and even triggers the immune reaction of plants. Soil fertility has to be improved by using crop rotations, cover cropping, green manure, application of compost and manures, and mulching:

› Besides the beneficial effect on soil fertility, **crop rotations** are important to avoid pests and diseases incubating in the crop field. An interval of 1 to 3 years between crops of the same family grown on the same field breaks the life cycle of the pathogens. The minimal duration of the interval depends on the disease's or pest's persistence in the soil. Some diseases stay dormant as spores in a field for many years (e.g. bacterial wilt stays infectious for at least 2 years, late blight up to 4 years, and Fusarium species up to 6 years). Many pests like rice stem borer or plant-parasitic nematodes will easily die from starvationi if crops are not available in the following year. If soil-borne pests and diseases are a problem, improved fallows for at least one season can also be applied.
› **Cover crops** and **green manures**, besides feeding the soil and improving its organic matter content, can reduce pests by confusion and diseases by biofumigation. Pest species like aphids, root flies or weevils will not find the crop plants due to the intercrop causing olfactory confusion.
› Application of **compost** can help control plant pests and diseases through (i) successful amendment of the soil with insect pathogenic microorganisms (ii) antibiotic production by beneficial microorganisms and (iii) activation of pest-tolerance or disease resistant genes in plants by essential nutrients of composts.
› Application of organic **mulches** can, in special cases, reduce pests like root flies, cutworms or aphids by olfactory confusion or by hiding the preferred places for egg laying. In special cases, they reduce diseases by altering the immediate environment or by reducing raindrop splash-dispersal of some soil-borne diseases. However, organic mulches might also enhance some fungal diseases by enhancing soil moisture.

FIELD HYGIENE AND SANITATION

Tool 4: Conservation tillage

Conservation tillage aims at creating a suitable soil environment for growing crops and conserving soil, water and energy resources through reduction in the intensity of tillage and retention of plant residues. Plant residues serve as additional organic matter incorporated in the soil. Conservation tillage practices improve soil structure and enhance micro-, meso- and macrofauna in the soil. This additional diversity of organisms at the same time can improve plant health through competition, parasitism, or antibiosis with the soil-borne pests and diseases.

Tool 5: Field hygiene and sanitation

› The use of disease free seeds and planting materials is a very effective tool to prevent development of seed-borne pests and diseases. Certified seeds are normally clean, but if such seeds are not available to the farmers, the seeds should be treated before use to eliminate seed-borne diseases (see hot water treatment).
› Sanitation of existing crops, especially perennial crops should be done regularly. Poorly managed or abandoned perennial crops can result in build up of pest and disease problems. All damaged plant materials and rotten fruits from the ground must be either burned or deeply buried at least 50 cm deep.
› Pruning eliminates inoculum in perennial crops. All infected branches or shoots should be cut at least 20 cm below the visible damage. Pruning also improves aeration and light exposure to the crown, which contribute to prevention of diseases.
› Regular cleaning of all the tools used for pruning infected plants or gardens is important, especially in the case of bacterial and viral diseases. If possible, alcohol (>70 %) can be used to disinfect the tools or heating the metal parts of tools over a fire.

3.2 Habitat management to control pests and diseases (2nd step tools)

Organic farmers make use of habitat management practices like conservation biocontrol, intercropping and trap cropping to encourage natural enemies of pest and disease causing organisms. For improving habitats, only non-host plant species of important pests and diseases should be chosen (e.g. avoiding plant species of the Brassica family in case of Turnip mosaic virus or Solanaceae family in case of late blight).

Habitat management also includes the adjustment of the environment around and within the field to improve air circulation (e.g. pruning trees and bushes limiting the air circulation in the main wind direction and avoiding dense crops). In contrast to pest management, the possibilities to reduce diseases by habitat management are more limited. However, the practices are also helpful to stabilize the entire system.

Tool 6: Conservation biocontrol

The natural enemies of pests are other organisms (fungi, bacteria, viruses, insect predators, and insect parasitoids) which kill pests—therefore, they are 'friends of the farmer' as they help to control pests. Hence, many pest species can be managed by enhancing the efficacy and abundance of the existing natural enemies. This can be achieved through modification of the environment or existing practices—this is called 'conservation biocontrol or conservation biological control'.

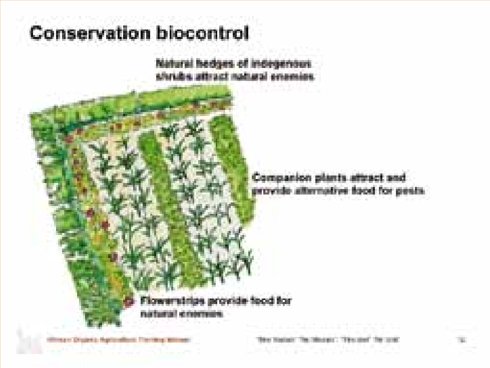
Conservation biocontrol is appropriate for organic agriculture because organic farmers use a minimum of disruptive broad-spectrum pesticides that otherwise would constrain the efficacy of natural pest enemies. The goal of conservation biocontrol is to diversify vegetation by adding plant species within and especially in the vicinity of crop fields. This will help natural enemies to find food sources like pollen, nectar and alternative hosts and preys and will satisfy their requirements for shelter (microclimate). There are many possibilities to enhance floral diversity within and along the boundaries of crop fields:

› **Hedges -** Use indigenous shrubs known to attract pest predators and parasitoids by offering nectar, pollen, alternative hosts and/or preys. Most flowering shrub species have this property. However, care should be taken to not use plant species known to be alternative hosts of pests or diseases.
› **Beetle banks -** Strips of grass in the neighbourhood of crop fields harbour different natural pest enemy groups like carabids, staphylinid beetles and spiders. In order to lower the risk of weeds and plants known as host plants of crop pests and diseases, one to three native grass species can be sown in strips of 1 to 3 meters.
› **Flower strips -** Use indigenous flowering plant species known to attract predators and parasitoids by offering nectar, pollen, alternative hosts and/or

Discussion on habitat management for pest and disease control

Discuss all the measures of habitat management with the farmers. Invite the farmers to share their experiences on conservation biocontrol, intercropping and trap cropping. Visit a farm with a diverse natural habitat and identify plant species that may be promoted to control pests and diseases.

CONSERVATION BIOCONTROL



preys. Most flowering plant species have this property. However, care should be taken not to use alternative hosts of pests or diseases. Three to five native flowering plant species can be sown in well-prepared seed beds, arranged in strips of 1 to 3 meters on the boundary of the crop field. After flowering, seeds can be collected to renew the strip or create new ones.

› **Companion plants -** Natural pest enemies can also be attracted by companion plants within a crop. These companion plant species can be the same as used in the flower strips. A few (1 or 2 per 10 square meters) flowering companion plants within a crop serve as a 'service station' for natural pest enemies.

Tool 7: Intercropping (or mixed cropping)

Another approach for managing pests and diseases involves intercropping with other crops. The idea behind it is to have less concentrated areas of host plants which are less easy to be detected and colonized. Distantly related crop plants can visually or chemically interfere with specialist pests, making the habitat less favourable. Mixed intercropping systems where two or often more species are grown intermingled without distinct rows are very commonly used in the tropics. Row intercropping (growing two or more crops together in rows) and strip cropping (cropping by growing two or more species in strips) must be sufficiently wide to allow separate management regimes, but sufficiently close to influence each other. These types of mixed cropping systems have been widely investigated as they have great potential for reducing pest attacks.

