African Organic Agriculture Training Manual

A Resource Manual for Trainers

9-3 MILLET

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Ready for field testing

FiBL

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9-3 GROWING MILLET THE ORGANIC WAY

SET OF TRANSPARENCIES

FLYER 3: MILLET

Learning targets for farmers:

- Know that millet is the cereal crop with the highest heat and drought tolerance and very suitable to contribute to sustainable food security in hot and dry climates.
- Understand the underlying principles of organic production.
- Understand that considerable increases in millet yields are possible with improvement of soil fertility and application of improved management practices.
- Understand that proper crop rotation or crop mixtures are essential components to organic millet production in order to reduce or prevent soil fertility decline and promote reduction of the major pest stem borer and the parasitic weed Striga.
- Recognize that the push-pull method can be a very effective method to control stem borer and Striga with potential to provide many other advantages in organic millet production.
- Learn about pheromone traps as one of the ways to control stem borer.

1. Introduction and challenges

Millet is considered the 6th most important cereal in the world. It is a robust cereal crop and an important staple of the African semi-arid tropics. It is mostly grown for food (flour processed into fermented and unfermented products), but also for beer making and animal feed. Nine species are common in Sub-Saharan Africa, but only four are grown on a significant scale: Pearl or candle millet (*Pennisetum glaucum*), Finger millet (*Eleusine coracana*), Teff (*Eragrostis teff*) and Fonio (*Digitaria exilis* and *Digitaria iburua*). Pearl millet is by far the most important, by cultivated land area, due to its high yield potential under drought and heat stress. Finger millet is also common in Eastern and Southern Africa; Fonio only in West Africa, while Teff is only grown in the dry mid-highlands of Ethiopia where it contributes about 25 % of total national cereal production.

COMMON MILLET PRODUCTION SITUATION

Millet is known for its very wide adaptability to different growing conditions and its tolerance to dry spells, drought and heat. The crop is mostly grown in areas, where rainfall is low and irregular, and where other crops such as maize or sorghum have failed as it has great potential to avert hunger and/or famine in harsh climates. As the world becomes drier and hotter, millet may attain more importance as a staple food crop. This is more so in Africa where desertification levels are increasing and threatening food security.

Pearl millet contains more protein and minerals than most other cereals. It contains more than three times the iron content of maize and would thus be an important dietary component particularly in view of the high prevalence of iron deficiency among many populations in Africa, particularly women. Compared to sorghum, pearl millet is also reported to have better digestibility properties. Due to its high nutritional properties, pearl millet is used to prepare some traditional weaning foods.

Main challenges associated with millet production and utilization

The main challenges to millet production in Africa are declining yields, which are mainly due to short and unreliable rainy seasons with frequent dry spells, droughts, declining fertility of soils and poor crop management. The yields of millet range between 500 and 1500 kg per hectare, but can be as low as 150 kg per hectare. The low yields are also partially due to the crop's low harvest index (less than 20 %), but it is also due to the circumstance that millet is mostly cultivated on poor soils with no or very little inputs. However, if soil fertility is adequate and the required rainfall amount is received (or irrigation applied), millet can reach 3000 kg per hectare or more. Other reports also suggest that millet production is declining due to the switch by farmers (and consumers) to other cereals such as maize due to the difficulties associated with millet grain processing (e.g. hulling using traditional methods), taste preference. There are also views that the decline is partly due to the generally inadequate support to millet promotion from a research and policy point of view in many African countries.

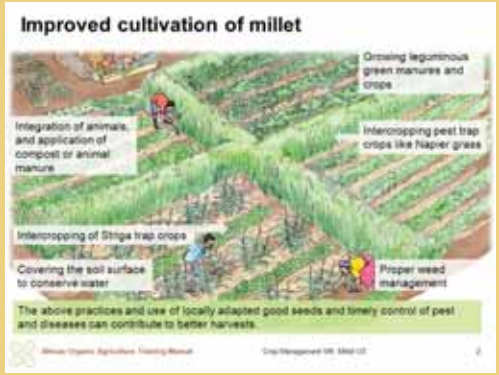
Millet is regarded as a crop that has less pest and diseases problems than most other cereals; however, devastating diseases and pest attacks can also occur as elaborated in later sections.

Assessment of millet production in the area

Inquire about the local millet production situation, using the following questions:

- Is millet a common crop in the area? Under what conditions is it commonly grown?
- What are the average yields of millet?
- Which other crops are grown with or in rotation with millet?
- Which are the main challenges in millet production? Have the farmers tried to address the challenges and how?

IMPROVED MILLET MANAGEMENT SITUATION



Organic production practices

Pearl millet is generally regarded as a crop with few pest problems and rather low nutrient requirements. Nevertheless, it responds well to improved growing conditions. Organic practices can increase yield and yield security of millet improving soil fertility, diversifying the cropping system, preventing weed competition, as well as major pest and disease problems.

Therefore, the objective of this training unit is to encourage farmers to introduce the organic approach, which can be adapted to the local conditions to increase yields and yield security.

2. General climatic and soil requirements for pearl millet

Pearl millet is a warm season crop and is sensitive to frost. Temperatures of around 28 to 30 0C are regarded as suitable for crop growth. Pearl millet is generally sensitive to low temperatures during the seedling and flowering stages. The crop grows well in a wide range of rainfall regimes ranging from 200 to 1,500 mm per annum although 250 to 700 mm is considered as the ideal range. The rainfall is preferably evenly distributed throughout the growing season. Too much rainfall during flowering is reported to cause yield reductions. The seed matures best in a non-rainy, dry and cool climate.

Even though millets are drought tolerant, prolonged dry spell can reduce yields significantly. But its rapidly developing root system, the special mechanism of its root system to prevent desiccation during periods of moisture stress, and its high tillering capacity make pearl millet tough to drought.

Millet grows well in deep to loamy sands but performs best on deep well drained fertile soils. Deep soils are ideal, as the pearl millet roots can grow to nearly 3.6 m depth. Pearl millet also performs relatively well under acidic soil conditions. But the crop does not grow well in calcareous soils.

3. Diversification strategies in millet production

There are many ways to diversify a millet cropping system. It can be achieved through growing different millet species or varieties, or growing millet together with other crops – in rotations or in mixtures.

Inquiry on organic production

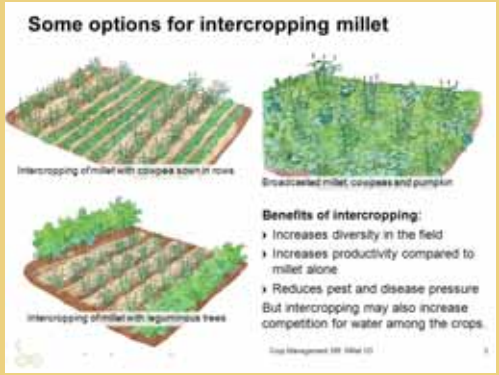
Enquire about organic millet production in the area using the following questions:

- Are there any farmers growing organic millet in the area?

