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African Organic Agriculture Training Manual

A Resource Manual for Trainers

ORGANIC VEGETABLE PRODUCTION – BASIC PRINCIPLES AND METHODS

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This generic training manual is intended for use by trainers during the training of trainers and of farmers on organic vegetable production. The usefulness of some of the approaches and techniques is contextual and may require adaptation to suit the specific needs of the category of smallholder farmers or farmer groups in question. Those trainers who are new to organic farming would need to undergo some training on general organic farming and also make reference to other training modules to enhance their knowledge and skills on organic..

Comments and recommendations for improvement to this version are welcome.

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KCOA
Knowledge Centre for Organic Agriculture in Africa

CONTENTS

1 Introduction to organic vegetable production in Africa 2
2 Overview of key challenges 5
3 Requirements for successful organic vegetable growing 7
4 Seed pre-sowing treatment 34
5 Testing for seed viability through a germination test before sowing 36
6 Proper nursery management in vegetable production 37
7 Good field establishment and management 45
8 Good weed management 48
9 Vegetable water requirements – determining vegetable water needs 49
10 Proper pest and disease management 55
11 Indigenous vegetable production under organic management 61
12 Greenhouse vegetable production 68
13 Harvesting vegetables 72
14 Vegetable postharvest handling and management 74
15 Hygiene during the production and postharvest life of vegetables 87
16 Economic considerations in vegetable production 91
17 Marketing and organic certification of vegetable 96
Bibliography and recommended literature for further reading 101

ORGANIC VEGETABLE PRODUCTION – BASIC PRINCIPLES AND METHODS

SET OF TRANSPARENCIES

How to use this Manual

This manual is intended for use by trainers of trainers and trainers of farmers on organic agriculture. The manual highlights generic approaches to organic vegetable production. It has been developed with the understanding that farmers live in various contexts that may require unique adaptations of these guidelines.

Users may require further references to existing training materials for more information:

- Africa organic agriculture training manual Module nr. 1: Definition and Benefits of Organic Agriculture.
- Africa organic agriculture training manual Module nr. 2: Soil Fertility Management.
- African organic agriculture training manual Module nr. 4: Pest, Disease and Weed Management

Learning targets for farmers:

- Know that organic vegetable production can significantly contribute to smallholder farmers' income, especially in peri-urban and urban areas where the domestic demand for vegetables is steadily increasing.
- Recognise that successful organic vegetable production requires good quality seeds and appropriate varieties, good soil fertility management strategies which feed both the soil and the plant using well-prepared compost and green manures etc., intensive crop management and provision of good quality water for irrigation, as well as good irrigation practices.
- Appreciate the importance of integrated pest and disease management, as well as weed management in organic vegetable production.
- Understand that diversification in vegetable plots through a proper crop rotation and intercropping is very important for successful pest and disease management as well as soil nutrient management.

- Understand the potential for protected vegetable production for organic farming.
- Be aware of how to deal with some of the post-harvest challenges faced in organic vegetable farming.
- Be aware of some possible home-level preservation techniques particularly when there is excess produce.

1. Introduction to organic vegetable production in Africa

1.1 Importance of vegetables

Essential food

Vegetables (both traditional and exotic) are by far one of the most important and widely grown crops by smallholders in Africa. Most vegetables are short duration crops, harvested for their leaves, shoots, fruits, seeds, root/stem tubers and eaten in raw, cooked or processed forms. In view of the widespread malnutrition prevalence in Sub Saharan Africa (SSA), vegetables are important sources of food and nutrition security and income in rural, peri-urban and urban areas in the region. They provide vitamins and minerals needed for proper human growth and development, and should be part of everyday meals and diets of any family.

Large production potential

Production, processing and/or marketing of vegetables provides a source of employment to many people. Despite the rapid increase in their production and consumption, and the numerous benefits they present to households, in general, the economic production and utilisation of vegetables in Africa is still lagging far behind the global average. Annual vegetable production in Africa is estimated at approximately 50 kg per capita, constituting less than half the rate of most other regions of the world. Consumption rate is far lower than the WHO/FAO recommended levels of 200 g vegetables per person per day.

Great diversity of species and production systems

The range of vegetables grown varies greatly depending on the traditions and growing conditions of the different regions, which makes the list of vegetables produced and consumed in Africa complex and inexhaustible.

SOME INDIGENOUS VEGETABLES

Examples of indigenous vegetables

Photo: Irene Kadzere (FiBL)
African nightshade

Photo: Irene Kadzere (FiBL)
Spider plant

Photo: Irene Kadzere (FiBL)
Amaranthus

Photo: Irene Kadzere (FiBL)
Cowpea

Photo: Wikimedia commons
Jute mallow (bush ocra)

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   1

CONSUMED PLANT PARTS OF INDIGENOUS VEGETABLES

Nutritious parts of indigenous vegetables

Plant	Part consumed as vegetable
African nightshade	Leaves
Spider plant	Leaves
Amaranthus	Leaves
African eggplant	Tender and ripe fruits
Cowpea	Leaves, young pods, grain
Jute mallow	Leaves
Ethiopian mustard	Leaves
Yam, sweet potatoes, cassava, pumpkin, beans	Leaves
Citrullus species	Spined and non-spined fruits like melons

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   2

Organic producers grow traditional and exotic vegetables as sole crops in rotations, or in various combinations or mixtures with other crops under rain-fed and/or irrigated conditions. Farmers grow the vegetables in small kitchen gardens, large gardens or main fields. Producers also harvest and consume or sell leaves from field crops like yams and cassava as delicacies. In many parts of Africa, households harvest some vegetables like black jack, spider plant, Amaranthus species, bush okra, and many others from the wild, especially during the rainy season.

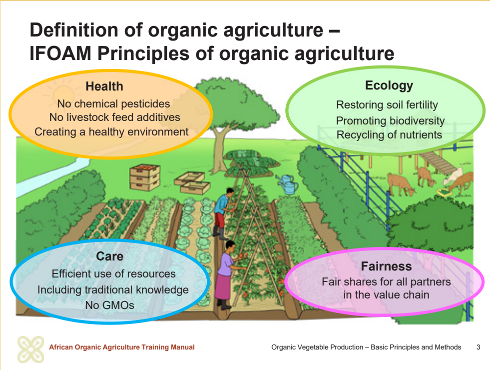
A variety of vegetables are also produced in specialised or protected environments like greenhouses, screen houses, tunnels, etc. to extend the production season, or protect them against harsh weather or from pests and diseases.

1.2 Relevance of indigenous (or traditional) vegetables

Indigenous vegetables, also known as traditional vegetables, in Africa, include African nightshades *(Solanum scabrum)*, the Spider plant *(Cleome gynandra)*, Amaranthus species and others. They are highly nutritious. Amaranthus, for example, is one of the most nutritious leafy vegetables with reported high contents of vitamin A, iron, protein and containing more than 8 times the calcium content of onion and 23 times that of tomato. Spider plant leaves have been reported to contain more than 100 times the amount of calcium while nightshades are said to have more than 4 times iron content than tomato. With the higher vitamin C contents, they are believed to facilitate iron absorption.

Besides providing high nutrition to households, these vegetables also have the potential to contribute to income and general welfare of households in rural smallholder farms and in many cities. These and other indigenous vegetables are widely grown and marketed in many African countries. With their high iron contents and ability to grow during the rainy season when most exotics would suffer from severe pest and diseases damage, the traditional vegetables have the potential to alleviate nutritional iron deficiency (anaemia) which is highly prevalent among many in Africa, particularly women. They are also believed to contain high contents of bioactive compounds which help to protect the health of consumers.

PRINCIPLES OF ORGANIC FARMING



Besides the nutritional and health benefits, other advantages of indigenous vegetables include:

i. Easier to grow than some exotic vegetables
ii. Adapted to the often-adverse growing conditions in many African regions, including to pests and diseases
iii. Ability to grow under lower input conditions (although they can respond well to improved management)
iv. Respond well to improved growing conditions such as improved soil fertility.
v. Can easily be sun dried and stored for later use.

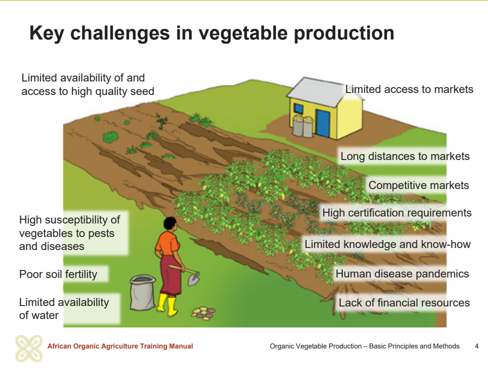
There is a growing market for the vegetables in both rural and urban areas owing to their unique nutritional, health and other benefits.

1.3 Introduction to organic vegetable production

In simplified terms, organic vegetable farming is a method that involves growing and nurturing the vegetables without using synthetic based fertilisers and pesticides (including herbicides). The method relies on ecologically balanced and sound approaches whereby the farmers observe and practice good crop rotations and/or mixtures for synergies and diversification. Farmers also use companion crops or plants, green manures, organic materials, e. g. animal manures and plant wastes/residues, as well as mineral nutrients and rock additives like phosphate rock. Further, the farmers apply biological methods of pest weed control, taking advantage of natural pest enemies and other natural techniques, practicing good hygiene and general good agricultural practices which are ecologically sensitive.

In their planning and practice, organic farmers ought to keep in mind the four principles of organic farming, **Health**, **Ecology**, **Fairness**, and **Care**. The trainers can find detailed explanations on these four principles on the IFOAM Organic International Website.

CHALLENGES



2. Overview of key challenges affecting organic vegetable production and utilisation in Sub-Saharan Africa

A number of biological, environmental, climatic and socio-economic factors reduce the optimal production, use of and benefits from organic vegetables in sub-Saharan Africa.

Poor seed quality and limited availability of and access to high quality seed at local level: Healthy seeds from adapted species and varieties are essential to prevent introduction of seed-borne diseases, impart resistance to some diseases and pests, and promote vigorous growth and attainment of proper development. Many producers fail to access healthy vegetable seeds and often are unaware of the availability of some well-adapted varieties for their situation.

Pest and disease infestations: Vegetables are highly susceptible to many pests and diseases both in the humid tropical and sub-tropical conditions of sub-Saharan Africa. Proper control management of pests and diseases in organic farming requires considerable knowledge of their life cycles, influencing factors, and possible preventive and direct control measures together with intensive monitoring and management of the crops.

Poor soil fertility and limited availability of water: Most vegetables require well-drained fertile soils and a lot of good quality water. Due to a number of constraints, most smallholder farmers often grow vegetables on poor soils, without or with limited supplementary irrigation and attention, resulting in sub-optimal yields. Having a good source of water in areas where supplementary irrigation is needed is an important consideration. Soil structure, texture, and chemical properties are also important factors to consideration in vegetable production. Therefore, the size and layout of a vegetable garden, whether big or small, must be matched to local water and weather conditions.

Marketing challenges:

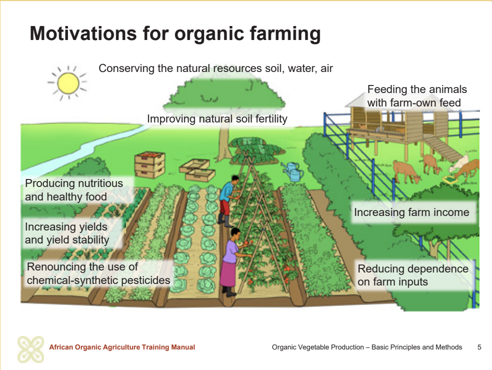
- Most rural farmers have no or limited access to markets and, therefore grow vegetables mostly for home consumption. Others sell surplus vegetables after meeting household needs, and yet others grow vegetables for the key purpose of marketing.

Discussion: Assessment of the local vegetable production, marketing and consumption situation

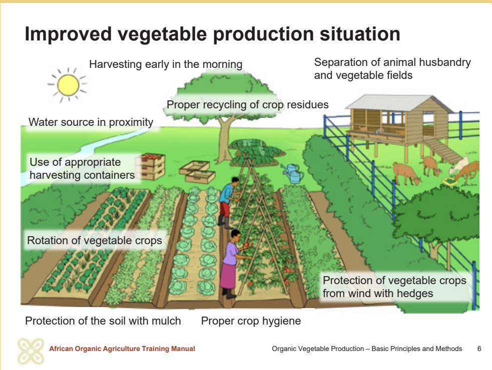
Inquire among the farmers about their interest, knowledge and experience with vegetable production, marketing and consumption using the following questions:

- Which vegetable types are commonly grown or consumed in the area?
- Are there seasonal fluctuations in the production, consumption and marketing of certain vegetables?
- Have the farmers been involved in income generating-oriented vegetable production or marketing? If so how?
- Do they try to produce vegetables in such a way that they can be available during non-peak periods to take advantage of possible higher prices?

MOTIVATIONS FOR ORGANIC FARMING



PROPERLY MANAGED VEGETABLE GARDEN



- Most vegetables are highly perishable and require rapid consumption or utilisation, quick delivery to the market, or storage under cool conditions before use. In many cases, farmers are not well-organised in groups to take advantage of collective marketing.
- Long distances to markets and disaggregated quantities often produced or irregular supplies may not warrant the transportation costs to urban centres where prices can be higher.
- The markets are very competitive, often offering low prices particularly during peak periods.
- For organic certified crops, traceability issues and low capacity to meet certification requirements and expectations can be key drawbacks for smallholder producers.
- Some consumers lack knowledge on where to find organic vegetables, and the importance of including a diversity of vegetables in their diets.

Limited knowledge and technical know-how:
- Very often, particularly during transition from conventional to organic, the farmers lack knowledge, skills and information on suitable organic production practices, and on marketing and potential markets.
- Many smallholder farmers, both organic and non-organic, lack good knowledge and skills on, or facilities for, proper storage of vegetables. The majority of farmers have neither cool storage facilities nor ready means to deliver the vegetables quickly to the markets.

Human disease pandemics: Disease pandemics including HIV/AIDS and COVID-19 constrain production and utilisation of vegetables through many ways. They reduce production capacity due to ill health and labour shortage. They cause diversion of resources from investment into food production to other household needs such as health costs. With ill health and lockdowns, there is often limited mobility for capacity development activities – farmers or other actors may fail to participate in trainings, field days, let alone travel to markets, etc.

Lack of or limited access to financial resources: Smallholder farmers do not have easy access to capital from the banks due to a number of reasons. The lack of suitable collateral, poor access to information, unbankable landholdings, low production levels and others and some of the contributing factors.

Discussion (continued)
- What major constraints do the farmers face in vegetable production?
- How have the farmers tried to address these constraints?
- What constraints do farmers face in marketing vegetables, if any?