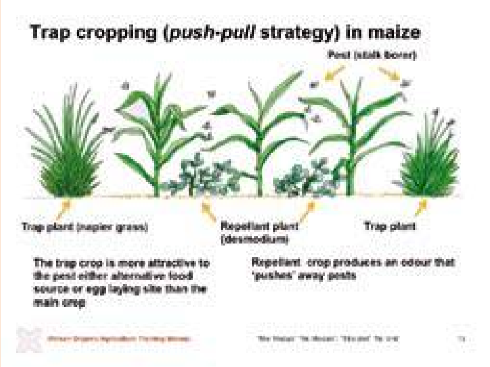
The mixture of plants needs to be carefully chosen. Anise, chives, garlic, onions, radish, parsley and many other species are reported as good partners for intercropping. The example of the Mexican marigold shows the advantage of repelling pest insects like aphids and root nematodes, but attracts slugs and can have an herbicidal effect on cabbage.

Tool 8: Trap cropping

Trap cropping necessitates that the trap crop is more attractive to the pest as either a food source or egg laying site than the main crop. A particularly successful example is the push-pull trap cropping used in East African corn production.

Push-pull strategy is a simple cropping strategy, whereby Napier grass *(Pennisetum purpureum)* and desmodium legume *(Desmodium uncinatum)* are used as intercrops in maize. Desmodium is planted in between the rows of maize. It produces an odour that stem borer moths do not like and, therefore, 'pushes'

TRAP CROPPING/INTER-CROPPING



away the stem borer moths from the maize crop. Napier grass is planted around the maize crop as a trap plant. Napier grass is more attractive to stem borer moths than maize and it 'pulls' the moths to lay their eggs on it. But Napier grass does not allow stem borer larvae to develop on it. When the eggs hatch and the small larvae bore into Napier grass stems, the plant produces a sticky, glue-like substance which traps them, and they die. So, very few stem borer larvae survive and the maize is saved because of the *'push-pull'* strategy. In addition, the ground cover of desmodium within the maize field reduces witch weed *(Striga* spp.). Desmodium suppresses the witch weed by herbicidal compounds produced in the roots. Being a legume, desmodium also fixes nitrogen in the soil and thus enriches the soil.

Other examples of trap crops known to be applicable in Africa:

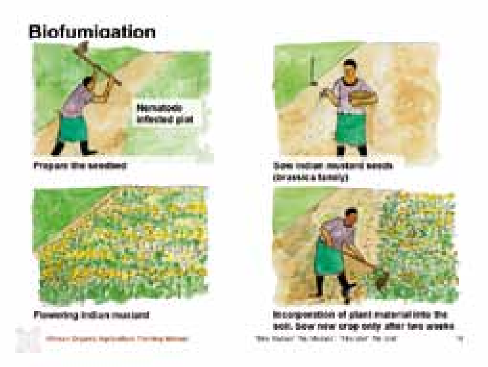
- Mexican marigold against slugs in vegetable crops.
- Indian mustard *(Brassica juncea)* to attract the diamondback moth *(Plutella xylostella)* in brassica crops.
- African tall variety of marigold (cv. Golden Age) reduces both eggs and larvae of the African bollworm *(Helicoverpa armigera)* when intercropped within tomatoes, Pigeon pea, chick peas, crotalaria, maize, tobacco, sorghum and sunflower are also attractive for the African bollworm during the flowering period. Therefore, planting this variety of marigold in strips or around a crop field can protect against African bollworm damage.

Sequential trap cropping uses an earlier planting of the same crop on reduced surfaces to attract pests. The early trap crops can either be destroyed to kill the pests or can easily be treated with biocontrol agents or insecticides *(see chapter 4.2.3)*. For all kinds of trap crops, it is crucial to check them regularly to detect the presence of pests. In most cases, trap crops must be destroyed when they become severely infested, and before they are killed by the pest or have completed their lifecycle. This is important because the pests may move from the trap plants to the main crop. They can be removed and buried.

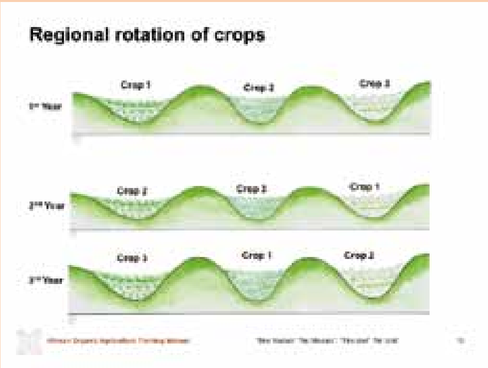
Tool 9: Biofumigation

Biofumigation is based on incorporating fresh plant mass into the soil, which will release several substances (mainly isothiocyanates) able to suppress soil-borne pests. Good effects of biofumigation are also seen against *Sclerotinia* and

BIOFUMIGATION



REGIONAL ROTATION OF CROPS



Phytium disease, damping off *(Rhizoctonia solani)* and bacteria rot (*Erwinia* sp.).

Plants from the Brassica family (mustard, radish, etc.) release large amounts of these toxic substances in the soil while decomposing and are considered the best material for biofumigation. Different mustards (e.g. *Brassica juncea var. integrifolia or Brassica juncea var. juncea*) should be used as intercrops on infested fields. As soon as mustards are flowering, they are cut and instantly incorporated into the soil by hoeing or ploughing. While incorporated plant parts are decomposing in a moist soil, nematicidal compounds are produced that kill nematodes. During the decomposing process, phytotoxic substances are released too. They can kill weed seeds, but they can also affect crop plants. Therefore, a new crop should only be planted or sown two weeks after incorporating plant material into the soil.

Tool 10: Crop isolation through quarantine practices

Knowledge about pest and disease distribution in the region must also be considered, especially for those considered epidemic. Sometimes isolation of farms or field locations far enough from pest or disease infested areas is needed for proper control. A regional crop rotation regime, working with other farmers, may be the only effective option to limit the spread of pests and diseases.

3.3 Direct control measures in pest management (3rd step tools for pests)

Direct control measures against pests include biological control (using other living organisms like bacteria, viruses or beneficial insects to control pests) and the application of insecticides of biological or mineral origin, pheromones for mating disruption, repellent agents as physical barriers and traps for mass-trapping. All measures are used as a last option for the control of pests when all methods used in preceding steps failed. For certified organic production, only agents of non-synthetic origin are permitted. One allowed exception is the use of synthetic pheromones because they are contained in dispensers and, therefore, do not come into contact with crops.

Sharing of experiences on direct control of pests

Invite the farmers to share their experiences on direct control of pests. Do they have experiences with direct control measures other than the use of synthetic pesticides? Which criteria do they consider relevant to ensure the success of direct control measures? How relevant is timing of the application? How is proper timing defined? Do they practice regular scouting of the pest prior to application?