If there are, enquire further about the following:

- How/where do farmers obtain seed for organic millet production?
- What weed management strategies or methods do they use in organic millet production?
- How do they manage soil fertility and pest management?
- Where do the farmers sell the organic millet, is the market guaranteed?
- What are the major challenges which they face in organic millet production and postharvest management?

INTERCROPPING OF MILLET



Varietal diversification

Millet has a wide range of maturity periods. Some varieties mature in as little as 60 to 80 days (short duration) while others take about 100 days (medium) to mature. Long season varieties can take up to 180 days to mature from planting. Cultivation of short-duration varieties reduces the risk of crop failure. In areas with two rainy seasons, millet can be grown during the short rains. Where rainfall is sufficient, double cropping is possible after short-duration millet.

Mixed cropping

In traditional cropping systems, millet is mostly grown together with other crops. The reason lies in the numerous advantages associated with mixed cropping such as higher total and safer yields, better use of the resources, and cultural advantages such as better weed control and soil protection. In West Africa, pearl millet is often intercropped with other cereals like other millets or sorghum, or with legumes like cowpea or groundnut. Intercropping patterns vary depending on rainfall regime and other factors such as crop preferences. Intercropped legume and millet are usually sown in alternating rows. In the case of cowpea, growing two rows of millet and four rows of cowpea has proved more productive than alternating single rows of both crops. Sowing times, varieties and cropping patterns should be chosen in a way that avoids competition by the legume for water, nutrients and light. Cowpea may be sown two to four weeks after millet. Longer growing seasons offer greater possibilities of adapting the system. Intercropping of millet with a drought-tolerant legume in general increases productivity of both crops compared to cultivation of a sole crop.

Cultivation of nitrogen fixing trees in rows increases the diversity of the cropping system, while offering additional, highly nutritional forage for livestock, enriching and protecting the top-soil with the fallen leaves in the wet season, fixing nitrogen on its roots and drawing nutrients from deep soil layers. All these effects contribute to improvement of yields of millet. Although millet prefers unshaded conditions, it will profit from improved nitrogen supply and soil conditions in proximity of the trees. Drought stress, phosphorus deficiency, and increased bird damage (harboured by the trees) may though limit advantages of diversification of the farming system with trees.

Crop rotation

Pearl millet grows well after a legume or root crop. Rotation of millet with legumes allows growing the legume at higher density than it is possible in an intercropping system. Depending on the species, their nitrogen fixation rate and their use (feed for livestock, incorporation into the soil as green manure, grains for human consumption), legume crops grown prior to millet will have a more or less positive impact on the yield of the following millet crop. Rotation (and to a smaller extent intercropping) of millet with legumes furthermore reduces infestation of the parasitic weed Striga, an economic weed for millet. Rotation of millet with fallow, which is another possibility of diversification that is traditionally used, does also contribute to better growth of millet, but in general does not substantially improve soil fertility, and regeneration of soil fertility is slower under natural fallow.

For more information on crop rotation see section on soil fertility management.

Using millet as feed for livestock

Basically, organic agriculture encourages the introduction of livestock into the farming system, as they transform plant biomass into animal products and provide manure for the crops. But where land is short and plant growth is limited due to scarce rains, there may be need to renounce to the introduction of livestock, or there may be need to remove livestock from the farming system to avoid competition to human food production and provide more biomass for soil fertility management. It may be more efficient to farm less land applying proper soil fertility management without using animal traction, than to manage a larger area poorly. If the stubbles, tree leaves and other plant materials are grazed by livestock, biomass will not be available for soil fertility management and the soil is left more or less bare through the dry season - creating unfavorable conditions for improvement of soil fertility. If the farm is managed without livestock, surplus grain legumes may be substituted for some livestock products and increased planting of a wider variety of legumes would improve the sustainability of the cropping system.

Where conditions allow, pearl millet can be grown for livestock feed where animals with high nutrient requirements such as growing animals, lactating dairy cows, or calves are allowed to graze on the growing crop. In this case, the pearl millet can be used either under a continuous or a rotational grazing sys-

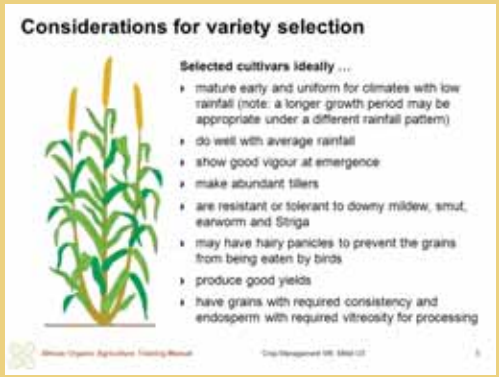
Discussion on diversification strategies in millet production

Ask the farmers, if they know any other (indigenous) methods to enhance yields and reduce losses of millet. Let them identify any other practices which they think can contribute to increased and better production of millet. Guide the selection of appropriate practices based on local applicability and affordability.

Discussion on crops for rotation and mixed cropping

Find out, if farmers practice planned rotations. Determine and evaluate together with them suitable crops for rotation or mixed cropping. Estimate potentials and constraints of the different combinations.

VARIETY SELECTION



tem. For most efficient use of the pearl millet, animals can be turned into pastures when pearl millet has reached a height of about 50 to slightly over 60 cm. The animals can be allowed to continue grazing until the pearl millet plants have been reduced to about 15 to 20 cm height. Overgrazing must be avoided, if the pearl millet is to be allowed to regenerate for the next rotational grazing phase.

Besides grazing, the pearl millet can be processed into hay and silage. Due to the thick pearl millet stems, the curing time in hay production is longer than with other hay crops, but the curing time can be reduced by crushing the stems, if facilities are available. The best times to cut the millet are: first cutting at 60–65 days after planting when the plants are about 90 cm tall; thereafter at intervals of 30 to 35 days. For making silage, the pearl millet should be cut at boot to soft dough stage as this gives an optimal nutritive value to the silage. The plants should be wilted before chopping for storage.

4. Choosing the right variety to plant

Millet varieties differ in many respects. The time to flowering, plant height and leaf numbers vary among varieties. Millet occurs with different shape, structure and size of the panicle. In some varieties, the panicle is open and erect; in others it is compact and head-like. Other attributes which vary include i) tolerance to drought, ii) pest (including birds) and disease tolerance, iii) tillering capacity, iv) height of plant, v) time to maturity, vi) yield, vii) grain colour and size, viii) size of hairs (bristles) on the panicle, ix) length of grain storage, x) hull and grain processing characteristics, and xi) milling quality.