Discussion on local vegetable garden situation
Ask the farmers to compare the setup of the vegetable garden shown in transparency 3 to their own situation.
- Which details are characteristic of the local situation for most farmers, which ones are not?
- What is their general impression of what they see in Transparency 3?

3. Requirements for successful organic vegetable growing

In general, all vegetables require optimal growing conditions and good management in order to ensure reliable yields.

3.1 Climatic requirements

All plants have a lower and an upper limit to climatic growing conditions where they can grow and produce optimally. Unfavourable environmental conditions can induce stress on plants resulting in lower yields. Matching a crop or variety with its climatic requirements is important for successful production and optimal yields. Most vegetables grown in Sub-Saharan Africa, however, may tolerate a wide range of temperatures to varying extents, as long as enough water is available and the soils are good.

3.1.1 Temperature during the growing period

In most cases, only vegetables of temperate origin grow better in very cool conditions, while vegetables of tropical origin grow better in warmer conditions. Many tropical vegetables suffer from physiological damage when subjected to temperatures below about 12.5 °C, but some can withstand lower temperatures provided this is not prolonged. Good seed germination and seedling emergence requires warm conditions. Germination is delayed, and or slower in sub-optimal temperatures and the seed can end up rotting before germination.

During growth, prolonged low temperatures may result in slow growth of some vegetable crops. Very low temperatures can lead to damage of susceptible vegetable types, for example, severe frost damage can occur when tropical crops are exposed to temperatures slightly below 0 °C as a result of ice formation inside the plant tissues. This damage can occur on all or part of the plant, depending on the severity of frost. Most crops of temperate origin (colder climates) can withstand some level of frost exposure, but others such as lettuce can suffer damage at temperatures near 0 °C. Extreme cold and hot conditions are undesirable to all vegetables regardless of whether grown organically or non-organically.

Discussion: What do different types of vegetables need to grow well?

Ask the farmers the following questions and collect all responses that you can continuously refer to as you introduce the requirements below:

- Is the prevailing climate and soil suitable for growing certain vegetables?
- Which vegetable species are easy to grow in the area?
- Have the farmers failed to grow any particular vegetables in their gardens or fields? If so what could have been the causes?
- What types of soil fertility management practices do the farmers use for vegetable production?
- Is water a key limiting factor for successful vegetable production? Are there good sources of irrigation water?

EXAMPLES OF WARM AND COOL SEASON VEGETABLES

Temperature requirements of vegetables species

Warm season vegetables (ideal temp. of 21 to 35 °C)	Cool season vegetables sensitive to frost (minimal day temp. of 4.5 to 10 °C)	Cool season vegetables not sensitive to frost (minimal day temp. of 4.5 °C)
Cantaloupe	Beets	Asparagus
Cucumbers	Broad beans	Brussel Sprouts
Egg plant	Broccoli	Cabbage
Green beans	Carrots	Garlic
Lima beans	Cauliflower	Kale
Peppers	Celery	Leeks
Pumpkin	Chard	Onion
Snap beans	Chinese Cabbage	Peas
Squash	Lettuce	Radish
Sweet corn	Mustard	Shallots
Sweet potato	Potato	Spinach
Tomatoes		
Water melon		

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 7

VEGETABLE SUSCEPTIBILITY TO FREEZING INJURY

Susceptibility of vegetables to freezing injury

High frost susceptibility	Moderate frost susceptibility	Low frost susceptibility
Beans	Lettuce	Cabbage
Eggplant	Peas	Carrots
Potatoes	Spinach	Kale
Sweet potatoes		
Tomatoes		

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 8

Temperature also affects vegetables through evaporation (water loss directly from the soil surface) and transpiration (an indication of water loss through plants) as well as its effects on processes (of a biochemical and physiological nature) internal to the plant that are important for its growth and development. Water or moisture loss from soils and plants is higher when temperatures are high, e. g. during hot times of the day or year. If water loss persists without replenishment through irrigation or rainfall, plants may wilt and eventually die.

Therefore, knowing the temperature requirements of vegetables …

- helps in selection of suitable vegetable species and varieties for a given location;
- helps the farmer to plan for situations of extreme temperature variations, for example by providing shade to the crop, covering the soil surface with mulch or by irrigating;
- helps to establish a responsive vegetable growing pattern throughout the seasons to conform with temperature variations.

Types of frost affecting vegetable production

It is important for farmers to understand the two types of frost, i. e. radiation and advective frost, and that calm clear nights pose the greatest danger of frosts. Knowing these frost types can help farmers in taking preventive measures to the crops.

For frost sensitive crops or varieties, it is important that farmers select sites which are frost free, or varieties that can withstand the frost. If this is not possible, then the crops must be protected from frost, particularly during their sensitive stages. Low temperature stress can cause other physiological disorders in vegetables. For example, poor fruit set, catfacing and puffiness in tomatoes are all caused by low temperatures experienced during flowering and fruit development. All these can severely reduce the crop yields and can contribute to significant yield losses.

Knowing the climatic and weather processes which lead to frost and its damage can help the farmer to prepare and apply preventive measures.

a) **Radiation frost** forms when skies are clear and the winds are calm during the night. Because there are no clouds to trap it, heat is lost faster from the land into higher atmospheric layers on clear nights. Without wind, the air will not easily mix to form uniform temperatures. As a result, cold air which is nor-

Discussion (continued)

- What are the main sources of irrigation water? Are the water sources dependable throughout the year?
- Do any of the farmers have experience growing vegetables organically? What are his, her or their experiences?
- From where do the farmers get vegetable seeds? What do they think about the quality of the seed that they use?

mally at the top (air temperature decreases with height) will collect to the bottom and thus pushing up the warm air to the top through a process called inversion. Collection of cold air near the ground will expose the vegetables to cold temperatures. If this air is cold enough to cause temperatures around the plants to drop to freezing or near freezing levels, then water vapour in the air can accumulate and condense on the plants or onto the ground to form white ice crystals (white frost). Sometimes the water inside the plants can freeze without formation of a white frost on the leaf and other plant surfaces and this is known as black frost. Depending on the severity of freezing, plant tissues succumb to damage and this can result in partial or complete killing of the plant.

b) **Advective frost** occurs when a thick layer of cold front with gusty winds, with or without clouds, passes through an area resulting in freezing temperatures which can cause freezing of water outside or inside the plants, hence damage to plant tissues.

There are several ways through which farmers can protect their crops from frost damage, e. g. late night or early morning irrigation, burning of slow burning materials like cow dung or maize husks in the fields, the use of napliners at night. Covering sensitive crops like tomatoes with a grass thatch during the night and establishing wind breaks can all help to protect crops from frost damage. Farmers should also know that it is more profitable to produce vegetables when the climatic conditions are not favourable hence the need to find solutions against adverse weather conditions.

DAY LENGTH BEHAVIOUR OF VEGETABLES

Required day length for proper vegetable growth

Vegetables requiring short day length (examples)	Vegetables requiring long day length (examples)	Day length insensitive vegetables (examples)
Carrot	Black-eyed peas	Brussels Sprouts
Lettuce	Sweet potatoes	Cabbage
Peas		Kale
Potato		Tomatoes
Onion		
Spinach		

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   9

3.1.2 Day length

Day length is the period of time in hours that the sun will be available during a day. Except in equatorial regions of Africa (such as parts of Kenya, Uganda, and others), during the cold season, the days tend to be shorter than nights while the reverse is true for the hot season. In the sub-tropics (e. g. parts of Zambia, Mozambique, Namibia, etc.), hours of sun availability per day in winter are much shorter and sunlight hours are among the highest in summer months.

Day length influences growth behaviour of some vegetable species. Vegetables that are naturally day length sensitive require a certain number of hours of

WATER DEMAND OF VEGETABLES

Water demand of selected vegetables

Examples of vegetables with low water demand (drought tolerant)	Examples of vegetables with high water demand
Bell peppers	Cabbage
Eggplant	Lettuce
Sweet potatoes	Broccoli
Mustard greens	Cauliflower
Peppers	Watercress
Okra	Celery
Swiss chard	Spinach
Squash	Kohlrabi
Water melons	Kale
Chickpea	Taro *(Colocasia esculenta)*
Lima bean	Garden pea
Amaranthus	Turnips
Tomato (many varieties)	Brussel sprouts
Artichoke	Collards (e.g. Sukuma in Swahili)

daylight before they can grow, flower, or produce fruit or other storage organs such as bulbs in onions and potatoes. Some species or varieties have been bred for moderate climates and long days and short-day conditions may cause early or premature flowering.

Other vegetables, e. g. tomatoes, okra, cucumbers, chillies, eggplants, etc. are not affected by short or long days during their growth and/or development. They are called day length-neutral plants. It is important for farmers to purchase vegetable varieties suited to their prevailing day length environments and for the time of year which they intend to grow them.

3.1.3 Water requirements

Sufficient water of good quality

Vegetables need sufficient water for proper growth. Besides rainwater, vegetables normally require additional water through hand watering or some other forms of irrigation. A vegetable garden should, therefore, be located close to a good and reliable water source (river, dam, lake, spring, well, borehole, etc.).

The quality of water used by organic farmers for irrigation is very important. Water quality also has a bearing on the types of crops that farmers can grow. Poor water quality can affect crop growth and yields, cause contamination in produce, and can affect soil physical and chemical conditions.

The quality of water also determines the way in which farmers should apply the water to fields, the performance of an irrigation system, and for how long an irrigation system (or components) can last. Heavy salts present in some water types can cause soil related problems over the long term, e. g. soil salinity through the build-up of salts applied with the irrigation water. If farmers know the quality of their water, they will be able to understand better the management changes that are necessary for sustainable irrigation.

For organic vegetable production, certain sources and/or types of water are prohibited, particularly for certified produce. Farmers should be aware of the following possible contaminants contained in irrigation water:

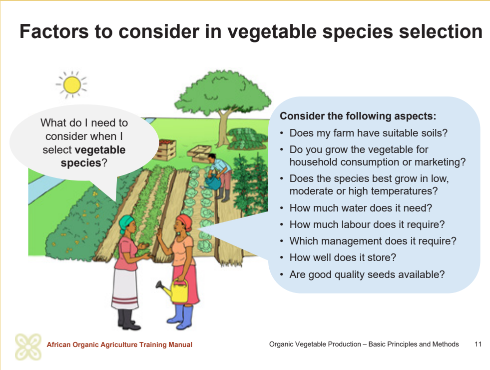
- Biological, e. g. harmful microorganisms in sewage water or water contaminated by sewage
- Agrochemicals such as herbicides, insecticides, fungicides, antibiotics, anthelmintics, acaricides, etc.

Discussion with the farmers

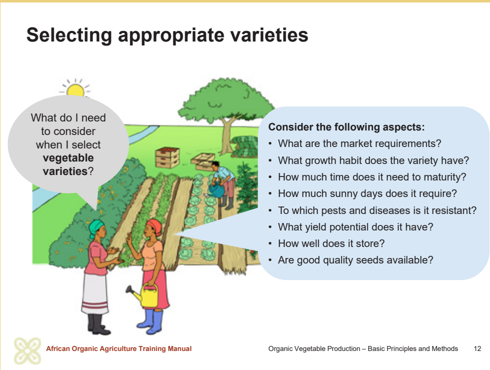
Discuss with the farmers the following questions:

- What do you know about the quality of water available for irrigation from different sources?
- What are your perceptions about the quality of water that you use?

VEGETABLE SPECIES SELECTION CRITERIA



VEGETABLE VARIETY SELECTION CRITERIA



- Heavy metals such as mercury, lead, arsenic from industrial pollution – some soils are naturally high in heavy metals like arsenic.
- Drugs, e.g. those used in medical treatment (then excreted through urine and human waste).

If in doubt, particularly for commercial certified organic production, farmers are encouraged to collect water samples and send them for quality analysis at an appropriate laboratory in order to make better-informed decisions. Possible ways to address water-quality related problems is to use biofilters and other types of filters. It is important that the producers consult with their certification agents or organic extension agents for expert advice.

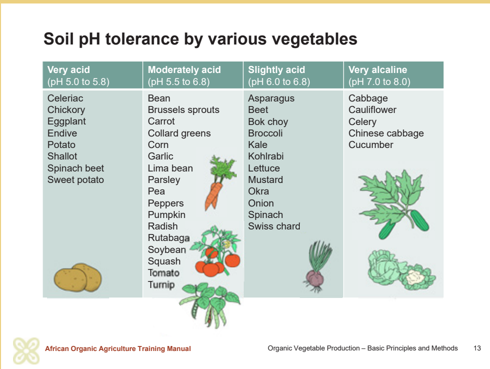
3.2 Vegetable species and varieties

Starting with a suitable crop and/or variety is one of the most important steps in organic production. Before farmers establish an organic vegetable garden or plot, they are encouraged to think about the type of crops to grow in relation to the prevailing growing conditions. This is very important, particularly in the case of commercial vegetable production in order to maximise returns and profits. Besides yield considerations, other factors to consider when selecting a type of crop to grow are:

Factor	Considerations
1. Purpose for producing the vegetables	The attributes, including quality aspects, to consider when producing vegetables for home consumption are less stringent compared to when a farmer is producing for the market. In the later, they adhere to certain minimum standards and consumer expectations, depending on the target market.
2. Disease and/or pest resistance	Vegetable varieties are adapted to different growing conditions and can also differ in their susceptibility to major diseases and/or pests. Before acquiring seed, farmers should be aware of these varietal differences so that they can select the varieties adapted to the prevailing growing conditions in their areas and also to suit their specific needs and choices.

3. Prevailing climatic conditions	**Warm season vegetables:** These require both warm soil and high temperatures for successful production. They grow best in areas with day temperatures ranging from about 21 to 35 °C, and are susceptible to frost damage. **Cool season vegetables:** These grow best in cooler areas, generally with temperatures ranging from about 15 to 26 °C. When grown in hot areas, they often become bitter tasting and can bolt to seed (premature flowering) rather than producing edible vegetative parts for longer periods. Cool season vegetables are classified as hardy or semi-hardy according to the extent to which they tolerate low temperatures and frost. Hardy cool season vegetables can still grow when daytime temperatures are as low as 4 °C and can withstand short spells of frost. The semi-hardy vegetable types are sensitive to frost damage. **Crop water requirements and tolerance to drought:** There is a variation in amount of water required by different vegetables for their optimum growth. Some vegetables require a lot of water to grow, while others can grow with a limited amount of water. For example, cabbage requires large amounts of water for successful growth compared to, e. g. garden peas or chick-peas.
4. Type of soil	Before growing vegetables, farmers are encouraged to consider soil conditions such as pH (the extent of acidity or alkalinity), clay content and drainage capacity, salinity, etc. as these will affect proper growth of the vegetables. Some of the soil conditions will need amendment before sowing or planting, for example applying lime to raise soil pH and decrease its acidity if vegetables that are sensitive to acidic conditions such as cabbage, cauliflower and celery are to be grown. Yet, some vegetables can tolerate significant levels of acidity, e. g. eggplants and Irish potatoes. More details are provided in subsequent sections.