Tool 11: Biological control of pests

Biological control implies using other living organisms, for example, natural enemies to control pests. Natural enemies help the farmer to control insect pests that eat crops and prevent them from causing economic damage. Biological control of pests is based on releasing mass-reared live agents such as bacteria, viruses, fungi, insect predators and insect parasitoids into crop fields to control pests for a brief or extended period. Biological control strategies are considered direct control measures that are employed when indirect measures are not sufficiently effective. However, not all commercially available biocontrol agents can be used in organic agriculture; for instance, genetically modified organisms are prohibited. Biological control is widely used in greenhouse crops, but is still limited in field-grown crops.

The best-known biocontrol agent used in field crops is the **bacteria** *Bacillus thuringiensis* var. *kurstaki* and *B. t. var. aizawai* against diverse lepidopteran pests, and the B. t. var israeliensis against mosquitoes. B. t. var kurstaki is produced in local factories in different African countries (e.g. South Africa, Kenya and Mozambique) and can be used against different pests (African armyworm, African bollworm, bean armyworm, beet armyworm, cabbage webworm, cabbage moth, cabbage looper, cotton leafworm, diamondback moth, giant looper, green looper, spiny bollworm, spotted bollworm, pod borers, tomato looper).

There are a few **fungi** known to be entomopathogenic. The best-known species are *Beauveria bassiana* (against termites, thrips, whiteflies, aphids and different beetles) and *Verticillium (Lecanicillium) lencanii* (against whiteflies, thrips and aphids). Many different products (mycopesticide) are on the market, but they are mostly designated to be applied in greenhouses. These entomopathogenic fungi need high air humidity to develop. To overcome this problem under field conditions, a few products are formulated with (plant) oil. The fungus *Metarhizium anisopliae* var. *acridum* is a fungal biocontrol agent specific to killing the species of short-horned grasshoppers. This fungus is widely distributed in Africa and causes local epidemics in grasshopper or locust populations under favourable climatic conditions. Its biological and physical properties make this fungus an ideal candidate for augmentative biological control. Spores of *M. anisopliae var. acridum* can easily be mass-produced. It is available either as dry spore powder or as oil miscible concentrate. The product is applied as an oil suspension and can be sprayed with usual equipment or aerial applications for large scale application. Usually, the control of locusts with this mycopesticide is implemented through either the government or through non-governmental organizations, which work directly with farmers that follow mainly participatory approaches. This might be the best way to make use of this biocontrol agent.

There are different other biocontrol agents known to be effective against pests:
- Granulosis **viruses** against lepidopteran pests such as *Plutella xylostella* Granulovirus against the diamondback moth, *Cydia pomonella* Granulovirus against the codling moth in apple.
- Entomopathogenic **nematodes** against different weevil species (e.g. *Steinernema carpocapsae, Heterorhabditis bacteriophora*).
- Insect predators such as ladybird beetles, predatory gallmidges, hoverfly larvae against aphids and psyllids.
- Insect **parasitoids** such as *Trichogramma* species against the African bollworm are bred in some laboratories in Africa against lepidopteran pests and aphids. A successful introduction of the neotropical parasitoid *Apoanagyrus (Epidinocarsis) lopezi* against the cassava mealybug *(Phenacoccus manihoti)* caused a satisfactory reduction of *P. manihoti* in most farmers' fields in Africa. This is one of the success stories of classical biocontrol.

However, most of these biocontrol agents are not available to small-holder farmers in Africa. The reasons are the insufficient number of factories or farmers cooperatives producing the biocontrol agents, problems of a rapid distribution from the production factories to the users, and the susceptibility of most agents to heat.

Tool 12: Insecticides of vegetal or mineral origin

There are commercial organic insecticides available in many countries of Africa (e.g. neem, rotenone and pyrethrum). Most of them can be handcrafted by farmer cooperatives or by the individual farmers.

The **neem** tree *(Azadirachta indica)* originally comes from India, but today it is known all over Africa. The neem tree has over 100 compounds with pesticidal properties. The highest concentration of the most important compound *azadirachtin* is in the fruit, especially in the seeds. Neem acts as a broad-spectrum repellent, insect growth regulator and insect poison. Unlike most botanical insecticides, neem also has a somewhat 'systemic' effect. This means that plants can take up neem extracts through their roots and leaves, spreading the material

Sharing of experiences on botanical mixtures for pest control

Choose the most commonly used botanical mixtures for pest control. Make a list of all materials that are needed to prepare them and let experienced farmers show others how they make them. Have they made any observations on the best time of application and the efficiency of the preparations?
Farmers should be encouraged to find out more about the efficacy of the different insecticidal mixtures by conducting their own farm experiments. They should set up their own plots as a group or individual farmers to be able to compare the effects between treated and untreated plants.

throughout the plant tissues. For this reason neem can help control pests such as leaf miners. Neem products are effective against a wide range of pests: about 400 pest species are known to be affected by neem extracts. In spite of its broad-spectrum action, neem products generally do not harm natural enemies.

Neem products with high oil content are phytotoxic to some plants, meaning that plants may be burned when neem extract is used at a high dosage. Therefore, the extracts should be tested on a few plants before going into full scale spraying. At the same time, however, neem extracts are rapidly decomposed by sunlight. For this reason, commercial products usually contain a sunscreen that protects the extract from sunlight, allowing for a longer exposure to sunlight.

Recommendation to farmers about preparation of neem pesticides:

Neem pesticides can be prepared from the leaves or from the seeds. The leaves or seeds are crushed and mixed in water, alcohol or other solvents. For some purposes, the resulting extracts can be used without further refinement. Ground neem seeds (neem cake) or neem kernel powder is used as a soil amendment and is effective for control of nematodes. It is also used for control of stalk borers and to prepare water extracts, which are then sprayed onto plants. Neem cake has a considerable potential as a fertilizer and at the same time it will hinder nematode attacks of the crop roots (e.g. tomato). Put neem cake in the planting pit (200g per m2) and mix it with substrate. The neem cake will repel and even kill nematodes and other root pests. Insecticidal agents (azadirachtin) will be translocated to above-ground parts of the plant and help to get rid of pests there.

Pyrethrum is a natural insecticide derived from African *Chrysanthemum cinerariaefolium* flowers. They are perennial plants with a daisy-like appearance and white flowers. The plant is most productive at altitudes above 1600 meters and ideally in semi-arid conditions. On richer soils the insecticidal properties are reduced. The content of the active substances increases with altitude and cooler average temperatures. Pyrethrum extracts should not be mixed with lime, sulphur, or soap solutions during application since pyrethrum is broken down by both acid and alkaline conditions. In addition, pyrethrum extract is also rapidly broken down by sunlight. Pyrethrum is a broad-spectrum and contact poison for controlling pests on flowers, fruits and vegetables. It can be used to control most aphids, spider mites, thrips, whiteflies, African armyworm, African bollworm, cutworms, maize stalk borers and potato jassids.

Recommendations to farmers on preparation of pyrethrum pesticides:
Pyrethrum powder is made with dried ground flowers. Use pure or mix with a carrier such as talc, lime or diatomaceous earth and sprinkle over infested plants. To make liquid *pyrethrum extract* (mix 20g pyrethrum powder with 10 l water), add soap to make the substance more effective. Strain and apply immediately as a spray. For best effects this should be applied in the evening. Pyrethrum can also be extracted by alcohol.

Chillies and capsicum pepper have both repellent and insecticidal effects.