Although traditional cultivars have a low yield potential, they have the advantage of being well adapted to local growing conditions. However, improved cultivars have shorter growth duration of 75 to 80 days, higher protein content, and may attain higher yields even under conditions of drought-stress and low nutrient level. Some cultivars are resistant to diseases like blast and rust. The local extension services may be able to give more information for choosing the right millet cultivar.

Recommendations to farmers for good variety selection:

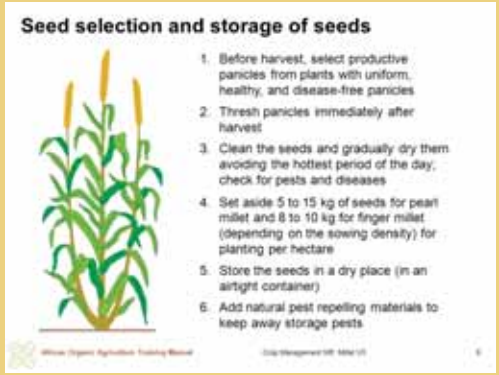
› Use early and uniform maturing varieties to increase yield security in climates with low rainfall, as periods of drought can be avoided. Cultivation of

Discussion: Selection of millet varieties

Invite the farmers to share their experiences with locally available millet cultivars. You may aks them:

› Which criteria do you normally consider when selecting millet cultivars to grow?
› How do you select and store seeds for the next season's crop? Do you face any challenges and how do you address them?
› Do you have any experiences with improved millet varieties?
› Do you buy millet seed or do you produce your own? How can you tell that it is the best variety for your area?

SELECTION AND STORAGE OF SEEDS



short-season cultivars furthermore may allow growing a second crop, ideally a legume.

- Before scaling-up production of a new cultivar, test it first on a small scale.
- For best results and to minimize risk of crop failures, choose cultivars that do well with average rainfall, show good vigour at emergence, abundant tillering, are resistant or tolerant to downy mildew, smut, earworm and Striga and produce good yields.
- Hairy panicles prevent the grains from being eaten by birds. For processing, the consistency of the grains and the vitreosity of the endosperm are also important characteristics.

Seed selection and saving

Traditionally, farmers saved seeds from one season for sowing during the next season. Over the years, breeding programmes have produced improved varieties of millet of which farmers can buy seed and grow. However, there are farmers who still save their own seed for various reasons. To save own seed, the farmers select panicles from the best plants which they identify before harvest. Panicles from these plants are then harvested and stored separately from those to be used for consumption. Some of the attributes which farmers consider in selecting plants from which to harvest seed are plant vigour, tillering capacity, plant height, absence of disease infection, panicle size and grain size.

Panicles are not always selected before harvesting. In some cases farmers only select the panicles for seed saving after harvest. With this method they are not able to tell the characteristics of the plants from where the panicles were harvested. It is therefore advisable for the farmers to use the first approach where panicles are selected before harvesting so that farmers also consider the plant characteristics in selecting the seed.

After thorough drying on wooden racks or on a flat rock preferably in the shade until they are dry (after one week or when the seed moisture content gets to 12 %), the panicles are threshed and seed is further dried if necessary, particularly if the grains are larger and drying on the panicle is slower. When properly dried, the seed is mixed with ash and then stored in bags in huts used for cooking where the smoke and heat help to preserve the seed from pests and diseases. Seed can also be stored in clay pots to keep them cool and protect them from pests. Alternatively the seed can also be stored with leaves of plants such as neem and tephrosia, or with pyrethrum to deter pests. If farmers intend to keep

SALT WATER FLOATING METHOD

the seed for longer periods, seeds should be dried to around 8 to 9 % moisture while even lower moisture of 5 to 7 % is encouraged for long term storage of the seed. To prevent the seed from absorbing moisture during storage, they should be stored in sealed containers which are not permeable to moisture.

Controlling diseases in millet seed

Seed borne diseases such as ergot (described in more detail in a later section) can affect the panicles and carry the pathogen to the next crop. Farmers are encouraged to remove affected panicles/plants to avoid diseases spread. However, the infected seeds must also be eliminated from the seed lot. In India, the salt water floatation method is used to separate or eliminate ergot infected seeds.

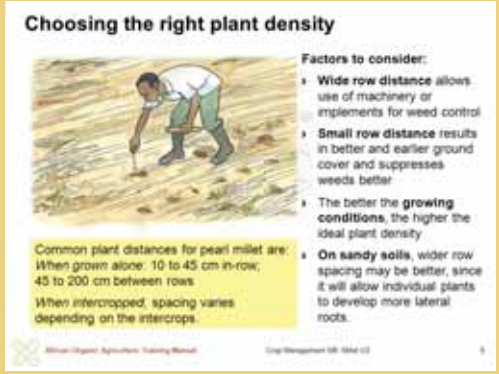
Treating the seeds with 600 g of Azospirillum (*Azospirillum brasilense*, a nitrogen-fixing bacterium found in the rhizosphere of various grass species) per 4 kg seed and with *Phosphobacterium* will enhance the availability of nitrogen and phosphorus to the subsequent millet crop.

Seed treatment and preventing seed from absorbing moisture during storage

Non-toxic chemicals can be used to protect pearl millet seed. The method reported by TamilNadu Agritech is to treat the seeds with a halogen mixture at the rate of 4 g per kg of seeds. Calcium oxychloride + calcium carbonate + *Albizia amara* leaf powder are mixed in the ratio of 5:4:1 and stored in an air-proof container for a week to prepare the halogen mixture before applying it to the seed. To prevent the seed from absorbing moisture, moisture vapour proof containers like polyethylene bags (of 700 gauge thickness) must be used for seed that has moisture content 8 % or less. Polylined cloth bags can be used for seed at 10 % moisture content. It is important to place the bags on wooden pallets to prevent absorption of moisture from the floor and walls. If large quantities of millet seed have been produced, bags should not be over-stacked (more than 7 bags per stack) as this will exert pressure to the seeds in the lower bags causing loss of seed viability.

MILLET GROWING SYSTEMS

PLANT DENSITY



5. Sowing and proper field establishment

Short-duration cultivars are sown early after the first rains of the season, and preparation is limited to a light hoeing. In contrast, long-duration cultivars are sown later and land preparation is usually done more thoroughly. Any hard pans in the soil or other forms of soil compaction must be broken to prevent subsequent root growth restriction. Most farmers still prepare the seedbed by ploughing the land and harrowing it to a fine tilth. This land preparation ensures that all the volunteer crops and residues from previous cereal crops are properly buried as part of the pest and disease management strategy. But it exposes the soil to sun, wind and rain, and may result in soil erosion and loss of soil moisture. No-till or conservation-tillage for soil preparation for millet can be successful and is desirable especially on highly erodible land or clayey soils. It also has the advantage of better seed depth control, as the soil stays firmer. Crop residues or biomass from a previous green manure crop may be left on the soil surface to build a mulch cover. Millet may then be sown in rows into this mulch.