SOIL PH TOLERANCE AMONG DIFFERENT TYPES OF VEGETABLES



Soil pH tolerance by various vegetables

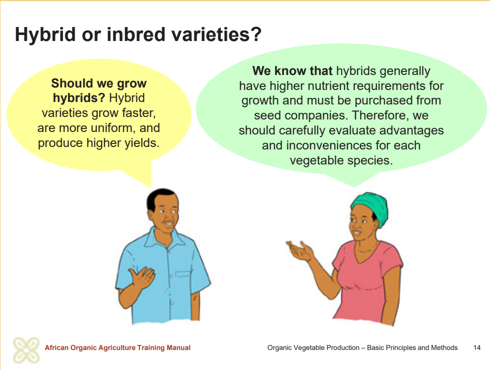
Very acid (pH 5.0 to 5.8)	Moderately acid (pH 5.5 to 6.8)	Slightly acid (pH 6.0 to 6.8)	Very alcaline (pH 7.0 to 8.0)
Celeriac Chickory Eggplant Endive Potato Shallot Spinach beet Sweet potato	Bean Brussels sprouts Carrot Collard greens Corn Garlic Lima bean Parsley Pea Peppers Pumpkin Radish Rutabaga Soybean Squash Tomato Turnip	Asparagus Beet Bok choy Broccoli Kale Kohlrabi Lettuce Mustard Okra Onion Spinach Swiss chard	Cabbage Cauliflower Celery Chinese cabbage Cucumber

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   13

5. Growth requirements / growth habit	Certain vegetables demand more care than others. For example, some farmers regard cauliflower as one of those types that are difficult to produce due to the extra care needed for successful production. Growth habit – farmers should think about the growth characteristics of crops as this affects management needs, space requirements and suitability for mixing or rotating with other crops. The bushy type of plants requires less space compared to the spreading types. On the other hand, the indeterminate growing types (e. g. some tomato and bean varieties) can provide harvest over a longer period and thus help farmers to extend food availability and income generation. Whether perennial (e. g. asparagus and rhubarb) or annual (e. g. most leafy vegetables) in relation to crop rotations and suitability for intercropping is also important to consider.
6. Growth duration	The growth duration is important as this affects management requirements and the ability to harvest early. For many crops, certain varieties grow and mature in less time while others take longer periods to mature (days to maturity). In cooler climates, vegetables generally take longer to grow and develop compared to warmer climates. The length of the harvesting period may also vary with different varieties. Some Amaranth varieties, for example, have a longer vegetative phase (period before flowering) and can therefore be harvested over longer periods than others thereby supplying more food to families.

7. Market expectations or require-ments and suitability	The target market dictates the types of produce required and their quantities, and timing, including peak demand seasons. Perishability of the vegetables in relation to location of the target markets; the distances to markets; availability and reliability of transport are also important factors to consider. For example, green beans are more perishable than dry beans while spinach is more susceptible to wilting than cabbage. Long distance transportation of highly perishable products can lead to huge losses unless if suitable conditions are pro-vided in transit.
8. Labour requirements and peak labour demands	Some vegetables require training during their growth, e. g. trellising tomatoes, and this can be cumbersome and labour demanding. Similarly, harvesting of french beans also de-mands a lot of time and labour. Farmers need to make good planning and forecasts to ensure that there is enough labour available at the peak labour demands for a specific crop, and that the peak labour demands do not overlap as this can cause logistical problems and labour shortages or bottle-necks.
9. Postharvest characteristics and nutritional content	Depending on the vegetable type, varieties may differ in their shelf life or the period that they can be stored at ambient temperatures without significant negative changes or losses to their quality. For instance, tomatoes that have a firmer texture and stronger skin can store for longer periods under normal room conditions than others. They are more easily transported to distant markets with less bruising and/or compression damage compared to those softer varieties. Va-rieties may also differ in their nutritive content, for example some amaranth varieties have higher nutritional contents than others.

SEED TYPES FOR SELECTED VEGETABLES



3.3 Vegetable seed and seed sources

Most vegetables are raised from seed although some, such as potatoes, are easier raised through vegetative methods. Seed for organic production is still quite scarce in most African countries. Farmers can produce their own seed where possible. It is important that farmers seek for information from their extension / advisory agents regarding availability of organic seed, or which seed to use particularly when growing for certified organic markets.

3.3.1 Methods of vegetable seed production

While some smallholder farmers retain their own seed for certain vegetables, others prefer to buy certified seed. The different types of seed are described in the next sections.

a) Hybrid seed

Many commercial vegetable species are grown from hybrid seed that is produced professionally under controlled breeding conditions by breeders. To produce hybrid seed, compatible types of plants (acting as the parent plants) are cross-bred to produce a plant that has desirable characteristics of both parents. Seed companies perform this task of carefully selecting seed, sometimes crossing and multiplying a number of varieties. Hybrid varieties are popular because they often grow faster, produce higher yields and more uniform leaf, fruit, bulb or root compared to inbred lines. They may also be resistant to important diseases. However, they are usually more expensive than non-hybrid ones and have higher management requirements, e.g. higher demands for nutrients and other resources during growth.

Note: Saving seed from a hybrid variety that cross-pollinates with other varieties may result in loss of quality after the first season. It is therefore important that, unlike inbred varieties, farmers avoid saving seed from hybrid varieties, as the risk of poor performance by the crop in subsequent seasons is high. Farmers are recommended to buy the hybrid seed from seed companies or their trusted outlets, e. g. local agro-dealer shops. There are cases, however, where farmers have successfully saved seed from hybrid varieties over short-term periods.

SUITABLE VEGETABLE CROPS FOR OWN SEED PRODUCTION

Suitable vegetable crops for own seed production

Self-pollinated vegetables	Cross-pollinated vegetables
Dwarf bean (*Phaseolus vulgaris*)	Amaranths species
Lentils (*Lens culinaris*)	Cucumber (*Cucumis sativus*)
Lettuce (*Lactuca sativa*)	Muskmelon (*Cucumis melo*)
Peas (*Pisum sativum*)	Pumpkin (*Cucurbita moschata*)
Peppers (*Capsicum species*)	Spinach (*Spinacea oleracea*)
Tomato (*Lycopersicon escul.*)	Squash (*Cucurbita pepo*)
	Watermelon (*Citrullus lanatus*)

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 15

MINIMUM RECOMMENDED NUMBER OF PLANTS

Minimum number of plants from which to collect seed

Selected vegetable species	Suggested minimum number of plants
Species not susceptible to inbreeding depression	
Beans, Cucumber, Lettuce, Melons, Peas, Peppers, Pumpkins, Tomatoes	1 plant (but more than 1 plant gives better results)
Species susceptible to inbreeding depression	
Brassicas	6 to 40 plants
Corn	100 plants
Onion	20 to 50 plants

Sources: *Ashworth, S. and Whealy, K. 2002; Deppe, C. 2000*

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 16

b) Inbred lines

An inbred vegetable variety is produced from vegetables that have flowers containing both male and female parts which are self-fertile, i.e. the male part can pollinate and fertilise a female part from the same flower. An inbred variety is a pure line and results from crossing two or more different varieties of the same species. Following this crossing, selections are made in subsequent self-pollinating generations. The offspring from repeated cycles of self-pollination are also called inbred lines. Inbred varieties will produce offspring with the same genetic makeup as the parent variety itself. This means that seed harvested from an inbred vegetable variety can be sown in subsequent seasons without loss of identity. However, care must be taken that they do not cross-pollinate with other varieties as this will result in loss of varietal identity of the inbred line.

c) Open pollinated seed

Under smallholder conditions, hybrids may not always be superior to inbred varieties and their seed may not always be available, or when available it can be very costly. Farmers can save seed from open pollinated varieties (OPVs). These are varieties which are pollinated by wind or insects. Open pollinated vegetable varieties are capable of producing seeds that will produce plants with characteristics similar to the parent plant.

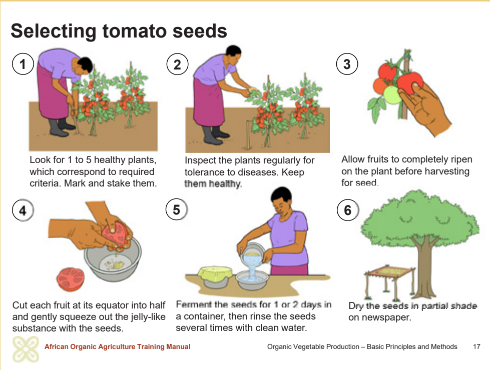
Whichever type of seed the farmers use, they are encouraged to use good quality ones. Provided other growing conditions are optimal, starting with good quality seed helps the farmers to avoid some problems such as seedborne diseases, poor germination and emergence, or poor growth.

3.3.2 Vegetable seed saving by smallholder farmers

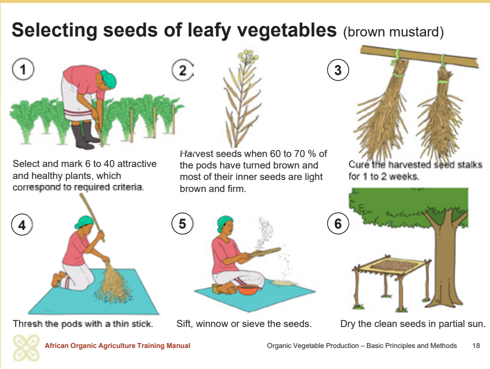
As already highlighted earlier, organic farmers may prefer to save their own seeds due to cost and availability reasons, adaptability, organoleptic qualities such as taste, colour, texture, smell/flavour, and other characteristics. It is important to remember that most vegetable seeds lose viability very quickly if they are harvested prematurely, harvested from diseased plants, poorly dried, or improperly stored after harvesting. Many factors need to be considered by farmers when selecting own seed.

Attribute	Considerations
Type of vegetable	In general, farmers can save seed from local varieties that have been grown in their areas for a long time. Also, seed of varieties of self-pollinating crops such as beans and peas can be saved successfully if care is taken.
Characteristic of the product	This pertains to whether the economic or useful part of the vegetable is a leaf, fruit, bulb, root, pod, flower, etc. The size, shape, colour and taste/flavour are also important considerations.
Time to harvesting the target products	› With **Leafy vegetables** such as kale where the aim is to have as many leaves as possible, farmers are encouraged to select seed from those plants that flower later as this allows a longer harvesting period. › **Fruit vegetables** such as tomatoes – the farmers can choose and/or combine early, medium and late flowering plants so that they can stagger the ripening period of their crop and take advantage of window-market periods. Choosing seed from the early flowering plants of good quality will allow farmers to advance their crop harvest and thus send produce to the markets with less competition from other growers. › **Bulb producing vegetables** such as onion – selecting seed from a commercial crop may encourage bolting (premature flowering) tendencies in the future crop. Bolting is undesirable in onion production as this compromises the quality of bulbs. This is also true for vegetables such as *Brassica juncea* which exhibit a bolting tendency when exposed to hot weather during growth resulting in failure to continue with formation of good leaves, the edible part.
Plant health	Regardless of the type of vegetable, farmers should select healthy plants and allow the seed to mature properly before harvest. Weak plants and those attacked by diseases and pests should not be selected for seed harvesting.

STEPS IN OWN SEED SELECTION: FRUIT VEGETABLE E.G. TOMATO



STEPS IN OWN SEED SELECTION: LEAFY VEGETABLE E.G. BRASSICA JUNCEA



Steps in seed selection

The number of plants from which farmers should select and collect seed varies from vegetable to vegetable. For those vegetables where identity and quality is lost from generation to generation require a large number of plants compared to those where quality is not easily lost. For example, farmers can successfully select seed from fewer bean and tomato plant numbers compared to brassicas.

Box 1: Vegetable seed saving by farmers: Steps in seed selection and harvesting

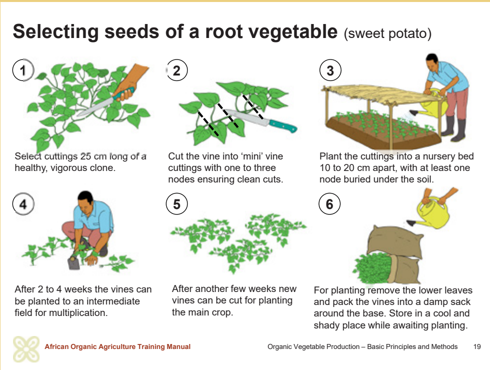
1. Consider the attributes or characteristics that are important for the particular crop on which plant selection for seed saving will be based (size of end-product, colour, shape, taste, tolerance to certain adversities, keeping quality, etc.) as already discussed earlier.
2. Ensure that the target vegetable crop is growing under optimal conditions of temperature, water, soil nutrients and day length with good pest and disease management.
3. Select and mark healthy growing plants during the vegetative stage and observe these until flowering and seed formation. Farmers must not use seed from one plant only; they should collect seed from several plants.
4. For cross-pollinating species, farmers must observe minimum distances, or set up barriers, between the plots where they want to harvest seed and plots with other varieties of the same species.
5. Maintain good plant health during growth – farmers ought to control for pests and diseases and avoid collecting seed from plants that have fallen over to the ground as they pose a high risk of contamination by soil borne pathogens.
6. Harvesting: Regardless of the crop, it is always best for farmers to harvest the seed when it is mature. Brassicas, for example, are susceptible to shattering when the pods are dry and it is best to harvest seed when about 70% of the pods have turned brown and the inner seed is light brown in colour. To harvest seed from vegetables that produce pods and are prone to cracking/bursting open or splitting on impact like beans and brassicas (also known as dehiscent types), the stem holding the seed capsules is cut off and the harvested parts maybe dried further before threshing. After

Discussion on seed selection

Invite the farmers to discuss about the following:

- Their experience with growing hybrid and inbred varieties of vegetables and how they select and or process seed.
- Varietal differences and basis for selecting plants to collect seed from depending on choices and prevailing growing conditions:
  - Climatic adaptation
  - Days to maturity and/or length of harvesting period
  - Yields
  - Disease and/or pest resistance and/or physiological disorders
  - Nutritional contents
  - Shelf life and requirements for transportation to markets
  - Crop water requirement

STEPS IN OWN SEED SELECTION: ROOT VEGETABLE E.G. SWEET POTATO



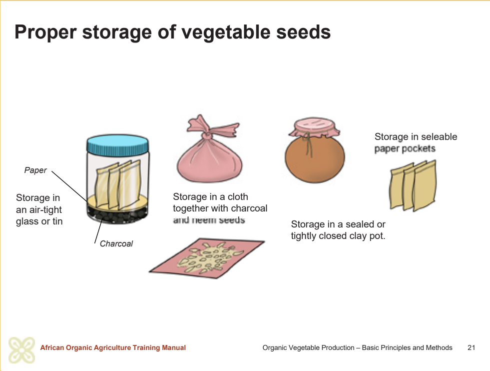
STEPS IN OWN SEED SELECTION: SEED VEGETABLE E.G. BEANS

threshing, seed is cleaned by winnowing to remove chaff/trash/impurities and the weak seed while the remaining healthy seed is further dried to the appropriate moisture content before storage. A seed moisture meter can help farmers to test the moisture content of their seed and decide whether to proceed with storage or to continue drying the seed. However, in the absence of a moisture meter, many farmers use their experience to determine when the seeds have dried enough.