Recommendations to farmers on preparation of chilli pesticides:
To make the chilli extract: grind 200 grams of chillies into a fine dust, boil it in 4 litres water, add another 4 litres of water and a few drops of liquid soap. This mixture can be sprayed against aphids, ants, small caterpillars and snails.

Garlic has antifeedant (insect stop feeding), insecticidal, nematicidal and repellent properties. Garlic is reportedly effective against a wide range of insects at different stages in their life cycle (egg, larvae, adult). This includes ants, aphids, armyworms, diamondback moth, whitefly, wireworm and termites. Garlic is non-selective, has a broad-spectrum effect and can kill beneficial insects as well. Therefore, it should be used with caution.

Recommendations to farmers on preparation of garlic pesticides:
To make the garlic extract, grind or chop 100 grams garlic into 0.5 litre water. Allow mixture to stand for 24 hours, add 0.5 litre of water and stir in liquid soap. Dilute at 1:20 with water and spray in the evening. To improve efficacy, chilli extract can be added.

There are many **other extracts of plants** known to have insecticidal effects like tobacco *(Nicotiana tabacum),* yellow root *(Xanthorhiza simplicissima)*, fish bean *(Tephrosia vogelii)*, violet tree *(Securidaca longepedunculata)*, and nasturtium *(Nasturtium trapaeolum)* which are traditionally used to control pests in Africa.

Precautions to farmers regarding use of plant extracts:
- Do not have direct skin contact with the crude extract during the process of preparation and application. Plant extracts like tobacco can also be very toxic to humans. Contact with plant extracts should be avoided in the eyes.
- Make sure that you place the plant extract out of reach of children during storage.

EXTRACTS OF AFRICAN PLANTS KNOWN TO HAVE INSECTICIDAL PROPERTIES

› Wear protective clothing (eyes, mouth, nose and skin) while applying the extract.
› Wash your hands after handling the plant extract.

Sulphur is probably the oldest known pesticide in use. In organic agriculture it is mostly used against plant diseases (see tool 18), but is also used against mites (acaricide). The acaricidal effect of sulphur is best at temperatures above 12° C. However, sulphur has the potential to cause plant injury in dry hot weather (above 32° C). It's also incompatible with other pesticides. Sulphur should not be used together or after treatments with oil to avoid phytotoxicity.

Wood ashes from fire places can be efficient against ants, leaf miners, stem borers, termites and potato moths. Ash should be dusted directly on pest colonies and infested plant parts. The ash will dehydrate the soft bodied pests. Wood ashes are often used when storing grains to deter storage pests such as weevils.

Tool 13: Pheromones for mating disruption

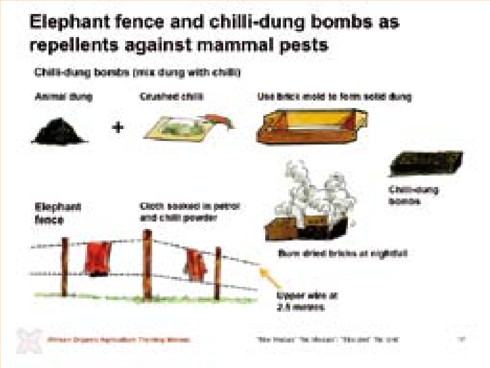
Pheromone dispensers release a sex hormone from the female insect. Few dispensers combined with special traps attract the male insects into the trap in which they get stuck. Pheromone traps are mostly used for monitoring pest insects but can also be used for mass-trapping. Several types of pheromone traps have been developed for monitoring African bollworms, cutworms, fruit flies, etc. and are widely used. However, in most parts of Africa, pheromone traps are not locally available and imported ones are not affordable to small-holder farmers.

Sex pheromones can also be used for mating disruption. Here, a high number of dispensers are installed in the crop (apple orchard, vineyard) to get a pheromone cloud within or over the crop. Male insects will then not be able to find the female and mating is, therefore, disrupted. Consequently no offspring will damage the crop.

Tool 14: Repellents against mammal pests

Not only insect, mite, nematode and slug species are known as pests, mammals such as elephants, monkeys, wild pigs, etc., destroy subsistence crops and threaten the livelihood of rural farmers across Africa. However, there are effective, non-lethal repellents known to drastically reduce the damage caused by elephants. The basic repellent agent is derived from *Capsicum* chillies or hot peppers *(Pili pili kali)*. If crops are protected with elephant fences (at least 2.5 meters or 8 feet

ELEPHANT FENCE (CHILLI DUNG BOMBS)



high with two parallel lines), squares of cloth or burlap soaked in a petroleum-based agent (motor oil) mixed with chilli powder can be fixed between lines. The very strong odour of capsicum peppers causes adverse physical reactions from elephants, including irritation of the eyes and burning sensations in the trunk. An additional approach is to produce chilli dung bombs with crushed chilli and animal dung. To give the mixture of chilli and dung a solid shape, the farmer may use a brick mould. The elephant bombs should dry for a day or two and then be placed in equal dispersal around the field. The farmer may set fire to them at nightfall. Elephant bombs will create a spicy smoke that keeps elephants out of farmers' fields of maize, sorghum and millet. The same agent can be prepared against wild pigs, monkeys and other mammals.

Anise, chillies, chives, garlic, coriander, nasturtium, spearmint and marigold are plants known to have a repellent effect on different pest insects (aphids, moths, root flies, etc.) and can be grown as intercrop or at the border of crop fields. Marigold is especially known to deter root nematodes, while neem cake is known to deter mice.

Tool 15: Traps for mass-trapping of pests

Mass-trapping of pests is an additional control measure. They often can easily be built with cheap material.

Light traps can be used to catch moths such as armyworms, cutworms, stem borers and other night flying insects. Light traps are more efficient when placed soon after the adult moths start to emerge but before they start laying eggs. However, light traps have the disadvantage of attracting a wide range of insect species. Most of the attracted insects are not pests. In addition, many insects that are attracted to the area around the light traps (sometimes from considerable distances) do not actually fly into the trap. Instead, they remain nearby, actually increasing the total number of insects in the immediate area.

Colour and water traps can be used to monitor adult thrips. In some cases thrips can even be reduced by mass trapping with coloured (blue, yellow or white) sticky traps or water traps in the nursery or field. The colour spectrum of the boards is important for the efficacy of the sticky traps. Bright colours attract more thrips than darker ones. Sticky traps with cylindrical surfaces are more efficient that flat surfaces. They are best placed within a meter of crop level. Traps should not be placed near the borders of fields or near shelter belts.

FRUIT FLY TRAP

- **Water traps** should be at least 6 cm deep with a surface area of 250 to 500 cm2, and preferably round, with the water level about 2 cm below the rim. A few drops of detergent added to the water ensure that thrips sink and do not drift to the edges and escape. Replace or add water regularly.
- **Yellow sticky traps** can be used to control whiteflies, aphids and leaf mining flies. Yellow plastic gallon containers mounted upside down on sticks coated with transparent car grease or used motor oil, is one such trap. These should be placed in and around the field at about 10 cm above the foliage. Clean and re-oil when traps are covered with flies. Yellow sticky boards have a similar effect. To use, place 2 to 5 yellow sticky cards per 500 m2 field area. Replace traps at least once a week. To make your own sticky trap, spread petroleum jelly or used motor oil on yellow painted plywood (size 30 cm x 30 cm). Place traps near the plants but faraway enough to prevent the leaves from sticking to the board. Note that the yellow colour attracts many insect species, including beneficial insects, so use yellow traps only when necessary.