Sowing can be done on the flat, on hills, on ridges, in furrows, in Zai pits or on raised beds. Raised beds and ridges are especially important, if the soils are poorly drained. In some areas farmers broadcast the seeds along planting rows and then cover them lightly with soil.

The better the growing conditions, the higher the ideal plant density. On sandy soils, wider row spacing may be better, since it will allow individual plants to develop more lateral roots. In drier areas and on light soils millet is sometimes sown in furrows or pits/holes to harvest rain water and improve access to soil moisture.

Row distance for pearl millet can range from 45 cm to 200 cm, depending on whether the crop is grown alone, or whether it is intercropped. In-row spacing can range from 10 to 45 cm. While wide row distances allow use of machinery for weed control also, small row distances will result in better and earlier ground cover by millet and will thus suppress weeds better.

The common seed rate is around 5 kg per hectare, but depending on the plant density, seed rates can vary from 2 kg per hectare to as much as 20 kg per hectare, if several seeds are sown per hole. The seeds should be sown into a shallow (as pearl millet seeds are small), firm, mellow and moist seedbed, to obtain good contact between the seeds and the soil, and ensure good field establishment.

6. Thinning

If several seeds are sown per planting hole, many seedlings can emerge per station and form a cluster. To reduce competition for nutrients, water and sunlight within the cluster, the millet seedlings must be thinned to three or less per station, although some farmers prefer to leave four plants per station. Wider spacing on sandy soils allows individual plant to develop more lateral roots and make the plants more resilient to droughts.

Thinning is normally done within about one month from sowing, before tillering starts. It is mostly done by hand. The less vigorous seedlings and those appearing to be diseased or weak due to some reason, must be removed. If necessary, removed seedlings which are healthy can be used to fill in gaps in places where emergence was poor. Seedlings used for gap filling should be used on the same day that they are thinned out, and adequate moisture should be available to facilitate their re-establishment.

7. Improving soil fertility

Pearl millet is highly responsive to increased soil fertility although it is reported to be a crop with low nutrient demands, requiring less nitrogen than sorghum. Therefore, it is worthwhile for millet farmers to invest in soil fertility.

Instead of applying mineral fertilizer, which includes costs and may increase the risk of moisture stress to the crop, organic farmers look at avoiding loss of soil fertility and supplying fresh or decomposed biomass to the soil, and practicing planned cultivation of leguminous crops to collect nitrogen from the air.

Nutrient requirements of pearl millet are modest compared to other cereals like sorghum or maize. Nitrogen requirements of millet are around 25 to 35 kg per hectare for grain crops and common seed rates. Requirements are higher, if planting densities are higher. Excess nitrogen may produce tall crops that are prone to lodging. Phosphorus requirements of the crop are 5 to 10 kg per hectare. In very acidic soils, application of lime 3 to 6 months prior to planting millet allows for the lime to react with the soil and improve availability of the applied phosphorus. The quantities of lime to apply depend on the amount of acid to neutralize in the soil (or the target pH to be reached after liming). Advice on this is best based on laboratory analyses.

SOIL FERTILITY MANAGEMENT

Organic approaches to soil fertility management in millets

Basically, there are three organic approaches to increasing soil fertility in millet production: i) Preventing soil and organic matter loss, ii) Growing crops that feed the soil in rotation or together with millet, iii) Adding manures, compost and other organic amendments to the soil before and after planting.

(a) Preventing soil and organic matter loss: soil and moisture conservation

The organic approach to solving the land shortage problem due to degradation is to build the productivity of the existing land. Special attention is necessary to prevent loss in soil fertility, as the soils favourable to millet production are generally sandy and are extremely prone to degradation. Farmers therefore need to conserve the soil by preventing the loss of top soil through erosion and conserving soil organic matter.

Soil protection measures include (these are discussed in more detail in Module 2: Soil Fertility Management) i) growing a soil cover (intercropped with the millet crop, or grown after the millet), ii) mulching (with straw, crop residues etc.) iii) relay intercropping to increase soil cover, and iv) construction of barriers and terraces to hold the soil in place.

When growing millet on slopes, the first measure to reduce soil erosion by water run-off is to plant millet across the slope and dig trenches and build bunds along the contour lines. Farmers are discouraged from burning plant residues or burning fallow fields. Instead, they are encouraged to retain residues in the field to protect the soil and also to provide livestock feed. If not collected for use as thatch or reserve fodder, any remaining residues at the end of the dry season can be gathered and placed in trash lines along the contour ridges or at the periphery of the field where they will help to stabilize the soil and reduce erosion.

(b) Integrating leguminous crops into millet production

Planned rotation or intercropping of millet with leguminous food crops or green manures improves soil fertility, hinders the build-up of pest populations, diseases and weeds, and reduces the risk of total crop loss in cases of drought.

Intercropping

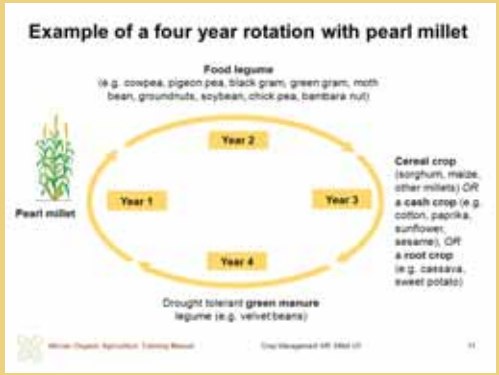
Leguminous crops like cowpea, pigeon pea, green gram, chick pea or soybean fix atmospheric nitrogen during their growth. Part of this nitrogen becomes available to the following crop such as millet. Other crops commonly intercropped with

Discussion on soil fertility management in millet production

Ask the farmers, how they manage soil fertility in millet production.

- Do they practice soil protection measures such as growing a soil cover, mulching, or constructing barriers and terraces? What do they think about these practices?
- Do they grow millet together with any other crops or in rotation with leguminous crops or green manures?
- Do they apply any organic manure to millet fields?
- Do they make compost? Have they received any training on compost making? Discuss the materials which farmers use to make compost and how they ensure good compost quality.
- Discuss the techniques they use in managing and applying organic inputs to the soil.

CROP ROTATION



millet include pumpkins, melons, okra, cassava, indigenous cucumbers, indigenous vegetables and others. They help to suppress weeds and provide cover to the soil while providing a good source of nutrition to the household. When short duration varieties of millet are grown, in a good rainfall season a second crop of a short duration legume can be planted after the millet has been harvested (or in relay). Besides improving the soil, this helps to provide the household with a good source of protein (if a grain legume has been planted), or livestock feed.