7. Extraction, cleaning and drying: For fleshy vegetables like tomatoes and cucurbits, seed is best extracted from fully ripe fruits. In the case of tomatoes, the fully ripe fruit is cut open or cracked and the seed is either gently squeezed or scrapped out. The seed comes out with a gelatinous or slimy substance. This gelatinous substance can inhibit seed germination and, for good results, it must be removed from the seed. To clean the tomato seed of this substances, farmers can mix the seed with water and ferment in a warm place for a few days. When left standing for a few days and stirred daily, a fungal layer develops on top of the seed/water mixture. The fungus feeds on the gelatinous coating on the seed thereby cleaning out the seed. The fungus is also reported to produce natural antibiotics that help to control seed-borne diseases such as bacterial spot and canker. After a few days, the fermented seed is cleaned out by filling up the container with water several times and decanting all the pulp and weak seed that floats in the water. The seed is now ready for drying. For any seed, drying under shade is better but sun drying can also be done as long as temperatures do not exceed 37 °C.
   After cleaning and drying, if available the farmers can sieve the seed using appropriate mesh sizes to sort the seed into different sizes. With or without sorting by size, seeds that are of a different colour, shape or look infected with any disease or are shrunken must be removed and discarded. The remaining seed is ready for packaging.
8. Farmers can package the good seed into new or clean bags/containers and label the name of the variety and date of harvest or storage with a pencil or a bold marker on the bag. Placing another label inside the container can help in case the label on the outside becomes erased. For farmers to know the quality of their seed, they are encouraged to conduct a germination test.

Discussion on seed selection (continued)
Invite the farmers to discuss about the other types of planting materials they use such as cuttings, cloves, tubers, bulbs, etc.
- What are their advantages and disadvantages?
- How do the farmers ensure that the planting materials is clean and healthy before planting?

STORAGE OF VEGETABLE SEED



VEGETABLE SEED STORAGE PERIODS

Indicative seed storage periods for selected vegetables

Short duration (1 to 2 years)	Medium duration (3 to 4 years)	Long storage duration (5 years)
Lettuce	Beans	Cabbage
Okra	Cabbage	Cucumber
Onion	Pea	Egg plant
Parsley	Pumpkin	Musk melon
Sweet corn	Tomato	Spinach

The storage periods apply to well-dried seeds stored in dry places and at optimum temperatures (with about 8 % moisture content) stored in dry places (around 15 % RH) and low temperatures of about 4.5 °C)

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 22

When a thresher is used to process seed, caution must be taken to clean the thresher and remove any seeds remaining in the machine before threshing seeds of other varieties of the same or a different crop.

For more details refer to the following publication: Sukprakarn, S., S. Juntakool, R. Huang, and T. Kalb. 2005. Saving your own vegetable seeds – a guide for farmers. AVRDC publication number 05-647. AVRDC – The World Vegetable Center, Shanhua, Taiwan.

For further information on own-seed selection, the farmers are encouraged to consult with their local extension services so that they get help in selecting good quality seed.

Storage of vegetable seed

Seed storage is an important step in ensuring a good vegetable crop. Only fully matured dried seed of good quality should be stored. Poor seed storage can severely reduce seed viability leading to huge losses to the farmer especially in the case of commercial vegetable production. Regardless of the source (purchased or selected from own crop) of seed, when storing the seed farmers must ensure that seed is protected from:

i) moisture/water or damp conditions – dry seeds can reabsorb moisture easily, hence airtight containers need to be used to maintain seed dryness. Farmers can also add moisture absorbing materials such as dry wood ash, dry charcoal or small pieces of newspaper. The drying material should not take up more than 25 % (or a quarter) of the container space.
ii) direct sun and high temperatures
iii) insect pests and animals like rodents, chickens, etc.
iv) contamination by disease causing organisms

Protecting seed from the above elements will help to maintain quality and reduce loss of their viability. Farmers are highly discouraged from keeping any newly harvested seeds in a plastic bag as the seed is likely to rot due to the high moisture content of the seed and other factors.

Activity: Step by step seed selection with farmers

This exercise can be done with different groups of farmers to allow them to work on different vegetable types so that at the end they can share their experiences and discuss the differences among the different vegetables. The following procedures can be followed:

- Step 1: Determine types of vegetables to be grown and the timing
- Step 2: Determine seed quantities: Discuss about the seed requirements for the farmers to determine how much seed will be required.
- Step 3: Choose about 3 to 5 members for each seed collection group
- Step 4: For each type of vegetable, prepare a schedule indicating the following:
  a. Quality criteria to be used
  b. Stages for key operations in selecting the seed

Appropriate storage containers

Dry seed is best stored in airtight jars or cans, but the following materials can also be used: clean cloth bags, foil or manila envelopes, or suitable plastic containers.

Seed protection from pests

Traditionally farmers use local methods of protecting stored seed. If the risk of pest damage is high during storage, the seed can be stored with organic insect repellents such as garlic powder or with some abrasive materials such as ashes. In the case of beans, wood ash is mixed with the seed to protect them from weevil damage as the ashes make it difficult for the adults and larvae from moving around in the seed lot. The ashes can also cause physical damage to the pests. Other traditional ways include the use of *Tagetes minuta* branches, neem leaves or guava and gumtree *(Eucalyptus)* branches to deter away some storage insects. It is always a good practice by farmers to try out different techniques and choose what works best for them and their context.

Box 2: Organic ways of protecting seed during storage

The following is a list of products or techniques reported to be used by some farmers to store their seed. However, certified organic farmers are encouraged to consult with their certifying agents regarding use of these materials in storing their seed.

- Wood ash
- *Lantana camara* leaf powder
- Tephrosia leaf powder
- Neem leaf powder
- *Euphorbia ingens* ash
- Mopane tree *(Colophospermum mopane)* leaves
- Eucalyptus (gumtree) leaves (well dried)
- *Tagetes minuta*
- Garlic powder

Other strategies:

- Storing beans with sand/dust
- Storing beans and kale seed in their pods instead of storing threshed seed

Activity (continued)

c. Seed collection process, processing methods, drying, pre-storage treatments, storage containers and places

- Step 4: Undertake the activities planned according to the schedule above
- Step 5: Support the different seed collection groups to carry out a review of their seed collection procedure. The farmers can make any necessary modifications to the seed collection plans based on arising needs and situations.
- Step 6: Design any follow-up activities on own-seed selections by the farmers

- Storing maize on the cob above a regular source of smoke, e.g. in a fire cooking place
- The farmers can also apply other materials or methods which are commonly used in their areas.

Before storing the seed, it is wise for farmers to test for the viability of their seed as explained in later sections to the manual. The storage containers should be labelled with information indicating the following:

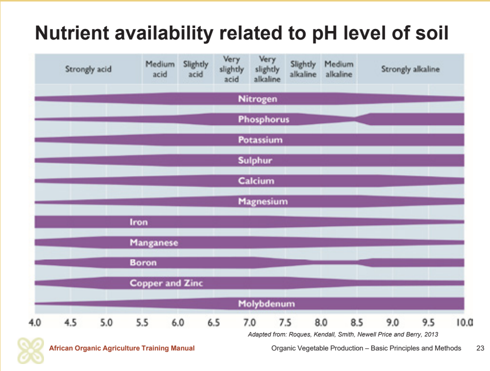
- Name or type of seeds
- Source
- Date of collection
- Germination % (if known)
- Date of storage

Seed storage periods

Not all seed types store for similar periods of time. Some seed can naturally store longer than others as long as storage conditions are optimal. However, under most smallholder farming the storage conditions are not as ideal as those used by professional or commercial seed producers. The storage periods of most seed among the smallholder farmers are therefore likely to be much shorter than those suggested in literature under controlled storage..

Note: Before using the stored seed, it is recommended that a germination test be done to establish viability levels and determine the seeding rates. Similarly, if the seed is known to possess dormancy, it must be treated to break this dormancy before sowing in order to trigger it into germination processes. The dormancy can be due to a hard seed coat (natural protective material for the seed), some natural chemicals within the seed which prevent the seed from germinating unless they are leached out, or it can be that the seed needs to be exposed to a certain temperature regime to stimulate it into germination.

NUTRIENT AVAILABILITY AT DIFFERENT PH LEVELS



3.4 Good soil fertility and good plant nutrition

3.4.1 Favourable soil pH

Soil pH indicates the level of acidity or alkalinity of a soil and is measured on a scale of 1 (extremely acidic) to 14 (extremely alkaline) with 7 being neutral. The pH of soils determines to some extent the availability of soil nutrients for crop uptake. Most vegetables do well in soils with a pH between 5.5 and 7.5, but the optimum is considered to be between 6 and 7. When soils are too acid (low pH) or too alkaline (high pH), certain nutrients become unavailable to the plants even if they are added to the soil in adequate amounts. Consequently, crops may grow poorly and show nutrient deficiencies despite adequate levels of the particular nutrients in the soil. Some nutrients are highly sensitive to soil pH than others. For example, volatilisation (loss as a gaseous form) of nitrogen from ammonium fertilizer used under conventional production can be worsened by high soil pH. Soil pH also affects the activity of soil microorganisms and the nitrogen nutrition of legumes. Rhizobium (the bacteria responsible for fixing nitrogen in legume roots) survival and activity is reported to decrease with increasing soil acidity (i.e. when pH decreases). As a result, legumes will fail to fix adequate amounts of atmospheric nitrogen into the soil under acidic soil conditions.

Knowledge of soil pH helps farmers to develop appropriate actions to reduce the negative effects of soil acidity or alkalinity on vegetable growth, development and yields. Farmers can use simple pH testing kits or send soil samples to an appropriate soil-testing laboratory for analysis.

High soil acidity can be corrected using lime and this can help to improve availability of nutrients which are normally unavailable under acidic conditions. Soil organic matter is very important for soil fertility because it balances soil pH and nutrients in the soil. Soil organic matter, or humus, is best improved through application of good quality compost, well decomposed animal or general farmyard manure, or plant residues to the soil. Adding wood ash to the soil can help to reduce soil acidity and raise soil pH.

IDENTIFYING VEGETABLE NUTRIENT DISORDERS (1)

Identifying common vegetable nutrient disorders (1)

The descriptions are indicative only. Proper diagnosis will be required before any corrective measures are taken.

Symptoms	General plant growth characteristics	General leaf characteristics	Nutrient likely to be deficient	Occurrence
Symptoms first appearing in old leaves	Growth upright and more spindly than normal	Leaves mottled, curling inwards with puffing and marginal scorching. Young leaves distorted.	**Molybdenum**	On very acidic soils
		Leaves fading to yellow green, often dying back from tips or being shed. Stems slender, fibrous	**Nitrogen**	Excessive leaching on light soils
		Leaves darker green than normal, developing reddish purple tints especially on the undersides. Stems slender and fibrous.	**Phosphorus**	On acidic soils, temporary deficiencies on cold wet soils
	Growth of normal habit or droopy	Leaves an unnatural green, usually darker or blue. Leaf margins bronzing or purpling, scorching and leaves cupping upwards. Stems slender and woody.	**Potassium**	Excessive leaching on light soils
		Leaves white or yellow mottled. Leaf margins may show marginal scorch. Leaves brittle.	**Magnesium**	On acid soils, on soils with very high potassium levels, or on very light soils subject to leaching.
		Leaves droopy and very pale or whitened.	**Copper**	Most cases of copper deficiency occur on muck or peat soils

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 24

IDENTIFYING VEGETABLE NUTRIENT DISORDERS (2)

Identifying common vegetable nutrient disorders (2)

Symptoms	General plant growth characteristics	General leaf characteristics	Nutrient likely to be deficient	Occurrence
Symptoms first appearing in old leaves	Growth upright and more spindly than normal	Leaves mottled, curling inwards with puffing and marginal scorching. Young leaves distorted.	**Molybdenum**	On very acidic soils
Symptoms first appearing on young leaves	Growth deformed or collapsing	Young leaves collapse and die.	**Calcium**	On acid soils, following leaching rains, on soils with very high potassium levels, or on very dry soils
		Young leaves deformed with spots, often brown. Petioles brilliant, often with splits.	**Boron**	On soils with a pH above 6.8 or on crops with a high boron requirements such as broccoli, carrot, cauliflower
	Growth not deformed but often spindly	Young leaves mottled, becoming pale yellow but not dying.	**Iron**	On soils with a pH above 6.8
		Young leaves mottled and developing dead areas.	**Manganese**	On soils with a pH above 6.7

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 25

Source:

3.4.2 Good soil physical properties

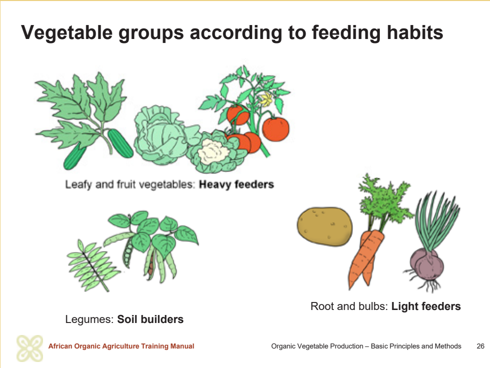
Vegetables can be grown on a wide range of soil types, but best are light to medium loams with good drainage and good amounts of organic matter. Lighter soils can also be used, but they need higher amounts of compost or manure and more intensive watering to keep the optimum moisture balances in the soil. Most vegetable roots reach about 30 to 40 cm depth, so the upper soil layers should be light and without any hard pans so as to encourage good root growth. Although leafy and fruit vegetables can tolerate slightly heavy soils such as sand clay loams, root and tuber vegetables like potatoes, onions and carrots grow better in lighter soils as these encourage formation of good quality bulbs and tubers.