Traps for house flies and fruit flies - Fruit flies and house or barn flies are attracted to fermenting fruit juice. The top of a plastic bottle can be cut off and inverted. A little sugar water or honey can be smeared around the rim of the bottle to further attract the flies, which will then enter the bottle containing sweet/fermenting fruit juice and be trapped. Fruit fly traps can be made locally using an ordinary jar with plastic containers or plastic bottles, in which holes have been cut. They can be used with food baits such as protein hydrolysates, yeast or sweet/fermenting fruit juice.

Tool 16: Physical barriers against pests

There are different physical barriers known to have a control effect on pests (like insect fences and fruit bagging). However, the most useful measure is fruit bagging.

Fruit bagging prevents fruit flies from laying eggs on the fruits. In addition, the bag provides physical protection from mechanical injuries (scars and scratches). Although laborious, it is cheap, safe and gives a more reliable estimate of the projected harvest. Bagging works well with melon, bitter gourd, mango, guava, star fruit, avocadoes and banana (plastic bags used).

FRUIT BAGGING

Recommendations to farmers regarding fruit bagging:
Cut old newspapers to fruit size and double the layers, as single layers break apart easily. Fold and sew or staple the sides and bottom of the sheets to make a rectangular bag. Blow in the bag to inflate it. Insert one fruit per bag then close the bag and firmly tie the top end of the bag with sisal string, wire and banana fibre or coconut midrib. Push the bottom of the bag upwards to prevent fruit from touching the bag. For example, start bagging the mango fruit 55 to 60 days from flower bloom or when the fruits are about the size of a chicken egg. When using plastic bags (e.g. with bananas), open the bottom or cut a few small holes to allow moisture to dry up. Moisture trapped in the plastic bags damages and/or promotes fungal and bacterial growth that causes diseased fruits. Plastic also overheats the fruit. Bags made of dried plant leaves are good alternatives to plastic.

3.4 Direct control measures in disease management (3rd step tools for diseases)

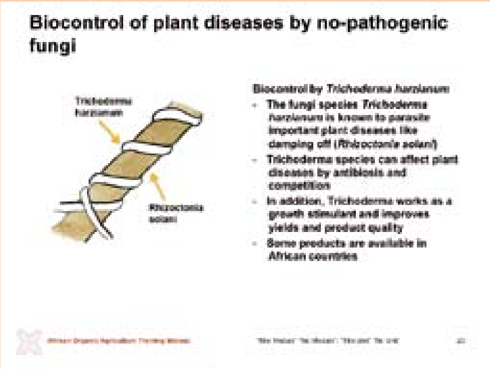
Direct control measures against diseases include biological control (using other living organisms like parasitic fungi to control diseases) and the application of fungicides of biological or mineral origin. All measures are used as a last option for the control of pests, when all methods used in the preceding steps have failed. For organic production, only agents of non-synthetic origin are permitted. Even the often criticized agents copper and sulphur are of mineral origin so their use is also restricted.

Farmers should be encouraged to find out more about the efficacy of the different materials by conducting their own farm experiments. They should set up their own plots as a group or individual farmers to be able to compare the effects between treated and untreated plants. Be aware that some materials have preventive effects while others (like copper) have therapeutic effects. Therefore, the agents with preventive effects must be applied before disease attacks.

Tool 17: Biological control of plant diseases
Fungi belonging to the genus *Trichoderma* are worldwide in occurrence and easily isolated from soil, decaying wood and other forms of plant organic matter. On the one hand, *Trichoderma* species are known to parasite other fungi and within them some important plant diseases like damping off *(Rhizoctonia solani)*. On

Discussion on direct control of diseases
Share experiences with the farmers on direct control measures against diseases. Find out the most commonly used botanical methods for disease control in the area in different crops. Invite experienced farmers to share their knowledge on preparing botanical preparations. Encourage discussion on timing and method of application and other criteria that are relevant for efficacy.

BIOCONTROL OF PLANT DISEASES BY NON-PATHOGENIC FUNGI



the other hand, antibiosis and competition are other impacts of *Trichoderma* species on plant diseases like *Sclerotinia, Pythium*, and *Botrytis.*

Trichoderma harzianum (different strains) were tested under subtropical and tropical climates. Some good effects are reported against red rot *(Colletotrichum falcatum)*, seed and seedling blight of cowpea *(Macrophomina phaseolina)*, powdery mildew and other diseases. In addition, *Trichoderma* works as growing stimulant and, therefore, improves yields and product quality (e.g. soybean). Products are available in a few African countries (e.g. T-Gro, Eco-T and Tricho-Plus in South Africa).

Species of *Aspergillus* are almost ubiquitously present in soils of tropical areas. They are best known for contamination of seeds with highly poisonous aflatoxins resulting from the presence of toxigenic strains of *A. flavus, A. parasiticus, A. nomius* and *A. bombycis.* However, there are also non-aflatoxigenic strains of *A. flavus* and *A. parasiticus* that can be used as biocontrol agents against dangerous *Aspergillus* species. *A. flavus* (BN22 and BN30) from Benin reduced aflatoxin contamination in maize up to 90 %. However, more research is needed to demonstrate field efficacy of biological control agents, their persistence, safety and commercial feasibility before practical application of biological control agents for plant disease control in Africa becomes a reality.

Some **bacteria** are known to control plant diseases. An often used bacterium is *Bacillus subtilis* (different strains) with effects against fungi diseases like Botrytis, powdery mildew or black spot. Other examples are *Pseudomonas fluorescens* (and other *Pseudomonas* species), *Bacillus* and *Azotobacter* species. The principles of action are competition for root niches, competition for nutrition elements, production of secondary metabolites and antibiosis. However, the use of these bacteria as biocontrol agents strongly depends on the availability of cheap products.

Tool 18: Fungicides of vegetal or mineral origin

There are commercial organic fungicides available in many countries of Africa including products with the fungicidal agents copper, sulphur and acidic clay.

Bordeaux mixture (Copper sulphate and lime) has been successfully used for over 150 years, on fruits, vegetables and ornamentals. Unlike sulphur, Bordeaux mixture is both fungicidal and bactericidal. As such, it can be effectively used against diseases such as leaf spots caused by bacteria or fungi, powdery mildew, downy mildew and various anthracnose pathogens. The ability of Bordeaux mixture to persist through rains and to adhere to plants is one reason it has been so effective. Bordeaux mixture contains copper sulphate, which is acidic, and neutralized by lime (calcium hydroxide), which is alkaline.

Recommendations to farmers on preparation of Bordeaux mixture:
Bordeaux mixture comes in several formulations. One of the most popular, effective and least phytotoxic formulations for general use is the following formulation: Mix 90 grams of blue copper sulphate with 4.5 litres of water (in a non-metallic container). In another non-metallic container, mix 125 grams of slaked lime with 4.5 litres of water. Stir both, mix both solutions, and stir again. This formulation was developed in recognition of the fact that copper, like sulphur, is phytotoxic and that the level of toxicity is related to the age of plant tissue being treated. Application of Bordeaux during hot weather (above 85° F or 30° C) may cause yellowing and leaf drop. Additionally, leaf burn can occur if it rains soon after a Bordeaux application. Care should be taken when applying this fungicide to young, tender leaves of fruit trees. Do not apply Bordeaux mixture to corn or sorghum, which are described as copper-sensitive plants.