Rotations with food and non-food legumes

When food legumes such as cowpeas are rotated with a millet/cowpea intercrop or sole millet crop, productivity of the millet and soil fertility can be increased significantly. When grown in between millet seasons or during fallow periods and incorporated into the soil green-manure crops like jack beans, perennial peanut or mucuna, will add substantial amounts of organic material to the soil. This will help to feed soil organisms and enhance their activity, and as a result improve nutrient supply to the millet crop. Pearl millet is sometimes rotated with non-legume food crops or cash crops. The types of crops used in the rotation however will vary among farms and among different geographic and agro-ecological regions.

Farmers with livestock are more likely to grow green manure legumes in rotation with millet as this would increase their options for dry season feed. In areas where markets for legume crops exist, the farmers are also more likely to grow legumes in rotation with millet so as to generate income to the households. In such a case, while income generation will be the main objective of growing the legume, the rotations would help to break cycles of pests and diseases and to improve the soil.

Different legumes grown in rotation or mixtures with millet have different capacities to fix nitrogen. Their ability to fix nitrogen is further affected by the growing environmental conditions such as soils. In the sandy soils, where millets are commonly grown, nitrogen fixation by legumes is affected by low soil fertility, as most legumes have lower capacity to fix nitrogen under conditions of low phosphorus. Amendments which help to improve the phosphorus content of soils, like applying rock phosphate, can help to improve the performance of legumes. The nitrogen fixation capacity of legumes is also compromised in acidic soils. Lime can be applied to increase soil pH (and reduce acidity) and create a more conducive environment for the legumes and subsequent crops. For other

legumes such as pigeon pea, which are deep rooted, breaking the hard pans in the fields through practices such as ripping will also help them grow better.

(c) Addition of organic materials

In many areas, nitrogen and phosphorus are the main limiting nutrients in millet production. Typical symptoms of phosphorus deficiency are stunted plants, reduced tillering and discolouration of leaves, while indiscriminate yellowing of leaves indicates nitrogen deficiency. It is reported that the nitrogen demands for pearl millet can be met from organic sources since modest quantities are required compared to other major cereals such as sorghum and maize.

Application of farmyard manure

Regular addition of organic materials to the soil from farmyard manure or compost improves the availability of nutrients to the millet crop. The use of farmyard manure is often constrained by the limited availability of sufficient quantities. In general, most of the manure available is of low quality prompting the need for higher application rates. The ideal application rates reported for farmyard manure range from 2 tons per hectare to 7.5 tons per hectare for a rain fed crop. Higher application rates of up to 15 tons per hectare are recommended for hybrids and high yielding varieties cultivated under irrigated conditions. In Niger in zai pits targeted application of manure at 300 g per plant was very successful. The optimal application rate was reported at 3 tons per hectare.

To be more effective, the manure needs to be applied before ploughing and then properly incorporated during ploughing. Effectiveness of the manure also depends on other factors such as its state and composition at time of application, timing of incorporation. In the double cropping system (wheat-rice and maize-millet) of Nepal it was demonstrated that yields of maize, millet and rice were greater when manure rather than mineral fertilizer was applied. In Niger, an intercrop of millet and cowpea yielded between 11 and 18 % more grain compared to yields from a pure millet field. Application of manure was also found to significantly increase the combined millet-cowpea biomass.

Corralling the farm animals during the nights on the fields during the dry season or allowing them rotationally to feed on plots destined to millet production, simplifies manure application by reducing the labour required in gathering, transporting and spreading the manure. However, the limitation with this

approach is that the livestock droppings will not be well decomposed and the crop may not maximize benefits from it.

Where manure or compost are in short supply, the benefits to the crops can be increased by banding the manure or compost in the furrows or zai pits where the millet will be planted. Targeted application is only possible with row planting, when seeds are sown in furrows or in lines on a flat surface.

Application of 'organic' mineral fertilizers

Some mineral fertilizers, naturally occurring and used in that form, are permitted in organic production. Before use in certified organic production, farmers are encouraged to consult with their extension experts or certifying agents about the use of different fertilizers. Based on the East Africa Organic Standards which are also in compliance with the IFOAM Standards, lime and rock phosphate are some of the mineral nutrient sources permitted in certified organic farming. In their research, ICRISAT demonstrated that millet yields can be significantly increased by applying phosphorus in millet/cowpea intercrop systems.

Use of biofertilizers

Azospirillum, a biofertilizer, can be used for organic production at 2 kg per hectare. To facilitate its application, the Azospirillum can be mixed with manure or soil and applied at the final ploughing or at sowing. Use of this biofertilizer is reported to enhance utilization of applied nitrogen sources by the plants. Alternatively, the biofertilizer can be used to inoculate millet seedlings before transplanting. To prepare the Azospirillum (biofertilizer) solution 1 kg of Azospirillum is added to 40 litres of water. Then, before transplanting, the roots of the seedlings are dipped in this solution for 15 to 30 minutes.

(d) Practicing suitable agroforestry techniques

When clearing land for cultivation, farmers in different parts of Africa retain certain tree species within the fields to provide fruits, firewood, medicine and other products, and services such as shade. They are aware of the positive interactions between some trees and crops. Acacia species, baobab (*Adansonoa digitata*), Faidherbia albida, African Locust Bean Tree or Néré (*Parkia biglobosa*), marula tree (*Sclerocarya birrea*), Strychnos species, and Ziziphus species are some of the trees often found growing in millet fields. The trees help to provide shade, supply nutrients to the growing millet crop and protect it from strong winds. The crop

also benefits from nutrients released during decomposition of animal droppings left when animals rest under the trees during the non-cropping season. Products from some of the trees, e.g. pulp from fruits of *Acacia digitata* can be mixed with millet porridge to enhance its taste and improve the vitamin content of the meal.

One major setback though about retaining or planting trees in the millet fields is that bird damage to the millet can increase, as the trees will provide a good habitat for the birds.

e) Moisture and nutrient management using the Zai pits

The zai pits is a planting techniques used in dry parts of West and East Africa to harvest water and to help concentrate nutrients where the crops will grow. This system can help farmers to conserve moisture and to target application of the often scarce organic soil inputs. The little available water and the little organic soil inputs are used more efficiently resulting in better grain and biomass yields. A number of case studies report improved yields of millet when grown using the zai system in West Africa. Using the zai system versus the normal planting on the flat increased millet yields in Niger by 3 to 4 times.

Millet biomass is a good source of fodder in dry regions. Techniques, which help to increase biomass yields therefore help to make more fodder available to the livestock. Although the results from various researches point to increased grain and biomass production, the responses are likely to vary from site to site depending on many other factors such as overall management, timing if planting, pest and disease control, weeding practices etc.