3.4.3 Nutrient requirements of different vegetables

A fertile soil is the basis for a sufficient and well-balanced nutrition of vegetable plants. A fertile and biologically active soil feeds the vegetable plants indirectly through its active microbial populations, which mobilise and mineralise nutrients out of the soil and make them available to the growing plants. Most vegetables require nitrogen (N), phosphorus (P) and potassium (K) in high amounts while other nutrients such as iron, copper, manganese and zinc are required in smaller or micro amounts. Where possible, and particularly for the production of large volumes of vegetables for sale, it is advisable that farmers get recommendations on the nutrient requirements based on a soil test. The reason is that adding excess amounts of nutrients than required can cause imbalances of nutrients in the soil and plants, and can also cause deficiencies of other nutrients in plants. Such imbalances affect plant growth and development, can be costly to the farmer and can also result in environmental problems including underground water pollution. Enhancing general soil fertility with all possible measures is therefore of high importance.

Note: Certain crops perform poorly in soils containing high amounts of organic matter, for example sweet potatoes may develop rough or irregular roots/tubers in soils that have excessive organic matter amounts. Leguminous crops and tomatoes grown in soils with excessive amounts of nitrogen produce more of vegetative parts at the expense of pods and fruits.

VEGETABLE GROUPING ACCORDING TO FEEDING HABITS



VEGETABLE FAMILIES AND THEIR FEEDING HABITS

Examples of vegetable families and feeding habits

Feeding habits	Vegetable group	Example of crops
Light feeders	Allium	Onion, leeks, shallots, garlic
	Legume	Beans, peas
	Amaranthaceae	Amaranth
	Mallow (*Malvaceae*)	Okra, Jute mallow
Moderate feeders	Umbellifers	Carrots, fennel, celery, parsley
Heavy feeders	Chenopods	Spinach, beets, Swiss chard
	Composites	Lettuce, artichokes
	Crucifers	Cabbage, cauliflower, kale, broccoli, Brussels sprouts, mustard
	Curcubits	Pumpkins, melons, squashes, cucumbers
	Gramineae	Maize, wheat
	Solanaceaes	Tomato, potato, peppers, eggplant
	Asparagaceae	Asparagus

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 27

Classification of vegetables based on nutrient uptake

Different types of vegetables require different amounts of nutrients for successful growth. Some vegetables are heavy feeders and require more nutrients and water for growth than others. If farmers face challenges in obtaining adequate organic sources of nutrients then they can grow moderate or light feeding vegetables such as carrots, onions, herbs or legumes like beans, peas and others. Those with good soil fertility can grow heavy feeding vegetables as well.

1. **Heavy feeders:** These vegetables require a lot of fresh rich fertiliser (well decomposed compost, reasonably aged manure and liquid manure, etc.) and can be planted immediately into a fertilised soil. They include: all leafy vegetables like head lettuce, spinach; brassicas such as cabbage and cauliflower; chard; endive; celery; leeks; sweet corn and vines particularly cucumbers and squash; and others. Rhubarb is a heavy feeding perennial root crop, and this needs to be taken into consideration when planning crop rotations.
2. **Soil conserving and improving plants:** Legumes such as peas and beans, and cover crops, often called fallow crops, are ideal to follow heavy feeders as they help the soil to regain some of its fertility, especially nitrogen. These plants give the soil a bit of a rest, as well as returning some nitrogen and fibre to the soil when they are incorporated into the ground by way of mulch (green or dead) or compost before the next crop.
3. **Lighter feeders:** They still require compost, but it must not be fresh as this will result in excessively lush growth. Well-aged compost suits such plants as all bulb and root crops like carrots, radishes, beets, parsley (a long tap rooted plant) and many herbs.

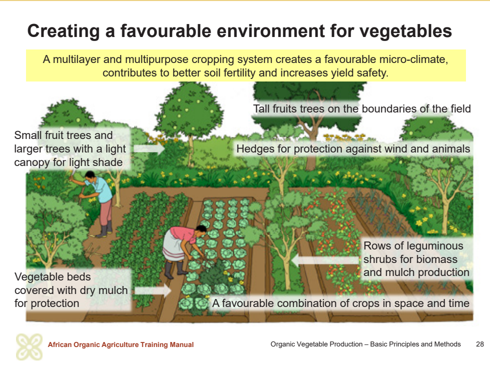
Sources of nutrients in vegetable production

Farmers starting a commercial organic vegetable production enterprise should carefully consider the sources of nutrients for their crop. With or without livestock ownership, farmers engaging in organic market gardening are encouraged to intensify the fertility of their soils by integrating compost (from plant residues and / or animal manures) and green manures. Green manures, therefore, form an important component of the crop rotations on a farm. Farmers can obtain animal manures from the farm's own sources, or procure from external sources (off-farm).

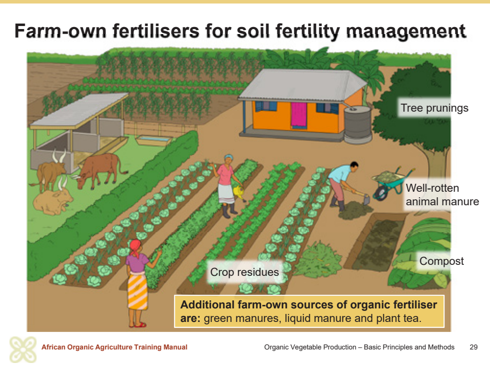
Discussion on nutrient sources

Determine with the farmers sources of organic material in the farm that can be used for making compost.
Are the quantities and qualities of the materials suitable for making compost?
Discuss also the farmers' experience with the use of different sources of nutrients and their management.

A FAVOURABLE GROWING ENVIRONMENT



SOIL FERTILITY MANAGEMENT SHOWING ORGANIC SOURCES



The options available depend on whether the farmer owns livestock (or has access to animal manure from other sources) or not. Either way, the farmer has to upgrade their soil nutrient management practices for successful vegetable production. The sources of nutrients are discussed below for the two scenarios.

i) A farm with no animals (or with just a few animals)

Under this situation, the possible sources of nutrients will include:

a) The soil itself – if the soil is inherently fertile and not depleted of nutrients
b) Green manures grown on the farm as short-term crops, or perennial herbaceous plants and shrubs or trees
c) Some legume crops – most can fix atmospheric nitrogen into the soil
d) Compost made on the farm from plant residues
e) Off-farm sources of manures e. g. from industrial waste (e. g. coffee residues, rice husks, neem cake, brewing resides, slaughterhouse wastes, etc.), animal manure from external livestock owners, etc.
f) Mineral fertilisers, lime and others permitted for use in organic production
g) Anthill soil spread into the fields to add significant amounts of nutrients

ii) A farm with livestock

Under this situation, the possible sources of nutrients will include:

a) The soil itself – if the soil is inherently fertile and not depleted of nutrients
b) Composted animal manure with or without green manures and crop / plant residues
c) Green manures grown on the farm and applied to the soil either directly (soil incorporation of green manures) or indirectly when the green manures are first fed to the livestock and the resultant manure applied to the vegetable plots.
d) Some legume crops – most can fix atmospheric nitrogen into the soil
e) Mineral fertilisers and others permitted for use in organic production
f) Anthill soil spread into the fields to add significant amounts of nutrients

Note
For further information on how to make compost or grow and use green manures and cover crops see the Module on Soil Fertility Management of the African Organic Agriculture Training Manual.

Farmers should consider having different types of livestock, i.e. small and/or large livestock. Small livestock manure are a good source of nitrogen and phosphorus. Crops and livestock should be integrated in such a way that promotes synergies and minimise conflicts – the livestock feed on crop residues or green manures and can control weeds in some plantation crops while the crops benefit from livestock manure, and other benefits.

Description of the various sources of nutrients

The five main sources of nutrients for feeding vegetable plants are discussed in more detail as follows:

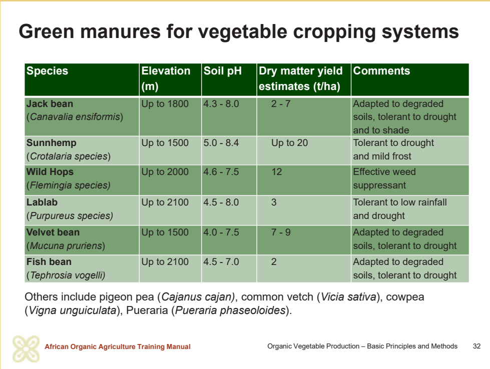
Source	Description
The soil itself	It is important to create good conditions for the mineralisation of organic nitrogen and the mobilisation of different nutrients that are naturally present in the soil. A high content of organic matter, including humus, in the soil is a good precondition for successful vegetable production. As such, soils are able to mineralise high quantities of nitrogen out of the humus, if they contain enough moisture to facilitate the process of releasing these nutrients. Thus, all measures enhancing the humus content and the biological activity in soils are very important for the fertilization of crops like tomato, pepper, eggplants, cabbages and carrots with a long growing period.
Compost	The most important role of compost is improving the humus content of the soil. Compost could be a good source of nutrients like calcium, potassium, phosphorous, magnesium nitrogen. Only well decomposed compost should be used in vegetable production. In the field, compost is applied locally either in the planting rows, planting holes or if available in sufficient quantities on the whole surface of the field before soil preparation prior to planting or sowing. An annual amount of 2 to 4 kg compost per m^2 is commonly recommended.

COMPOST PRODUCTION

LIQUID FERTILISER PRODUCTION

	a. **Compost from farmyard manures:** Farm yard manure can be applied to fields when it is fully rotten, composted or as 'liquid manure/slurry', and contribute considerably to the nitrogen supply of vegetable crops. Combined with a previous leguminous green manure, a basal dressing with compost and a topdressing with plant/manure extracts, it can meet the nutrient requirements of high nutrient demanding crops. Farm yard manure is best applied by spreading it over the soil surface and incorporate it into the soil superficially together with green manure. As a top dressing, farm yard manure is better for longer-duration vegetables like tomato, eggplant, and pepper. For the vegetable nursery, liquid manure and plant tea are suitable fertilisers. b. **Compost from plant residues:** Plant residues should be retained in the field, especially if there are no competing needs such as livestock feeding. Farmers are, therefore, encouraged to not burn any residues unless if this is demanded by law (e.g. destroying noxious weeds and serious pest or diseases). The residues can be incorporated directly into the soil (but allowed to rot before planting a crop) or added to a compost heap to facilitate decomposition before use. c. **Compost from animal manures:** Different types of livestock produce manures of different quality. In general, poultry manure contains higher amounts of N than cattle and other manures, hence is not suitable for crops that are sensitive to high nitrogen levels such as legumes.
Green manures	Green manures are grown for their high biomass production to feed the soil and their capacity to fix atmospheric nitrogen into the soil. Green manures are generally recommended before planting high nutrient demanding vegetables. They are ideally cut before flowering, when the plant has produced the highest biomass and accumulated the highest amount of nutrients. At this stage the plant will decompose easily, when incorporated into the soil. However, sometimes farmers prefer to wait for the plants to flower so that they can harvest seed before incorporating them.

EXAMPLES OF GREEN MANURES



Green manures for vegetable cropping systems

Species	Elevation (m)	Soil pH	Dry matter yield estimates (t/ha)	Comments
Jack bean (*Canavalia ensiformis*)	Up to 1800	4.3 - 8.0	2 - 7	Adapted to degraded soils, tolerant to drought and to shade
Sunnhemp (*Crotalaria species*)	Up to 1500	5.0 - 8.4	Up to 20	Tolerant to drought and mild frost
Wild Hops (*Flemingia species*)	Up to 2000	4.6 - 7.5	12	Effective weed suppressant
Lablab (*Purpureus species*)	Up to 2100	4.5 - 8.0	3	Tolerant to low rainfall and drought
Velvet bean (*Mucuna pruriens*)	Up to 1500	4.0 - 7.5	7 - 9	Adapted to degraded soils, tolerant to drought
Fish bean (*Tephrosia vogelli*)	Up to 2100	4.5 - 7.0	2	Adapted to degraded soils, tolerant to drought

Others include pigeon pea (*Cajanus cajan*), common vetch (*Vicia sativa*), cowpea (*Vigna unguiculata*), Pueraria (*Pueraria phaseoloides*).

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 32

To balance between the soil nutrient requirements and seed production, farmers can set aside part of the green manure plants to grow to maturity and set seed while the other part is used timely for the purpose of soil fertility enhancement.

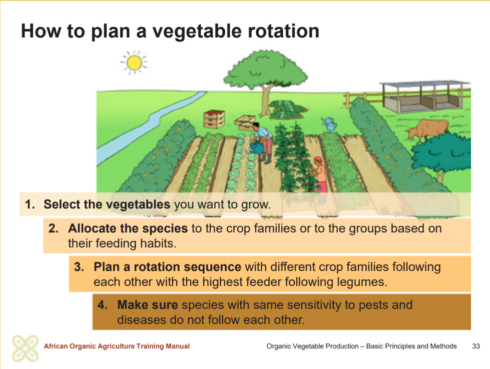
Under favourable conditions the nutrients from an incorporated green manure are made available to the following crop within a few weeks as the plants decompose.

Alternatively, the green material can be used as mulch, for making plant tea extracts, or for composting.

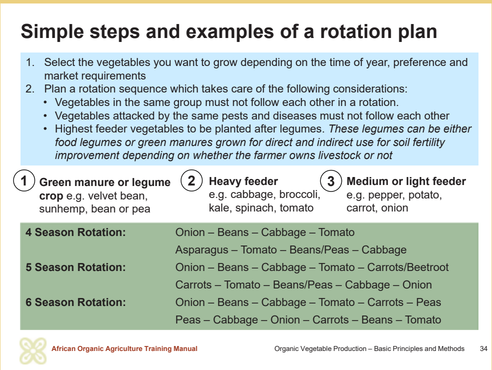
In vegetable growing, every time interval between crops of more than 6 to 8 weeks should be used for cultivation of suitable green manures. If at all possible, there should be living roots in the soil the whole year round. The living roots help to sustain microbial life in the soil and overall fertility. For a successful green manure, it is important that sufficient water is available for good establishment and growth of the green manure. More drought resistant green manures like the butterfly pea *(Clitoria ternatea*), centro *(Centrosema pubescens)*, cow pea *(Vigna unguiculata)*, jack bean *(Canavalia ensiformis)*, velvet bean *(Mucuna pruriens)* pigeon pea *(Cajanus cajan)* or sunhemp *(Crotalaria junca)* can also be grown. However, the chosen green manure should not be related to the previous or following crop to avoid the build-up of pest and disease populations. In frost prone areas, frost tolerant green manure crops must be selected if they are to be grown during the winter season.