There are other, very common and cheap copper formulations available on the market in most African countries: **copper hydroxide** and **copper oxychloride**. They are accepted in organic farming provided that the number of applications is strictly followed and a proper soil amendment is observed to prevent copper accumulation in the soil.

Sulphur is mostly used against plant diseases like powdery mildew, downy mildew and other diseases. The key to its efficacy is that it prevents spore germination. For this reason, it must be applied prior to disease development for effective results. Sulphur can be applied as a dust or in liquid form. It is not compatible with other pesticides.

Lime-sulphur is formed when lime is added to sulphur to help it penetrate plant tissue. It is more effective than elemental sulphur at lower concentrations. However, the odour of rotten eggs usually discourages its use over extensive fields.

Acidic clays have a fungicidal effect due to aluminium oxide or aluminium sulphate as active agents. They are used as an alternative to copper products but, are often less efficient. Different products are available on the market in a few African countries.

Milk has also been used against blights, mildew, mosaic viruses and other fungal and viral diseases. Spraying every 10 days with a mixture of 1 litre of **milk** to 10 to 15 litres of water is effective.

Mildew and rust diseases on plants can be controlled with a mixture of **baking or washing soda**. Spray with a mixture of 100 grams of baking or washing soda with 50 grams of soft soap. Dilute with 2 litres of water. Spray only once and leave as long gaps as possible (several months). Do not use during hot weather and test the mixture on a few leaves because of possible phytotoxic effects.

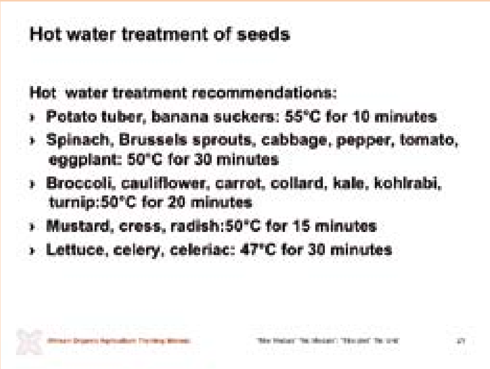
Many **plant extracts** are known to have fungicidal effects. **Onion** and **garlic** are effective against many diseases such as mildew and fungal and bacterial diseases. **Mexican** and **African marigold** act as a crop strengthener to help potatoes, beans, tomatoes and peas resist fungal diseases such as mildew. The leaves of **pawpaw** *(Carica papaya)* and sweet basil have a general fungicidal effect. Many other plant species in Africa are known to have fungicidal effects. Traditional knowledge might be of help to amend the range of plant extracts in each region of Africa.

Tool 19: Hot water treatments for seeds

Hot water treatment of own seed to prevent seed-borne diseases such as black rot, black leg, black spot and ring spot of crucifers is very effective. It reduces the seed-borne pathogens such as *Alternaria* spp., *Colletotrichum* spp., *Phoma* spp., *Septoria* spp. and bacterial pathogens *(Pseudomonas* spp. and *Xanthomonas* spp). However, hot water treatments are delicate as seeds can rapidly be destroyed by too hot temperatures.

Therefore, specified temperature and time intervals must be strictly followed in order to maintain seed viability. Use a good thermometer or ask for assistance from an experienced person or from your local extension officer. To make sure that the seed is not damaged it is advisable to test the germination of 100 heat-treated and 100 untreated seeds. Hot water treatment can also be used for potato tubers (10 minutes in water at 55° C) to control blackleg infection, powdery scab and black scurf, and banana suckers to control nematodes and banana weevils.

HOT WATER TREATMENT OF SEEDS



4 Tools to manage weeds

Organic farmers give first priority to prevention of the introduction and multiplication of weeds. The management practices aim at keeping the weed population at a level that does not result in economic loss of the crop cultivation or harm its quality. The goal is not to completely eradicate all weeds, as they also have a role to play on the farm. For example, weeds provide cover that reduces soil erosion. In addition, most of the biological diversity in our crop fields comes from the presence of weeds. They provide habitat for both beneficial biocontrol insects and mycorrhizal fungi. Because weeds offer pollen and nectar they allow biocontrol insects to maintain their populations and, therefore, serve as a valuable instrument in controlling pests.

4.1 Cultural practices to manage weeds (1st step tools)

Cultural practices like choice of competitive crop varieties, the use of weed-free seeds and planting material, appropriate sowing time, crop rotation and the application of mulches are crucial to prevent introduction and propagation of weeds.

Tool 1: Weed-free seeds and planting material
Avoiding the introduction of weed seeds into the fields through tools or animals is important. Even more important is to use only weed-free seed and planting material by using either quality seeds/planting material or carefully cleaned seeds.

Tool 2: Choice of crops and varieties
Tall crops and varieties with broader leaves will compete better with late occurring weeds than small varieties with narrow leaves. Some varieties will inhibit and suppress weeds while others will tolerate them. For example, there are witchweed (Striga) resistant maize and cowpea cultivars in many countries of Africa, which give better performance at the same level of weeds where other varieties are more affected.

Discussion on cultural practices for weed management
Share experiences among the participants on how to limit weed problems by cultural practices. Discuss in groups which weed species need special attention, according to the local situation.

Tool 3: Crop rotation
The success of rotation systems for weed suppression is based on the use of crop sequences. They create varying patterns of resource competition, allelopathic interference (e.g. root exudates of some plants act like herbicides), soil disturbance and mechanical damage to provide an unstable and frequently unfriendly environment for weeds. Considerable evidence exists that monoculture indeed leads to a less diverse and more intractable weed species than does crop rotation. Growing the same crops in the same site year after year will encourage build up of weed seeds in the soil. This build up of weed seed is referred to as the *'soil weed seed bank'*. Changing the conditions of the crop interrupts the living conditions of the weeds thus inhibiting their growth and multiplication. Some crops efficiently suppress weeds, while others encourage their growth. Crop rotation is thus the most efficient measure to regulate seed and root weeds.

In terms of weed control, crop rotations should include
- alternation of seasonal (spring, summer, autumn and winter or adapted to rain and drought periods) germinating crops.
- alternation of annual and perennial crops (including grass).
- alternation of closed, dense crops which shade out weeds, and open crops which encourage weeds.
- tillage and cutting or topping operations that directly affect the weeds.

Tool 4: Appropriate land preparation
A simple but very effective control tool is to prevent dissemination of weeds is proper land preparation. Land preparation should be timed to eliminate all flowering weeds before setting seeds. A regular scouting for weeds is necessary to limit propagation.