8. Proper weed management

Millet has a rather slow early growth and does not rapidly develop a dense canopy cover, which can help to smoother weeds. This makes the crop sensitive to competition by other plants during this time. Weed competition in early growth results in yield loss. Thus weed control prior to planting and until the crop has fully established is important. When the millet plants have produced enough biomass, they compete well with late-emerging weeds, when grown in dense stands.

Weed control options in organic millet production

Conventional farmers rely on the use of herbicides for weed control, when the

PREVENTIVE WEED MANAGEMENT

MECHANICAL WEED CONTROL

need arises. Organic farmers strive for optimizing non-chemical preventive and direct measures to control weeds. The use of herbicides is not allowed in certified organic agriculture.

a) Preventive measures

Preventive measures include i) using clean, weed-free seeds, ii) associating millet with crop(s) with good weed suppressing qualities, iii) choosing appropriate spacing, iv) selecting cultivars with good vigour at emergence and strong tillering, and v) applying proper crop rotation. Controlling weeds along ditch banks, roadsides, and field margins will also help prevent weed seeds from infesting the fields.

b) Mechanical control

Before sowing millet, any weeds present in the field should be removed through proper seedbed preparation. Crop residues and the removed weeds can be used to cover the soil as mulch or can be aligned at intervals as trash lines in order to cover the soil in between the rows and hinder new weeds from growing. Alternatively, the weeds can be collected and used for making compost, but care must be taken not to disperse weed seeds and diseases through the compost, if the compost is not well prepared. In case of high weed pressure additionally a pre-plant tillage operation is recommended to kill the weed seedlings prior to planting and to reduce weed pressure in early growth of millet. Light harrowing after emergence can help to control early weeds.

For good cultural practice, two weeding and thinning-out operations are usually necessary in millet. Eight to fifteen days after emergence (preferably after rain) the field should be thinned to 2 to 4 plants per station. When weeding by hand thinning is usually combined with weeding. The first weeding should be no later than 15 to 20 days after emergence. The second weeding should be done manually and follow the first by 10 to 15 days, but could vary depending on weed pressure. Thereafter, additional weeding should be performed as needed.

Weeding is commonly done with a hoe, but animal-drawn or tractor-drawn cultivators can be used, too. In case a drawn cultivator is used for inter-row cultivation, the weeds between plants within the rows are removed by hand. Broadcast millet can be mechanically weeded using a tine-weeder (a harrow with spring steel tines). Tine-weeding is very effective between sowing and plant emergence (called blind harrowing), as well as when the millet plants have three to four leaves and the weeds are not taller than 1 cm.

Discussion on weed management in millet production

Ask the farmers whether they experience any major weed problems. List the local names of major weed species and identify their characteristics. Inquire about local weed control strategies that are being used and discuss potential improvements.

WATER MANAGEMENT

c) Cultural control

Planned rotation or intercropping of millet with leguminous crops or green manures will prevent the build-up of weeds, including Striga. Striga does not do well in soils with a good fertility status. The combination of different weed management practices will most effectively reduce weed proliferation.

Controlling the Striga weed

Striga hermonthica (witch weed) is a parasitic weed, which is problematic in many cereal producing areas of Africa. Striga competes with the millet plants for both water and nutrients. Consequently low soil fertility and low rainfall favour Striga infestations. To prevent Striga from spreading, farmers should plant uncontaminated seeds and clean off soil and plant debris from machinery, shoes, clothing, and tools before entering fields. If the Striga plants are few, pulling-out the weed before it produces seed is an option, but not a long-term solution. Another method called trap cropping involves planting a species in an infested field that will induce the Striga seeds to germinate but will not support attachment of the parasite. Example of such crop is plumed cockscomb (*Celosia argentea*) planted in rotation with millet. The plumed cockscomb will 'trick' the Striga seed to germinate, but will not support any further growth of the weed seedlings. This helps to deplete the Striga seed bank in the soil while preventing formation of more seed by the weed. Other crops that are claimed to be effective against Striga include cotton, sunflower, groundnut, castor, dolichos bean, and linseed. In the push-pull system Desmodium species (silverleaf, *D. uncinatum* and greenleaf, *D. intortum*) are used to repell the stemborer moths. The same Desmodium species also control Striga.

9. Proper water management

In Africa, millet is commonly grown as a rain-fed crop in dry climates. It is very drought resistant and under conditions of low soil-water the crop is generally more productive than sorghum. The soils in which millet is grown are generally sandy with low moisture holding capacity, and are generally deficient of organic matter. Although it tolerates low soil moisture conditions, millet responds very well to additional water supply through better water harvesting and conservation practices or irrigation thereby producing higher yields.

MAJOR PEST AND THEIR CONTROL

Control of major pests of millet

Pests	Preventive and cultural measures	Direct control
Shoot fly	• Use of shoot fly resistant varieties (for late planting mainly) • Early, non-staggered sowing • Promotion of natural enemies • Incorporation of crop residues into the soil	• Removal and destruction of infested plants • Spraying of Bacillus thuringiensis or neem solution against larvae
Stemborer	• Early sowing and good soil preparation • Rotation with non-host crops • Intercropping of repelling plants like Silverleaf • Promotion of natural enemies • Planting of Napier grass or other trap crops • Incorporation of crop residues into the soil	• Application of a mixture of neem or a fish bean plant extract and sawdust/dry clay into the funnel of young plants • Locally-made pheromone-baited traps
Millet midge	• Early and uniform sowing with high densities • Use of resistant cultivars • Rotation with non-host crops • Removal of host weed species • Incorporation of crop residues into the soil	• Spraying of pyrethrum extract

Evaporation from the soil surface constitutes a large proportion of evapotranspiration. Practical methods of reducing evaporation from soils to conserve water are very important in millet production. The use of crop residues as mulch or soil cover is one solution except where they are fed to livestock during the dry season, or consumed by termites. Early/timely planting is another important strategy to ensure that the growth pattern of the crop coincides with the rainfall pattern.

Millet needs little water after germination, a small amount as the leaves appear, and light rain during the growing period. Moisture stress during flowering through to grain formation reduces yields, as does heavy rainfall. During grain development hot and dry weather is needed.

10. Effective pest management

Shoot fly, stemborer, earworm and millet midge are the most important pests in millet, but also grasshoppers, locusts, white grubs and various butterflies can attack the crop. Birds are also important millet grain pests.

The **sorghum shoot fly** (*Atherigona soccata*) is also known to attack millets. It lays single cigar-shaped eggs on the undersides of leaves of young millet plants between the 1- to 7-leaf stages. The eggs hatch after only a day or two, and the larvae feed on the shoot tip. Feeding activity by the larvae results in wilting and drying of the young plant leaving a dead heart (central leaf develops into a dead heart and comes out easily on pulling). If the dead heart is plucked, it releases a bad odour. If the plant builds side tillers, they may also be attacked. The adult shoot flies resemble small houseflies.