Shrubs and trees that fix nitrogen and can provide prunnings to feed the soil directly or through livestock manure (after they feed on the prunnings or browse) can be beneficial. Examples include *Sesbania* species, *Acacia* species, *Leucaena* species, *Calliandra* species, *Gliricidia*, *Moringa*, pigeon pea and many others.

PLANNING A VEGETABLE ROTATION



STEPS TO AND EXAMPLES OF A ROTATION PLAN



Commercial organic and mineral fertilisers	Crop and food processing residues like malt (from beer breweries), oil cakes of neem, cotton or castor, waste from slaughter houses, or other off-farm organic sources may also be used, if available at low or no cost. Such organic materials should be mixed with other organic sources and composted prior to their use in vegetables. Care should be made to not use contaminated sources of these materials. Permitted commercial mineral fertilisers may be used in case of deficiencies. In organic agriculture, synthetic fertilisers are not permitted for use, but naturally occurring ones like phosphate rock are permitted. Farmers should always check with the organic extension advisors for suitable options.

Legume crops generally can produce most of the nitrogen that they need with the help of rhizobium bacteria that are associated with their roots and fix nitrogen from the air. Therefore, beans and peas for example, have a much lower need of nitrogen than non-legume vegetable crops like cabbage. The most important sources of potassium and phosphorous in organic vegetable production are farmyard manures, compost, crop residues, and mined rock phosphate. The use of ash from wood fires can also significantly contribute to potassium and calcium supply.

3.5 Crop rotations and intercropping

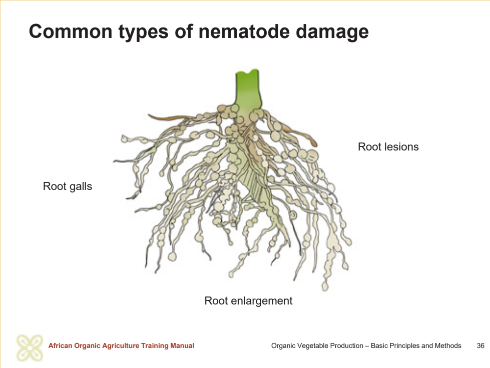
Crop rotations and mixes in various patterns are an important practice in organic farming. Long-term monocropping (using one type of crop continuously) is highly discouraged in vegetable production. For successful and sustainable vegetable production, farmers are encouraged to mix and rotate crops in their fields and derive many benefits. Crop rotation refers to the practice of growing a series of different or unrelated crops in the same area in sequence over seasons. This means that farmers grow specific groups of vegetables on a different part of their vegetable fields/plots every season or year. Intercropping refers to the practice of growing two or more compatible crops simultaneously (at the same time) on the same field or plot.

Sharing of experiences on crop diversification

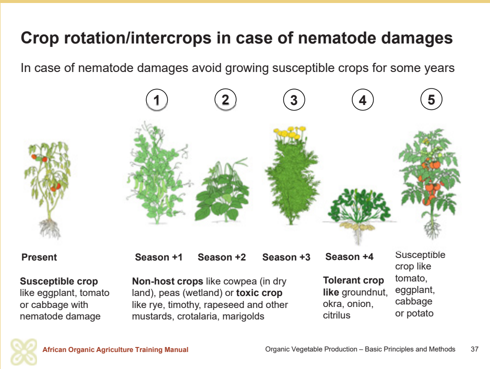
Invite the farmers to share their knowledge on crop diversification and local practices (including crop rotation, intercropping, companion planting, and trap cropping). Consider also the following issues:

- Types of crops grown
- Considerations made for mixing and rotating crops
- Experiences on the compatibility of plants to grow together
- Problems faced in practicing rotations and intercropping

GALLS AND LESIONS CAUSED BY NEMATODES



CROP ROTATION FOR NEMATODE CONTROL



3.5.1 Planning a vegetable crop rotation:

A well-planned rotation of crops contributes to fertility and health of the soil as well as plant and human health.

Reasons for planning a good crop rotation

i) **Ensuring efficient use of available soil nutrients and contribute to nutrient replenishment into the soil.** When legumes fix atmospheric nitrogen into the soil, they help to make it available to other crops that cannot fix this element. Certain crops, e.g. cabbage, sweetcorn, and tomatoes, have high requirements for the major nutrients (N, P, K) (they are heavy feeders) and they will benefit from the added nitrogen if grown after legumes. Legumes could also be planted after heavy feeders to replenish the soil before a next crop is planted.

ii) **Preventing or reducing development of soil-borne diseases and nematodes.** Mixed cropping or intercropping of two or more vegetables or plants delays the spread of pests and diseases. Rotations disrupt pest and disease cycles hence help to reduce their incidences. Crops in the same family should never follow each other in the rotation or intercropped on any given vegetable field to avoid the spread and multiplication of pests and disease-causing organisms.

iii) **Efficient utilisation of space and other production resources.** Many crops complement each other in terms of space occupation, e.g. bushy or short plants can be grown with tall plants provided they can tolerate some level of shading.

iv) Both crop rotation and intercropping are very important measures to grow vegetables successfully. Growing two or more plants or vegetables together can result in other benefits such as:
- Attraction of beneficial organisms like predator insects for biological control
- Repelling insect pests or diseases (under moderate attack)
- Promoting more vigorous plant growth
- Recycling nutrients from deep soil layers when deep-rooted plants are included in the rotation. Additionally, the deep roots can help to improve soil aeration and hence increase water penetration and uptake during rainfall events or irrigation.

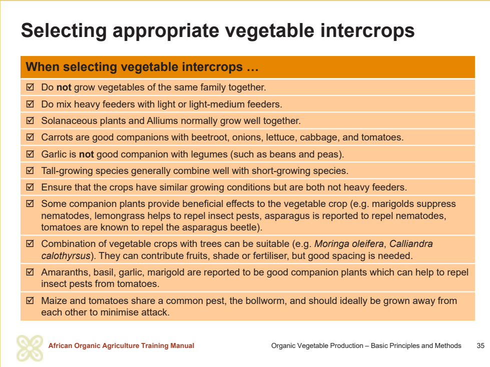
Discussion on nematode problems

Ask the following questions to the farmers:
› Do you know how to identify nematode problems?
› How have you controlled them?
› Have you tried out growing non-host crops or green manures in rotations or intercrops to reduce nematodes?

Identifying nematode problems

Carry out the following exercise with the farmers using mono-cropped and intercropped fields.
1. Identify weak tomato or potato plants with signs of unexpected wilting
2. Dig out a few plants with the roots.
3. If galls are observed on the roots, these are likely to be nematode galls. Nitrogen fixing nodules are normally pink in colour inside.

FACTORS TO CONSIDER IN VEGETABLE INTERCROP SELECTION



Selecting appropriate vegetable intercrops

When selecting vegetable intercrops …

- ☑ Do **not** grow vegetables of the same family together.
- ☑ Do mix heavy feeders with light or light-medium feeders.
- ☑ Solanaceous plants and Alliums normally grow well together.
- ☑ Carrots are good companions with beetroot, onions, lettuce, cabbage, and tomatoes.
- ☑ Garlic is **not** good companion with legumes (such as beans and peas).
- ☑ Tall-growing species generally combine well with short-growing species.
- ☑ Ensure that the crops have similar growing conditions but are both not heavy feeders.
- ☑ Some companion plants provide beneficial effects to the vegetable crop (e.g. marigolds suppress nematodes, lemongrass helps to repel insect pests, asparagus is reported to repel nematodes, tomatoes are known to repel the asparagus beetle).
- ☑ Combination of vegetable crops with trees can be suitable (e.g. *Moringa oleifera*, *Calliandra calothyrsus*). They can contribute fruits, shade or fertiliser, but good spacing is needed.
- ☑ Amaranths, basil, garlic, marigold are reported to be good companion plants which can help to repel insect pests from tomatoes.
- ☑ Maize and tomatoes share a common pest, the bollworm, and should ideally be grown away from each other to minimise attack.

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   35

- Promoting higher yields, diversified food and incomes.

v) Rotation and intercropping should also consider market requirements and profitability of the enterprises.

Note: The crops included in a rotation depend on the history of the plot. Keeping good records is therefore important for farmers in order to keep track of what is planted in the different plots in different seasons and how to manage the rotations. With small pieces of land, farmers may find it challenging to practice full rotations, and mixed cropping can be a more feasible option for them.

3.5.2 Intercropping

Depending on the size of production and intended use, farmers sometimes grow many types of vegetables in a single plot or bed. It is not uncommon to find as many as four or more vegetables in one plot. While this can be due to land constraints, there are economic and ecological benefits from this practice. Farmers can diversify food, and increase returns per unit land and invested labour when they practice proper intercropping. The crops can have beneficial effects to the soil while providing other companionship benefits. These benefits include maintaining good soil moisture or nutrients, reducing pest and weed incidence, and reducing disease spread. Not all plants, however, can grow well together. Therefore, and similarly to crop rotations, for sustainability and greater benefits, farmers should observe certain rules when planning or practicing intercropping. It is also good if farmers can make their own observations and decide which crops are best grown together or not.

Preparation of a vegetable intercropping plan

1. Select the vegetables you want to grow (e. g. tomato, cabbage, garden peas, potato, broccoli, beans, onions, etc.) depending on the season, your preference and market requirements.
2. Ensure that the chosen species are evenly distributed among the various crop families and that they are compatible.

Discussion on intercrops

Discuss with the farmers about their experiences with intercropping crops and beneficial non-crop plants. Have they observed any beneficial effects? Discuss these effects and request the farmers to list the benefits and rank them according to what they think is important. Discuss the challenges faced or potential bottlenecks.

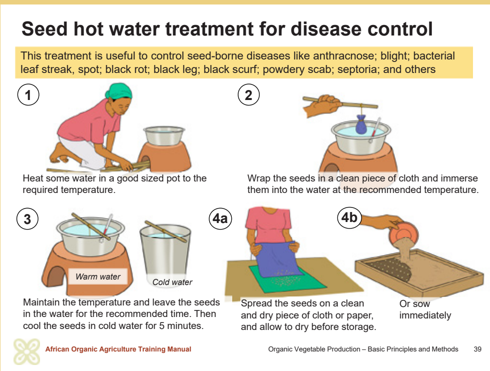
3. Plan an intercropping pattern which takes care of the following considerations:
   - Vegetables in the same family should not be grown together.
   - Heavy feeders should be mixed together, but with light or light-medium feeders.
   - Solanaceous plants and Alliums (onion family) normally grow well together. Carrots are known to be good companions with beetroot, onions, lettuce, cabbage, and tomatoes. Garlic and legumes such as beans and peas are reported as not good companions.
   - Commonly tall-growing species combine well with short-growing species and they compete less for light.
   - Ensure that crops planted together require similar growing conditions but as much as possible, ensure that they are both not heavy feeders.
   - Also, consider companion plants that provide beneficial effects to the vegetable crop. For example, marigolds have been found to suppress nematodes while lemongrass helps to repel insect pests. Asparagus is also reported to repel nematodes while tomatoes are known to repel the asparagus beetle.
   - Perennial crops which grow for several years on the same land should be considered in a crop mixture. Suitable tree-vegetable combinations can be included. These trees or shrubs can be for fruit production, shade provision, or soil fertility building.

Pest repelling plants

Farmers may already be aware of many locally growing plants that can repel insect and other pests from vegetable crops when they are grown together with the vegetables. For example, aromatic plants such as alliums and various herbs can repel certain pests from crops. Onion, for example, has been reported to repel aphids, snails, certain worms, etc. from cabbage crops. However, the extent of protection offered by such plants is relative and subject to many conditions and might breakdown under heavy pest infestations. A combination of approaches can offer better protection.

HOT WATER TREATMENT OF SEEDS TO ENHANCE GERMINATION

HOT WATER TREATMENT OF SEEDS TO CONTROL SEED-BORNE DISEASES



4. Seed pre-sowing treatment

Some seeds are naturally dormant and cannot germinate easily without certain pre-sowing treatments such as scarification. Most vegetable seeds, however, are generally soft and would germinate without needing scarification.

Seeds with a very hard coat require scarification to weaken the seed coat and allow water to be absorbed during germination. This can be achieved by immersing them in hot (75 to 95 °C, but not boiling) water or rubbing the seeds between two abrasive surfaces.

Some farmers do scarify squash and spinach seed as well as soak legumes (peas, beans) seed overnight in water before sowing to improve or enhance germination. If hot water is used for scarification, 10 to 20 times the volume of hot water as the seed should be used.

Seeds with a waxy coating should be washed several times in very hot water to remove the wax before the final soaking is done. In addition to scarification, the hot water treatment also helps to control seed-borne diseases.

Other seeds, particularly those that evolved in areas with cold winters, such as lettuce and chives require a cold treatment (stratification) to enhance germination. This requirement is not crucial for many vegetables. If required, this can be done by mixing the seed with moist sand and placing it in the fridge for 4 to 8 weeks before sowing. Seed of sub-tropical and tropical vegetables, e. g. eggplants, melons and peppers do not require this type of treatment.

4.1 Controlling seed borne diseases using the hot water treatment method

If farmers select and save seed from their own crop they will need to treat it for both external (on the seed coat) and internal (inside the seed e. g. in the embryo) diseases. Due to the restricted use of chemicals in organic production, and for other reasons, farmers can use the hot water treatment method which can be effective against diseases such as anthracnose (*Colletotrichum* spp.); bacterial blight and leaf spots (*Pseudomonas* spp.; *Xanthomona* spp.); bacterial leaf streak (*Xanthomonas* spp.); common bacterial blight (*Xanthomonas* spp.); *Septoria* spp.; and others. Care should be taken in treating the seed, i.e. recommended water temperatures and duration must be properly followed to avoid under treatment

TEMPERATURES AND DURATIONS FOR SEED HOT WATER TREATMENT

Recommended temperatures and durations for seed hot water treatment for disease control

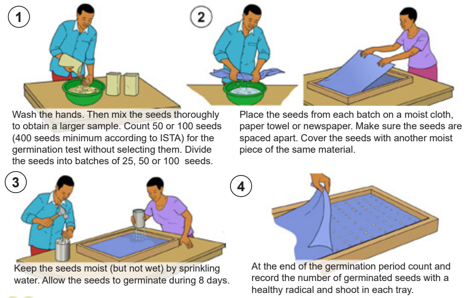
Vegetable	Water temperature (°C)	Treatment duration (minutes)
Brussels sprouts, eggplant, spinach, cabbage, tomato	50	25
Broccoli, cauliflower, carrot, collard, kale, kohlrabi, rutabaga, turnip	50	20
Mustard, cress, radish	50	15
Pepper	51	30
Lettuce, celery, celeriac	47	30
Shallots	46	60

Source: adapted from Ohio State University Extension

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 40

INDOOR SEED GERMINATION TEST WITHOUT SOIL

Indoor seed germination test without soil



African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 41

or over exposure of the seed to heat which can severely damage the seed and reduce subsequent germination capacity after sowing. For example, potato tubers must be treated for 10 minutes at 55 °C to control e. g. blackleg (*Erwinia carotovora*), powdery scab (*Spongospora subterranea*) and black scurf (*Rhizoctonia solani*). When doing it for the first time, it is recommended that farmers seek for special or extension support and advice.