Tool 5: Soil quality management
Proponents of organic farming have long promoted the view that the likelihood of weed problems is reduced with the establishment and maintenance of 'healthy' soil. The enhancement of soil fertility plays an important role in weed control. Especially the organic matter and the microbial activity associated with organically managed soils provide a buffering capability to maintain optimal nutrient and mineral balance in crop plants. However, due to fertilization, weed seeds germinate rapidly altogether. They can then be eliminated in one round of

CULTURAL PRACTICES OF MANAGING WEEDS

weeding. Soil fertility can be improved by:

- **Applying compost and farm manure -** Besides improving organic matter content and serving as slow-release fertilizer, compost can help control weeds if applied as a soil cover to eliminate light to soil surface. Weed seeds will then stay dormant. However, compost must be of best quality and should not contain weed seeds.
- **Applying organic mulches -** Mulches eliminate light to soil surfaces. Many small seeded weed species require light at and near the surface of the soil to trigger a break in their otherwise dormant nature. Dry, hardy material, that decomposes slowly, keeps its effect longer than fresh mulch materials which decompose very fast.

Tool 6: Appropriate sowing time and density
Optimum growing conditions enhance the optimum crop plant development and their ability to compete against weeds. Proper crop spacing will ensure that minimum space is available for the growth of weeds and will minimize competition with weeds. This will effectively restrict weed development. In order to apply this approach, the limiting weeds must be known and the seasons in which they occur. A weed calendar of the area or region, if available, might be of help. It will be used to manage weeds in a targeted fashion with proper timing and effect.

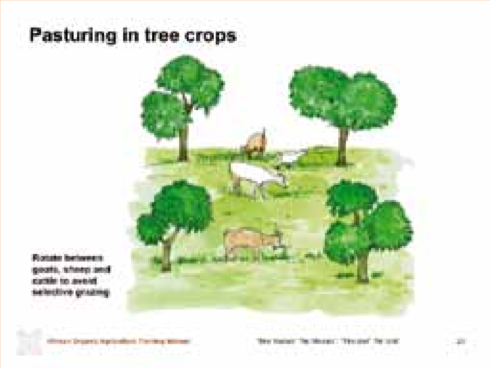
4.2. Habitat management in weed control (2nd step tools)

As part of habitat management, organic farmers make use of intercropping, mixed cropping and pasturing in a second step (2nd step tools) to suppress weed growth and limit multiplication.

Tool 7: Intercropping (mixed cropping and under-sowing)
Although intercrops are not always better than monocrops in weed suppression, in some cases they can be very effective if well planned. Intercropping with fast-growing weed-suppressive species ('smoother crop' or 'living mulch') between rows of main crop species is effective in weed control. There are different examples known to work in Africa, for example, sowing cowpeas and *egusi* melons or pumpkins as intercrops in cassava to reduce weed occurrence.

Discussion: Strategies to suppress weed growth and multiplication
Share experiences among farmers on how to limit weed problems by intercropping, mixed cropping, undersowing and pasturing. Discuss local examples for each of the strategies using locally grown crop species.

PASTURING FOR WEED CONTROL



Undersowing or cover cropping aims to cover the ground with a quick-growing, dense layer of vegetation underneath the crop. The undersown species is usually leguminous, which improves soil fertility on top of suppressing weeds.

Tool 8: Pasturing
In perennial crops like coffee, mangoes, avocadoes or cocoa, the use of sheep and goats to reduce rampant weed growth is becoming common. In case of cattle, broadleaf weeds tend to predominate due to the cattle preference for grasses. Therefore, it is necessary to rotate with sheep and goats which prefer broadleaves to overcome this selective grazing.

4.3. Direct control measures for weed management (3rd step tools)

Direct control measures include mechanical methods which are most common and widely applicable as well as other sophisticated methods such as the use of biocontrol agents and thermal weed control.

Tool 9: Mechanical weed control
Mechanical weed control is the most common and effective method of direct weed control. It can be used for the initial land preparation but also during the later stages of the crop growth. When weeds are found to be fully grown with deep roots, then they can only be controlled through mechanical weed control methods.

Mechanical weed control may involve weeding the whole crop or it may be limited to selective inter-row or intra-row weeding. Manual weeding is probably the most important mechanical control measure. As it is very labour intensive, reducing weed density as much as possible in the field will bring less work later on. There are different tools to dig, cut and uprooting the weeds; hand, ox-drawn and tractor-drawn tools. Using the right tool can increase work efficiency significantly. Whichever tool is used, weeding should be done before the weeds flower and produce seeds. The weather and soil conditions under which the operation is carried out will have a major influence on its efficacy (e.g. mechanical weeding is less effective when soils are wet during or after weeding operations).

Discussion on direct control of weeds
Share experiences among farmers on how to limit weed problems by direct control measures. Discuss in groups the methods that are the most effective for the predominant weed species.

MECHANICAL WEED CONTROL

Tool 10: Biological control of weeds

The soil-borne fungus *Fusarium oxysporum* (different isolates from Burkina Faso, Mali and Niger) is very effective in reducing the witch weed *(Striga hermonthica* and *S. asiatica)* in different cereal crops, leading to yield increases in scientific trials. Other *Fusarium* species found in Sudan and Ghana are very effective, too *(Fusarium nygamai, F. oxysporum* and *F. solani)*. This mycoherbicide is on the way to being formulated and registered in different countries in Africa.

Rhizobacteria capable of suppressing germination of witch weed (*Striga* spp.) seeds or actually destroying the seeds are particularly promising biological control agents since they can be easily and cheaply formulated into seed inoculants. *Pseudomonas fluorescens putida* isolates significantly inhibited germination of *Striga hermonthica* seeds. However, currently no biocontrol product is available.

Tool 11: Thermal weed control

Flame weeding by heating briefly to 100° C and higher is also another mechanical way of controlling weeds. This provokes coagulation of the proteins in the leaves and the bursting of cell walls. Consequently, the weeds dry out and die. Although it is an effective method, it consumes a large amount of fuel (gas) and needs machinery and is, therefore, expensive. Due to this, it is rarely used in Africa.

5 Management of storage pests and diseases in grains

Farmers, especially small-holder farmers in Sub-Saharan Africa, use poor postharvest technologies in the conservation of grains. Some of these methods greatly expose the stored grain to insect pests and disease infections, causing heavy losses. Some of these infections (e.g. fungi) are dangerous for human health because they produce mycotoxins (e.g. aflatoxin and patulin). These toxins remain in the stored product as residues and are very stable. They cannot be destroyed by boiling, pressing or processing. This means that infected produce has to be destroyed. The most important species belong to the genus *Aspergillus* and *Penicilium*. Storage fungi require a relative humidity of at least 65 % to develop, equivalent to a moisture content of 13 % in the grain. Storage fungi grow at a temperature range of 10° C to 40° C. Infection with certain species of fungi may already occur in the field, reducing the storage life of grains considerably.

PREVENTIVE MEASURES AGAINST STORAGE PESTS AND DISEASES

As organic farmers are not allowed to use any synthetic pesticides to control pests or diseases, the focus of this chapter is on proper preservation techniques as discussed below.

5.1 Preventive measures for storage pests and diseases

There are different measures to facilitate safe storage of grains. The most important ones are proper threshing, shelling and drying. At all stages of handling, proper hygiene and minimal exposure to moisture are important for effective management of storage pests and diseases. If the produce is already contaminated or exposed to moisture, it will not store well even under the best storage conditions. Storage itself can be done in different types of granaries, silos and other containers.

Tool 1: Proper drying
Drying is an important procedure in storage protection of grains. It prevents grains from germinating and prevents attack of fungi. All grains must be dried to 12 to 13 % moisture in order to be stored safely, immediately after harvest. Heat used for drying the produce will kill pests and fungi.