Infestations are especially high when millet planting is staggered due to erratic rainfall. Temperatures above 35 °C and below 18 °C reduce shoot fly survival, as does continuous rainfall. Parasitic wasps and several species of spiders are important predators on eggs. Therefore, these natural enemies should be encouraged through maintaining strips with flowering plants around the fields. To reduce carry-over from one season to the other the crop residues should be collected and destroyed after harvest and other sources of mulch should be used in place of the millet or sorghum residues. If available, shoot-fly resistant varieties should be used.

Discussion on water management and irrigation

Ask the following questions to the farmers to inquire about their approach to water management in millet production:

› What do you do to conserve soil water for growth of millet? Which measures proved effective to reduce evaporation of water from soil?

› Do you irrigate your millet crops? If yes, how do you decide why and when to irrigate? Do you face any challenges in irrigation like availability of water, issues of water sharing, or quality of water?

PUSH-PULL STRATEGY

Stemborer (*Coniesta igenfusalis*) is an important pest of millet, especially of pearl millet. The larvae feed on the growing points, leaves and stems of the plants at different growth stages, resulting in dead hearts. Destruction of crop residues through incorporation into the soil and good soil preparation contribute to control of the stemborer. Proper crop rotation breaks the pest's life cycle. Mixed cropping of millet with other species also confuses the pest. Promotion of natural enemies with strips of insect-feeding flowering plants is also helpful, as several natural enemies attack this pest at different stages of its cycle.

The push-pull method, developed in East Africa, is very effective in controlling of cereal stemborer. This involves use of trap crops to attract stemborer colonization away from the millet plants (pull) and intercrops to repel the pests (push) as it is practiced for other cereals. Examples of trap crops are Napier grass, Sudan grass and molasses grass (*Melinis minutiflora*). They are planted in three rows around the millet fields. Whereas the fodder legume silverleaf, *Desmodium uncinatum*, which acts as repellent, is intercropped between the rows of millet. Direct control is possible with application of neem during the evening.

Also inexpensive, locally-made pheromone-baited traps can be efficient in controlling stemborers. Placing simple locally made pheromone-baited traps along fences, or in the field, disrupts the mating activity of the stemborer moths by almost 90 % and results in a reduction of the population. The pheromone baited traps can also be used as a method for monitoring the stemborer adults to facilitate decision making on control of the larval stages. When the traps are placed in the field, 1,2 meters seems to be a good height at which the traps should be placed above the ground. Spacing between the traps in the field should be about 15 meters. Local extension agents can provide information on where and when to install the traps and where to obtain the pheromones.

Millet midge (*Geiromiya penniseti*) is abundant during the rainy season. The larvae of the fly feed on the developing seeds. As a result, infested grains do not develop and panicles have a blasted appearance. Appropriate rotation with non-host crops and intercropping reduce pest damage. After harvest crop residues should be destroyed to destroy the pest (although these would otherwise have been retained in the fields on the soil surface to protect the soil). Ideally fields are ploughed after harvest and shortly before sowing. Spraying of natural pyrethrum is possible, though not very economic.

Birds are the major pests of millet, especially *Quelea* spp. They prefer millet grains because of their small size. Preventive measures against bird attack in-

Discussion on pest management in millet production

Ask the farmers, whether they have experienced any serious millet pest problems in the area. Have they noticed any trends in pest problems over the years? Let them describe the signs associated with the pests and when they are most likely to attack the crop. Invite the farmers to also discuss any differences which they observe among different millet varieties and also discuss the control strategies which they use.

clude using cultivars with long, hard bristles. Risk of damage can be reduced by planting pearl millet away from tree lines or woods. Scaring of birds for several weeks before the harvest with efficient bird scaring methods is essential.

The lesser grain borer (*Rhyzopertha dominica*) and the khapra beetle (*Trogoderma granarium*) attack pearl millet at storage and can cause serious damage. Rats can also destroy harvested grains. For more information on control of storage pests see under paragraph 12 «Post-harvest handling».

11. Effective disease management

Downy mildew, smut, rust and ergot are widespread diseases where millet is grown in Africa. In general, effective disease management starts with prevention of attack by ensuring clean planting materials or resistant varieties which should be planted in a clean environment followed by proper field sanitary procedures and good husbandry practices. Normally all cultivation practices that encourage plant vigour will enhance the crop's ability to reduce the impact of disease attacks.

Downy mildew (*Sclerospora graminicola*) is the most devastating disease in millet and is important in most parts of Africa. The disease is transmitted through the soil, crop residues, contaminated seeds and tools, and is prevalent during rainy periods. Symptoms often vary. Leaf symptoms begin as chlorosis (yellowing between the veins) on the bottom leaves. White fungus may be observed on the underside of infected leaves. Severely infected plants are generally stunted and do not produce panicles. Inflorescence and glumes can become twisted and transform into leafy structures (green ear symptom). Spreading of the disease can be reduced by destroying prematurely infested tillers and infested crop residues. Some varieties that are resistant to downy mildew have been selected and can be planted, if the risk of downy mildew is high in a particular area. Early sowing is useful also, but is not always feasible due to competition for labour with other crops and the sowing window is often short in rain-fed situations.

Long smut (*Tolyposporium penicillariae*) attacks the millet plants during flowering by wind-borne spores and rain. Infections are most important when humidity of the air and temperature are high. Green fungal bodies larger than the seed develop on panicles during grain filling. As the crop matures, the fungal bodies change in colour from green to dark brown, containing dark spores. Con-

Making of a pheromone-baited trap

Develop a pheromone-baited trap as a stem borer monitoring system with the farmers. With the assistance of an entomologist or extension worker, the sub-activities could include the following:

- Finding out the possible pheromones and their sources for the particular area
- Constructing the pheromone-baited traps
- Field placement of the traps (distances between the traps, placement height etc.)
- Monitoring and evaluating effectiveness of the traps

DISEASES OF MILLET AND THEIR CONTROL

Control of major diseases of millet

Diseases	Symptoms	Control measures
Downy mildew	• Vivid green and white stripes on the leaves and heads • Inflorescence and glumes become twisted • Heads partially or completely sterile	• Rotation with pulses. At least 3 years between two sorghum or maize crops • Use of resistant cultivars • Use of clean, properly dried seeds • Early sowing • Proper plant spacing • Premature destruction of infested tillers • Incorporation of crop residues into the soil
Long smut	• Green fungal bodies develop on panicles during grain filling • The fungal bodies change to dark brown during maturing of the crop.	• Rotation with non-cereals • Use of resistant varieties • Avoiding of flowering of the crop during the rainy season • Removal of infected panicles for field sanitation
Ergot	• Pink sticky "honeydew" droplets, which ooze out of infected florets on the panicles • Development of dark brown to black fungal fruiting bodies	• Use of resistant cultivars • Rotation with pulses • Removal of infested panicles

trol of the disease focuses on preventive measures such as the use of tolerant or resistant varieties, timing of planting to avoid flowering during the rainy season, and by applying cultural measures that contribute to crop hygiene. With rainfall variability within and across seasons, timing of planting may be difficult; however it is important that farmers ensure that they are ready for planting with the first effective rains by having all inputs well before the rainy season starts.