The hot water treatment is appropriate for seed such as broccoli, Brussels sprouts, cabbage, carrot, cauliflower, celeriac celery, collard, cress, eggplant, kale, kohlrabi, lettuce, mustard, potato, pepper, radish, spinach, tomato, and turnip. Certain vegetables are reportedly not suitable for this method. For example, peas, beans, cucumbers, lettuce, sweet corn, beets and others are better not treated with hot water. Response to the hot water treatment is also variable with a species, e. g. cauliflower where the hot water treatment can damage seed of some hybrids while other cultivars are not sensitive.

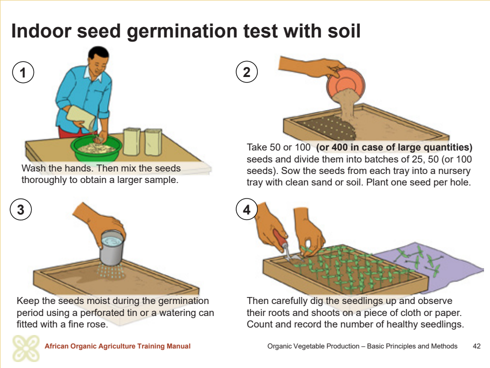
4.1.1 Procedure for hot water treatment

If controlled facilities are available (a hot water bath that can maintain constant temperature), it is best to use them as they give the best results. However, recognizing that most farmers have no ready access to such sophisticated equipment, a simple procedure is outlined below:

1. Fill up a large pot with water and heat the water to the required temperature.
2. Place the seeds into a loose cotton bag and submerge it in the water, the bag must not touch the bottom of the pot but must remain suspended in the water. Maintain the water at a uniform temperature throughout by constantly stirring the water while soaking the bag. If available, a thermometer can be used to check the water temperature and adjust the heat accordingly in order to maintain a uniform temperature.
3. After the recommended exposure time at the recommended temperature has elapsed, remove the bag and cool it in clean cold water to stop the heating.
4. Spread the seeds on a clean dry paper to cool down and dry.

Preferably, the treatment is done just before sowing so that the treated seed is sown immediately after it has been dried to avoid reinfection if stored. After the treatment it is advisable to test the seed for viability through a germination test.

INDOOR SEED GERMINATION TEST WITH SOIL



SEED GERMINATION TEST CALCULATION EXAMPLE

Example of a germination test calculation

	Batch 1	Batch 2
No. of seed used in the germination test (A)	20	20
No. of germinated seeds (B)	10	12
Germination proportion (C = B / A)	10 divided by 20 = 0.5	12 divided by 20 = 0.6
Germination percentage (D = C * 100)	0.5 * 100 = 50 %	0.6 * 100 = 60 %
Average germination percentage	**(50 % + 60 %) divided by 2 = 55 %**	

Easier calculations for each seed set

- If 20 seeds are used for each germination test, the germination percentage for each set can easily be obtained by multiplying the number of germinated seeds in each set by 5.
- If 50 seeds are used, multiply the number of germinated seeds by 2.
- If 100 seeds are used, multiply the number of germinated seeds by 1.

Note: The above examples are true only when all the seeds used are retained until the end of the germination test. If some of the seeds in the test are lost before the end of the test through e.g. consumption by rodents or if seeds fall out of the germination medium, then the test has to be redone.

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods 43

4.1.2 How to ensure that a suitable water temperature is reached:

A good thermometer and a watch should be used. Assistance from qualified personnel from the local extension office may be a good idea. Thus, farmers can decide to do this operation as a group so that an extension agent can be available to efficiently assist the groups and not individual farmers.

5. Testing for seed viability through a germination test before sowing

Before seed sowing, it can be helpful to do a germination test, particularly with seed that has been in storage for a long time, e. g. for a year or more.

- Wrap a minimum of 20 seeds in a moist medium such as newspaper, paper towel or suitable pieces of cloth, or placing the seed on damp cotton wool. Ensure that the seeds are well spread out on the medium.
- Keep the medium moist, but not wet, throughout the test. Both, too much or too little water can prevent seed germination. To moisten the seeds, a perforated tin, a hand sprayer or other tools that allow controlled application of water in low quantities can be used.
- Leave the seed for about a week or more to germinate, or to allow initial seedling growth in a nursery container.
- Small seeds are best germinated without soil, while larger seeds, such as beans, may rather be tested in a soil medium. If seed is not limiting, using 50 or 100 seeds will make it easier for farmers to calculate the germination percentage.
- To allow the seeds to germinate properly the container(s) should be kept indoors for the required germination period.
- After the estimated germination period has elapsed, the number of seeds which germinated successfully and started to grow shoots and radicles is determined.
- The number of germinated seeds is counted and expressed as a percentage of the total seed tested to obtain the germination percentage. Different vegetables have different germination capacities. The minimum acceptable germination level of carrot and celery is 55 % while the minimum required is 80 % for other vegetables such as peas, lettuce and cucumber. A germination test

Calculation of the required seed quantities

Undertake an exercise to allow the farmers to learn about estimating seed requirements taking into consideration the following:

- Size of field to be planted (including spacing etc.)
- Number of seeds per kg (or per other quantity appropriate for the seed e.g. per 100 g)
- Germination level
- Loss of seedlings at transplanting due to culling
- Gap filling requirements due to poor field establishment

will help to determine whether higher sowing rates are required to compensate for the low viability of a seed lot, or whether farmers should completely discard the whole seed lot and source for a fresh supply of the seed. It is recommended that at least two sets of germination tests be conducted for a seed lot to obtain an average germination percentage. However, if the seed is limited, it is not possible to use so much seed for the tests.

Although important, the germination test alone is not sufficient to determine the amount of seed required for a certain target planting area. Farmers must also consider other potential seedling losses at transplanting stage, gap filling requirements when transplanted seedlings get damaged, and other factors.

MINIMUM ACCEPTABLE GERMINATION LEVELS (1)

Minimum seed germination levels (1)

Vegetable	Minimum recommended germination rate (%)	Mean number of days to germination *(under conditions)*
Asparagus	60	10
Bean (Snap)	75	7
Beets	65	4
Broccoli	75	4
Brussels Sprouts	70	4
Cabbage	75	4
Carrot	55	6
Cauliflower	75	5
Celery	55	7
Chinese Cabbage	75	4
Cucumber	80	3
Eggplant	60	6
Kale	75	4

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   44

MINIMUM ACCEPTABLE GERMINATION LEVELS (2)

Minimum seed germination levels (2)

Vegetable	Minimum recommended germination rate (%)	Mean number of days to germination *(optimal conditions)*
Leek	60	7
Lettuce	80	3
Muskmelon	75	4
Okra	50	6
Onion	70	6
Pea	80	6
Pepper	55	8
Pumpkin and squash	75	4
Spinach	60	5
Sweetcorn	75	3
Swiss Chard	65	4
Tomato	75	6
Turnip	80	3
Watermelon	80	4

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   45

6. Proper nursery management in vegetable production

Most vegetables are small seeded and very sensitive to drought, pests and diseases and to competition after germination. Therefore, leaf and fruit vegetables that can transplant well are mostly raised from seedlings and transplanted to the field after they have developed a strong root system and overcome the sensitive early growth stage. Raising seedlings, rather than direct sowing procedure, allows for growing of young vegetables under ideal conditions, selection of the strongest plants only for transplanting, creating ideal plant stands in the field and limited seed wastage. If not properly done, transplanting can severely interrupt and retard crop growth and reduce yields. Also, it is important to note that some vegetables such as carrots do not transplant well and will perform best when seeded directly into the field where they will grow and mature.

6.1 Factors to consider when selecting a vegetable nursery site

Vegetable seedlings can be raised in open or protected nurseries. The nurseries can be fixed or movable depending on the size of operation, structures used for raising the seedlings, and other requirements.

A vegetable nursery is best raised at locations that are …

- close to a good source of water,
- well drained site to reduce the chances of damping off diseases that are caused by fungi such as *Phytophthora*, *Pythium* and *Rhizoctonia*,
- well positioned to receive good amounts of sunshine and good ventilation,
- easily accessible for regular care visits,
- protected from harsh climatic conditions such as heavy rains, hailstorms, and very high temperatures. Artificial shading and protection can be done using polythene nets of various sizes and colours, or an appropriate grass thatch,
- protected from animals, insect pests and diseases (the latter two can be managed through good cultural practices and use of biopesticides),
- be on a level ground or gentle slope to avoid erosion,
- close to the final planting site to minimise labour and transportation requirements and costs, exposure to the sun or dry winds, and overall transplanting shock for the seedlings.

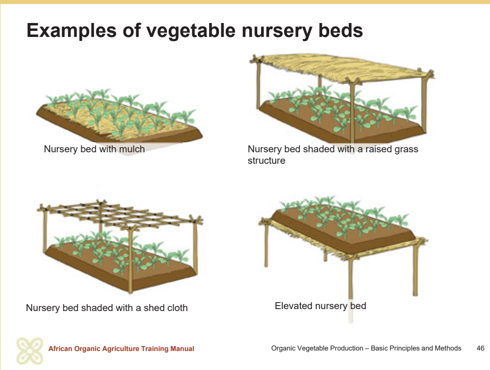
6.2 Preparing seedbeds

6.2.1 Nursery beds

The best type of seedbed to use depends much more on the particular climate and soil conditions than on the crop. The beds can be flat, raised, sunken depending on many factors. In high rainfall or waterlogged conditions, it is best to use raised beds while sunken beds can help to conserve moisture in semi-arid regions. Areas with moderate rainfall can use flat seed beds. The nursery site should be prepared well. All dead plants which appear to be severely diseased or to be harbouring harmful insects on the seedbeds under preparation must be removed and destroyed or buried deep into the soil. Healthy plant residues can be removed and added to compost heaps, or can be incorporated directly into the soil but should be allowed to decompose well before sowing the seeds.

The seedbeds can measure anything from 45 to 50 cm width and any desired length of up to 6 m. When raised, the beds are ideally raised to 10 to 20 cm or higher to facilitate good drainage, thus preventing water logging and associated problems in the germinating seed. Before sowing, the beds must be levelled to a fine tilth and the soil pressed gently to make it firm in order to hold the seed in

NURSERY BEDS SHOWING DIFFERENT TYPES OF SUN PROTECTION



STEPS ON HOW TO STERILISE NURSERY BED SOIL

Sterilising the nursery bed soil with fire

1. Prepare the seedbed and water thoroughly.
2. Place slow burning materials such as grain husks on top of the moist soil (exampes include rice husks, coconut leaves, brushwood, hay).
3. Burn the materials ensuring that the fire is started against the wind direction to slow down the burning and maximising the soil - heat contact.
4. Allow the soil to cool for about 2 days before sowing.
5. Ensure that the sowing tools for the seed are clean.

Instead of fire, soil solarisation can be used to ensure that the soil is free of pathogens.

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 47

SOIL SOLARISATION FOR STERILISING THE NURSERY BED SOIL

place during the process of germination and emergence. A gentle pressing also allows better seed to soil contact. Seeds are sown at depths normally 2 to 3 times their size and irrigated immediately after transplanting and regularly thereafter to enhance germination.

The seedbed soil should be mixed with well-decomposed compost or well decomposed manure at a rate of 2 to 5 kg per square meter depending on the type and status of the soil. If soils are already rich in organic matter then less amounts of the compost/manure can be used. If the nursery soils are heavy, with high contents of clay, then clean sand (or other suitable porous materials) should be mixed with the soil and manure to improve the drainage capacity and reduce the risk of damping off diseases.

Solarising seedbeds

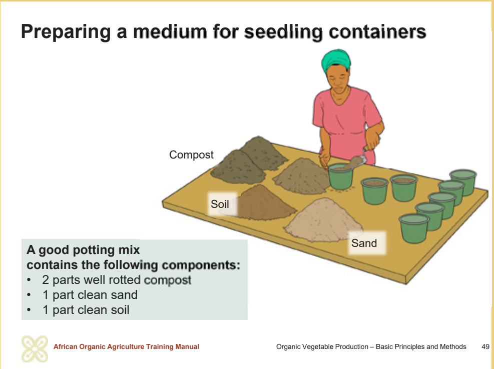
Solarisation, for controlling pests and diseases in the nursery soils, appears to be more feasible under the smallholder farming set up where equipment for steaming large quantities of soil might not be readily available. To perform soil solarisation, transparent polythene sheets of 1 to 6 millimetres (0.0254 to 0.1524 cm) thickness are used. These are placed and held at 3 to 4 cm above the soil surface and secured on the edges (by soil, stones or other heavy objects) to prevent them from being blown away by wind. The sheets are left on for about 4 to 6 weeks to facilitate 'heating' the soil prior to sowing. Prior to placing the polythene covers, the soil should be well irrigated (to field capacity) to activate weed seeds and soil-borne pathogens. The water is necessary to help the soil increase its capacity to retain heat during solarisation. Soil solarisation is considered an organic method for weed, insect pest and disease control.

When pest and disease attacks occur at potentially damaging levels to the seedlings, farmers can use recommended purchased or locally/homemade organic sprays or concoctions sprays to control them. Before using any products, farmers should consult with their organic certifying body.

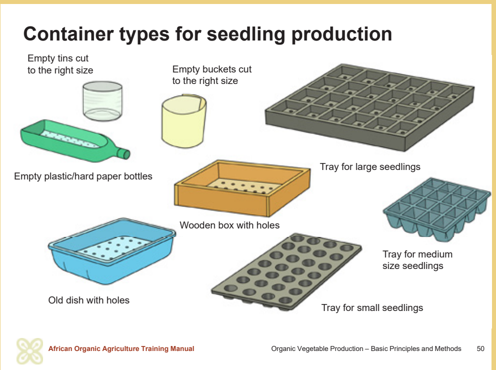
6.2.2 Preparing media for container raised seedlings

If seedlings are raised in containers, a suitable germination medium must be prepared. In general, a good sowing medium contains the following mixes:
2 parts compost : 1 part sand : 1 part soil

PREPARING A MEDIUM FOR USE IN SEEDLING CONTAINERS



TYPES OF CONTAINERS FOR RAISING VEGETABLE SEEDLINGS



The following options have also been suggested for organic vegetable seeds. It is important for farmers to try out and choose the method that best suits their situation depending on the raw materials available to them:

a. 1 part clean sand : 3 parts ripe compost : 1 part soil
b. 30 % compost : 30 % coconut fibres or tree bark and fibres : 40 % soil
c. 30 % compost : 10 % rice husks : 60 % soil
d. Milled or finely crushed biochar added at 20 % volume (one fifth) of the total mix in order to increase waterholding capacity of the seedling mix.