However, care should be taken to avoid overheating if drying grains for seed and should not exceed the following temperatures: beans 35° C, seeds 43° C, and cereals 60° C. A very simple method of drying is by spreading out the product to be stored in the sun on a clean surface for several days. The layers of cobs, panicles, pods or grains should not be thick and the material must be turned regularly in order to ensure good and even aeration. In the evening, the produce must be either put in a pile and covered or collected and spread again the following day. Another option is to use simple drying structures (driers), especially for smaller volumes.

Tool 2: Proper threshing
Threshed grain can more easily be stored to avoid losses by insects, rodents and diseases. After harvest, rice, wheat, sorghum, millet and the like are often traditionally threshed by beating sheaves with a wooden flail on a threshing mat, tarpaulin or paved yard. This reduces the amount of debris (soil, pebbles) in the threshed grain. Motorized threshers are also used in some areas, operated by

Assessment of the postharvest pest problems of grains

Assess the local situation regarding storage of grains by asking the farmers the following questions:
- Which kind of grains do you commonly grow? Do you store them?
- What are the main storage pests and diseases?

Let the participants share experiences on how they control infections.

PROPER STORAGE

farmer cooperatives to facilitate the threshing operation. Irrespective of the threshing method, it is important to minimise contamination and to winnow, sieve or sort out all trash and foreign materials properly from the threshed grain before storage. Sorted grain should be packed in jute bags and staked off the ground, but preferably on pieces of wood or pallets.

Tool 3: Proper storage
In Africa, between 60 % and 70 % of grain production is stored at farm level, generally for family consumption, but also for sale and for seed. Storage methods should be well adapted to local conditions, while ensuring adequate protection of the grain against deterioration due to rain, moisture, insect and vertebrate pests. Granaries for grain storage are sometimes made of plant material or clay. In the latter case, wire mesh/net provisions should be made in the wall to allow for some ventilation.

Before storing the new harvest, certain precautions are important:
› Remove all residual stocks as pests might be hidden within residuals.
› Clean the interior of the granary.
› Control pests by filling any cracks capable of sheltering insects with a mortar compound of powdered insecticidal plants (e.g. chilli powder, pyrethrum and neem). Burn millet or maize stalks or chilli powder inside the granaries to repel and kill pests. Keep out of the granary while burning chilli powder!

Underground silos, walled silos and above-ground structures made of clay, often mixed with a strengthening material, notably straw or cow manure can also be used to store grain. Modern metal silos might be an additional option in some regions in Africa. Metal and plastic drums make excellent grain containers, as they are inaccessible to rodents, efficient against insects and sealed against entry of water. However, they should be protected from direct sunshine and other sources of heat to avoid condensation by being located in shaded and well ventilated places. Physical protection against vertebrate pests like rodents (rats and mice) and birds is necessary. They consume large amounts of stored grain and if uncontrolled, they can lead to heavy losses. It is, therefore, necessary to properly seal off the grain store so that vertebrate pests are restricted from entering the store. Introduction of cats in the homestead will also help to keep rats and mice away from the homestead.

5.2. Direct control measures against storage pests

The main insect pests in storage can be grouped in beetles and moths. The beetle pests are bruchids (e.g. cowpea seed beetles and bean bruchid), grain borers (e.g. the larger and the lesser grain borers), weevils, flour beetles, Khapra beetles and dried fruit beetles. The larvae and some adult beetles feed on seeds and grain leaving small holes. Often a fine dust is found around the holes, which is the excrement of these beetles. This damage renders grains and seeds unsuitable for human and even for animal consumption. Moths are serious storage pests as well. The most important species are the angoumois grain moth and storage moths or tropical warehouse moth. All of them reduce the quality of stored products and often cause secondary infections by fungi due to increased humidity originating from their activity.

Tool 4: Biocontrol of insect pests

One of the most important storage pests is the larger grain borer *(Prostephanus truncatus)*. It is a serious pest of maize stored on the cob in ventilated granaries and cribs (narrow storage structures for maize). Twenty years ago a predatory beetle species, *Teretriosoma nigrescens*, was identified in Costa Rica as a potential candidate for classical biocontrol. This specific predator of the larger grain borer was introduced in early 1991 in Togo after thorough studies of its effect and safety aspects. Since then, this predator species substantially contributed to a reduction of larger grain borer populations in several African countries. To make use of this biocontrol method, the large grain borer should be monitored by using pheromone traps. In addition, the predator *Teretriosoma nigrescens* must be mass-reared in the country/region and released by local experts.

Tool 5: Control of storage pests by additives

Mineral substances such as fine sand (> 50 %), clay dust (at 5 to 10 %), kaolin (at 0.1 %) and lime (at 0.3 %) cause injuries to the joints of stored food pests and lead to dehydration. These powdery substances also fill the spaces between the grains, making it difficult for pest movement and respiration. The addition of mineral substances is particularly useful for protecting small farm seed storage or for storing small amounts for replanting. However, for large quantities of grains and seeds it is often more practical to mix the seed with any strong smelling plant material available to repel insects. Some plants such as pyrethrum and derris can actually kill storage insects.

Diatomite or diatomaceous earth is a special mineral substance mined in some East African countries. It consists of silica from tiny fossil diatoms. Diatomite is a cheap, very effective and non-toxic insect killer by drying pests out. In addition, it can absorb a lot of water. Usually, a treatment at 0.3 % should be effective against all storage beetles.

Wood ash either alone or mixed with powdered chilli pepper is an efficient method of pest control. However, ashes and chillies may have an effect on the taste of the treated product. The success of this method depends on the amount of ashes being added. Ashes at 2 to 4 % by weight of grain should give 4 to 6 months protection if the moisture content of the grain is below 11 %. Ashes from casuarinas, derris, mango and tamarind trees are particularly suitable. Any other ash mixed with powdered pyrethrum, Mexican marigold or syringa seeds will increase the protection against insects. Be aware that ashes do not control the larger grain borer.

Vegetables oils (coconut, castor bean, cottonseed, groundnut, maize, mustard, safflower, neem and soybean) can affect egg laying and egg and larval development of stored pests. Treatments with vegetable oil are particularly useful in protecting legumes against pulse beetles (bruchids). The addition of 5 ml oil per kg of grain/seed should be effective if all seeds are coated properly with oil. However, the effect of oil treatment decreases with time, so that seeds stored this way should be treated again if there are signs of infestation. Be aware that neem seed oil or any other non-food oil leaves a bitter taste (this is why it works as a repellent). This bitter taste can be removed by immersing the seed in hot water for a few minutes before food preparation.

Plant parts and dried powder are traditionally used against storage pests. Usually, these products are used at 50 grams per kilogram of stored product. Examples of plant materials that help protect the stored grain/seed are:

- Chillies (dried pods or dried powder mixed with ashes or fine clay)
- Neem (leaves, crushed seeds or oil)
- Pyrethrum (dried flower heads or dried powder)
- Derris (all plant parts as a powder or spray)
- Eucalyptus (leaves)
- Syringa (dried leaves or powder of ripe seeds at 2 %)

- Mexican Marigold (dried whole plants as a 3 to 5 cm layer in base of grain bins)
- Spearmint (dried whole plant powder at 4 %)
- Aloe (dried whole plant powder)

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