Ergot (*Claviceps microcephala*) develops after flowering. Pink sticky «honeydew» droplets ooze out of infected florets on the panicles. High humidity and temperatures between 20 to 30 °C favour the development of the disease. Within 10 to 15 days, the droplets dry and harden, and dark brown to black fungal fruiting bodies develop in place of seeds. During threshing they generally get mixed with the grain. The disease can be controlled by rotating millet with non-cereals, preferably pulses, growing resistant varieties, and avoiding planting seeds from infected panicles. For good field sanitation affected panicles should be removed and destroyed.

12. Harvesting and post-harvest handling

When the millet is mature and dry enough for harvesting, the grains pop out cleanly when the head is pinched. At this point, harvesting can commence. Millet is harvested manually using a knife or sickle. The panicles are harvested into baskets or bags and stored on a wooden rack to dry before they are threshed. The stover is also harvested and stored for fodder, however in some cases the millet stalks are left standing in the field and grazed by animals during the dry season.

Proper post-harvest handling of organic millet aims at maintaining grain quality, minimizing losses and avoiding any contamination risks from extraneous materials and agents. The post-harvest handling process starts with proper and timely harvesting and drying.

Harvesting

In Africa millet is usually harvested by hand by picking the panicles or harvesting the whole plant. Harvesting may be done several times, as panicles ripen unevenly in some varieties that produce many tillers. The crop is harvested, when the panicles are fully mature and the plant is nearly dry. To avoid unnecessary

Discussion on disease management in millet production

Ask the farmers, whether they have experienced any serious disease problems in their areas.

› Let them describe the signs associated with the diseases and when they are most likely to attack the crop.
› Discuss the control measures used by the farmers for different post-harvest diseases.
› Discuss the shortcomings of the methods and any possible methods which can help to improve storage and reduce postharvest disease damage for millet.

grain loss to birds or lodging caused by the storm, the grain should be harvested as soon as seed maturity is reached.

Drying

The harvested panicles are dried in the sun on a mat, on a tarpaulin to minimise ground contamination or on a raised platform, and in a fenced area to keep off domestic animals. The drying panicles should be protected from rain to avoid delay of drying and development of mould. Drying of the millets at temperatures of about 21 °C reduces reproduction of storage pests. The ideal moisture level after drying should be 12 to 13 %.

Threshing and Winnowing

Threshing is mostly done manually by beating the panicles packed in jute or sisal bags. With this method, care should be taken not to damage the grain. After threshing, grains are winnowed to remove any foreign matter. Threshing machines for millet also exist.

Storage

Millet grains store very well; the grains can be kept for longer time than maize and sorghum grains. If stored adequately, grains kept for seed can remain viable for several years. To reduce losses at storage the grains should be dry and clean. To avoid damage by the lesser grain borer and the khapra beetle millet seeds should be stored in sealed spaces or containers like in drums and at cool temperatures, for example underground. Alternatively the millet heads can be hung over kitchen fires to repel storage pests with the smoke. If stored on the heads, the glumes protect the grains to some extent. To prevent movement and dispersal of insects, the millet seeds can be mixed with inert substances such as sand and wood ash. These substances fill the enclosed spaces and act abrasive enhancing water loss through the insect cuticle and thus killing the insects. Seeds can also be mixed with repelling plant materials such as leaves of Boscia senegalensis, and mint, Hyptis spp, and pulverised pepper.

Rat-guards should be used to prevent entry of rats into the granaries. Stored grain can further be brought out periodically and exposed to the sun in order to reduce the build-up of high humidity conditions, which is a precursor for mould development. Exposing the grain to high sun intensities also kills pests, e.g. moth larvae and weevils.

Discussion on post-harvest handling of millet

Ask the farmers to describe, how they handle the millet crop from harvesting to final storage of the threshed grain highlighting drying methods/practices, threshing, storage containers, storage places and grain protection. Discuss also how they know that the millet is dry enough for storage. Identify any shortcomings with their methods and recommend appropriate modifications.

13. Requirements for organic certification of millet production

Organic certification of millet production is only reasonable if done as a market requirement, i.e. there should be a market that demands for it. In such a case, interested farmers should be willing to adopt the general organic production requirements, like no use of synthetic pesticides and synthetic fertilisers, treated and genetically modified seeds as well as other prohibited or not allowed practices specific to the organic standard applicable to the market. In addition, sustainable production practices like soil fertility, and pest and disease management should be observed. In terms of post-harvest handling, co-mingling of organic millet grain with in-conversion and conventional millet should be avoided throughout the handling process. Generally, farmers should be willing to learn and apply new knowledge to find organic solutions to any existing challenges to millet production.

Other considerations include:

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

Discussion on marketing and organic certification of millet

Ask the farmers, if any of them are certified organic. Are there any markets that require certified organic millet?

14. Sources and recommended further readings

Publications:

- Sorghum and millets in human nutrition. FAO Food and Nutrition Series, No. 27). ISBN 92-5-103381-1
- Standards of the Codex Alimentarius for sorghum and pearl millet grains and flours. FAO/WHO Food Standards Programme.
- Lost Crops of Africa: Volume 1: Grain. National Academy Press 1996. Washington D.C.
- Norman M.J.T, Pearson C.J; and Searle. 1995. Ecology of Tropical Crops. Cambridge University Press. 430pp
- Purseglove, J.W. 1988. Tropical Crops. Monocotyledons. Longman Group UK Ltd, Longman House, England. 607pp
- Andrews, D.J. & Kumar, K.A., 2006. Pennisetum glaucum (L.) R.Br. In: Brink, M. & Belay, G. (Editors). PROTA 1: Cereals and pulses/Céréales et légumes secs. [CD-Rom]. PROTA, Wageningen, Netherlands.
- Organic Farming in the Tropics and Subtropics, Naturland.
- D. Fatondji, C. Martius, C.L. Bielders, P.L.G. Vlek, A. Bationo, B. Gerard. 2007. Effect of planting technique and amendment type on pearl millet yield, nutrient uptake, and water use on degraded land in Niger: In: Advances in Integrated Soil Fertility Management in sub-Saharan Africa: Challenges and Opportunities, pp 179-193

Useful weblinks:

- Cultivars, improved varieties: www.icrisat.org
- Common pests and diseases: www.infonet-biovision.org
- Production, post-harvest handling, economies, nutritional aspects: www.fao.org