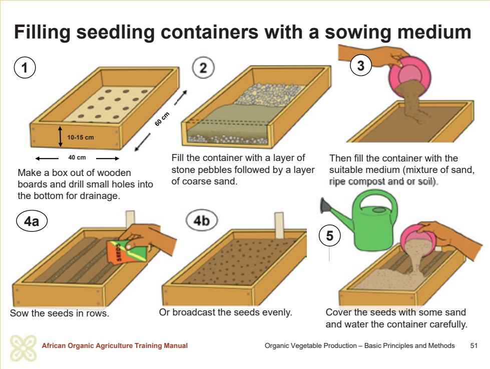
Note:

› If vermiculite is available, it can also be used in place of the soil.
› Good quality compost provides most of the necessary nutrients in adequate quantities except for N.
› Only mature and well-aerated compost should be used
› For use in vegetable seed trays, the compost must be finely sieved (<10 mm).
› Self-made compost must be turned often during the heat phase to destroy weed seeds and pathogens to increase its suitability as a medium component.

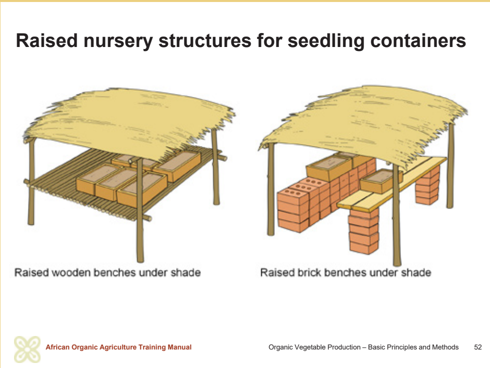
Besides nutrients, the compost will add beneficial bacteria and fungi to the soil which help the seedlings to grow better. Some of these microorganisms help to deter the growth of harmful bacteria and fungi which would otherwise damage the seedlings. The compost used must be well rotten. The sand will help to increase aeration in the sowing medium. The soil and sand must be clean, e. g. sterilised by heat (or in the case of sand, washed with clean water) to minimise contamination by soil borne diseases and pests. Farmers can either purchase sterile soil or potting mixes, or can also sterilise the soil from their gardens before using it in a homemade potting mix. For organic practices, sterilisation can be achieved through heat treatment in contrast to conventional production where chemicals soil fumigants are permitted for use. Such chemicals can have profound negative effects to the atmosphere. Sterile potting soils have no active weed seeds, insects or disease organisms. The vegetable seeds sown in sterilized soil are, therefore, less prone to damping-off diseases and other fungi that kill the seedlings.

It is also possible for farmers to use a soilless potting medium in the nursery. A soilless potting mix is a sterile growing medium widely used in horticulture as a soil substitute for growing plants in any contained environment. It comprises of

FILLING AND SOWING INTO SEEDLING CONTAINERS



SHEDS WITH ELEVATED SEEDLING CONTAINERS



various raw materials (such as sawdust, bark, coco-fibre and others), but without soil. The use of a soilless potting mix will help farmers to have better control of soil-borne diseases, weed seeds, and other problems such as soil-borne contaminants. Soilless media are also easier to work with as they are lighter and result in less compaction, hence provide a good germination medium for the seedlings.

6.2.3 Filling up the containers with a sowing medium

When filling up the containers with a sowing medium, farmers must observe aspects of good drainage by drilling holes or perforations at the bottom of the container (if these are not already present especially on homemade containers). Drainage is also enhanced by filling in a layer of stone pebbles at the bottom of the box (about 2.5 cm high) followed by a layer of clean coarse sand (about 2.5 cm high). The remainder of the box is then filled with a suitable sowing medium.

6.2.4 Containers for raising seedlings

When and why farmers should consider to use containers to raise seedlings:

› for seeds that are very fine, expensive or slow to germinate;
› to start a nursery early when weather conditions are still not suitable for outdoors seedbed sowing;
› to enable better control of the nursery as they can move the trays from place to place as needed. For example, to place the containers in a warm place or indoors, e. g. in a greenhouse to protect them from harsh weather;
› to help improve accuracy in water and fertiliser application while facilitating better monitoring and management of pests and diseases on the seedlings;
› to minimise root damage at transplanting;
› to transport or transfer seedlings easily to the field and move around within the field for transplanting.

Depending on availability and access, seedling trays, punnets and other types of suitable containers can be used to raise vegetable seedlings. Alternatively, farmers can construct their own containers using wooden materials or other suitable light materials. Wooden boxes can be used as seed sowing containers. These can be constructed from wooden boards that are light enough to allow the boxes to be moved around, but strong enough to keep the sowing medium intact. After constructing the wooden frame (can measure 60 cm long x 40 cm wide x 10–15 cm high) drainage holes must be drilled at the bottom of the box before filling the box with small stones and sand at the bottom and an appropriate sowing medium. A good medium has a good texture to allow for good aeration and moisture retention and should not be susceptible to shrinking. After sowing, the trays must be placed in a warm, sheltered place with good light but not direct sun.

6.3 Seed sowing

Steps to seed sowing after preparing the seedbed or containers:

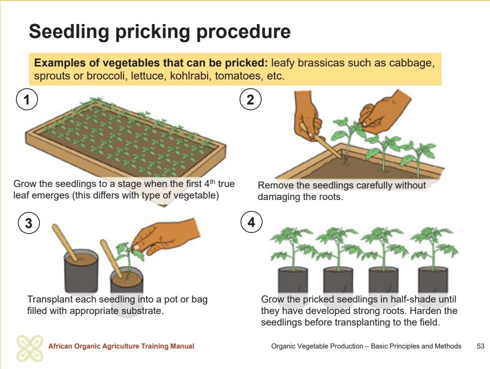
1. Water the seedbed or filled trays/containers using a fine rose about an hour or longer before sowing. Ensure that the soil/medium is not too wet at sowing.
2. Using a thin stick, drill into the moist sowing medium some sowing lines that are spaced appropriately according to the type of vegetable seed to be sown.
3. Carefully drop the seed into the drills and cover with the sowing medium or with clean sand before applying a light watering, preferably with a fine rose.
4. Alternatively, the seed, especially tiny ones, can be broadcast as evenly as possible on top of the sowing medium before a thin layer of the same medium or clean sand is applied to cover the seed and then watered carefully.

Regardless of whether soil beds or containers are being used, when sowing fine seed, farmers can mix dry clean sand with the seed to help spread the seed evenly in the seed beds or containers. This will reduce seed wastage, and result in better spaced and stronger seedlings. For example when sowing carrots seeds.

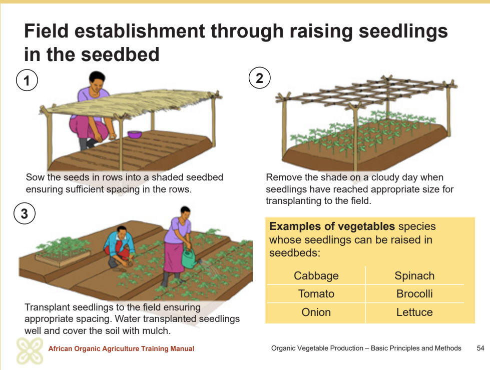
6.4 Watering seedlings in the nursery

After seed sowing, water is applied every 2 to 3 days to keep the soil moist (but not wet). The watering frequency depends on the prevailing weather. Care should be taken to not overwater as this will result in 'suffocation' of the seed leading

SEEDLING PRICKING PROCEDURE



RAISING SEEDLINGS IN THE SEEDBED



to rotting and poor germination. Overwatering can also lead to nutrient leaching, and in addition, it can increase susceptibility of the seed and/or seedlings to attack by damping off diseases. As a general rule, water should be applied when the soil or sowing medium surface feels dry but the soil or sowing medium should never be allowed to dry out. Water is best applied gently with a fine spray or rose, to avoid splashing or washing seeds away. In general, seedlings raised in containers such as trays require more frequent watering than those raised in seedbeds due to the shallow depth of the medium in the trays.

6.4.1 Nutrient management in the nursery – top dressing

In addition to the compost applied during seedbed preparation, some seedlings may require top dressing with nutrients. When true leaves appear (at about 2 weeks after sowing the seed depending on the crop), a weak leaf tea (at 0.5 litres for every 1.2 m^2) or weak liquid manure can be added and applied together with the irrigation water to improve nutrient availability to the seedlings. Note that for vegetables that have a shorter nursery period, top dressing with the leaf tea or liquid manure may not be necessary. However, for longer term seedlings such as tomatoes which are transplanted at a taller and later stage, the top dressing is required.

6.5 Seedling pricking

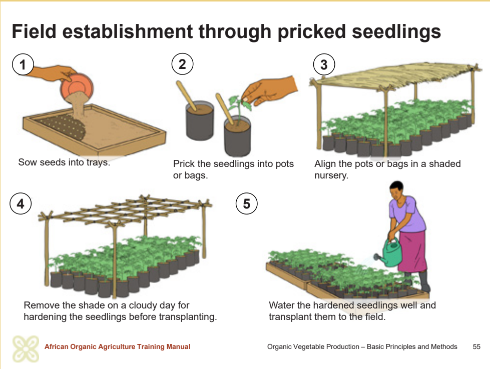
For economic and other reasons, farmers may decide to use smaller containers initially until a few weeks after seedling emergence when seedlings are then transferred to larger containers that have been filled with a suitable growing medium. This is called pricking out and is ideally done at about 2 to 4 weeks after germination, or at the 4 to 6 leaf stage.

Some key aspects about pricking:
- The timing for pricking depends on the type of vegetable.
- Vegetables that can be pricked include leafy brassicas like cabbage, Brussels sprouts, and broccoli, lettuce, kohlrabi, tomatoes, etc. For some vegetables

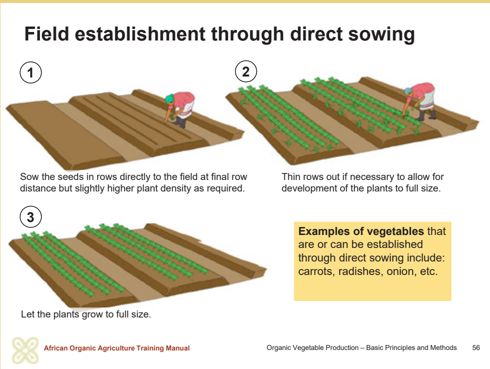
Practical exercise and discussion on the production and use of leaf and compost tea

Show the farmers how to make leaf or compost tea and discuss how and when to apply the ‘tea’ to seedlings, including the necessary dilutions.

RAISING SEEDLINGS IN POTS



DIRECT SOWING



such as chillies, pricking can be done even as early as the time when the cotyledon leaves (first/false leaves) have expanded fully.

› Pricking is particularly necessary if the seedlings are overcrowded, are diseased or growing poorly in the original containers.
› Another reason for seedling pricking is to stimulate vigorous root growth before field transplanting.
› Only the healthy seedlings with a good root system and showing no signs of damage must be pricked out.
› Care must be taken to avoid damage to the seedling stems and to minimise root damage during pricking out.
› Once pricked out, the seedlings must be watered gently and adequate soil moisture has to be maintained. They will also require liquid manure (at half the strength normally applied to growing crops – this is achieved by diluting the liquid manure with an equal amount of water) to be applied every few days to stimulate rapid growth.
› Pricked seedlings are ready for field transplanting within about 2 to 4 weeks after pricking and by then they will have grown a strong root system.

Vegetables that can be pricked include leafy brassicas such as cabbage, sprouts, and broccoli, lettuce, kohlrabi, tomatoes, etc.

6.6 Hardening off seedlings

All seedlings require hardening, or toughening, before they are transplanted into the field. This process involves progressively reducing watering and increasingly exposing the seedlings to full sun for a week before they are transplanted. If seedlings are raised in containers, the containers are gradually moved out of the shade into exposed sun conditions. When hardening the seedlings, care should be taken to not excessively stress the seedlings (through e. g. sun-scorching and severe moisture stress) as this might kill them. Hardening prepares the seedlings to be tolerant to transplanting shocks in the field.

6.7 Pest and disease management in a vegetable nursery

Preventive measures that are of special importance in organic agriculture include practical hygiene management and other cultural practices. Nursery sites or beds must be rotated, or farmers must change the site on which they raise seedlings to break pest and disease cycles. All nursery equipment must be properly cleaned to prevent transfer of diseases or pests such as nematodes. Proper destruction of infected plant material should be practiced. In cases where soil borne pests, diseases and weeds are known to be problematic, it may be necessary to heat the soil before sowing the seed. As discussed in prior sections, steaming and solarisation can be used depending on the facilities available to the farmers. Where seed-borne diseases such as black rot, black leg, black spot and ring spot of crucifers are common, hot water treatment of own-produced seed, or seed collected from non-formal sources, is recommended.

7. Good field establishment and management

7.1 Timely preparation of land

Land preparation is a major activity of vegetable production. Farmers should start preparing the land at least one month before the expected date of transplanting vegetables to allow adequate time for field preparation operations. Most vegetables require 3 to 4 weeks in the nursery bed, after which they need to be transplanted. Land for transplanting must be prepared on time to prevent keeping the seedlings longer than necessary in the nursery bed as this affects their quality. Preparing the beds early also allows weed seeds to germinate (false seedbed) and later be cleared before the crop seedlings are transplanted.

7.2 Depth of digging or ploughing, and fine tilth

Many vegetables have tender roots, especially at the seedling stage. It is important therefore, that the field to which they are transplanted provides the best conditions which encourage rapid root growth and proliferation. Plots for planting vegetables must be dug deeply to ensure deep water and root penetration.

RECOMMENDED SPACING (1)

Recommended spacing of vegetables (1)

Vegetable species	In row (cm)		Between rows (cm)	
	Minimum	Maximum	Minimum	Maximum
Asparagus	22.5	37.5	120	180
Bush bean	5	10	45	90
Pole Bean	15	22.5	90	120
Beet	5	10	30	75
Broccoli	30	60	45	90
Brussels sprouts	45	60	60	100
Cabbage	30	60	60	90
Carrot	2.5	7.5	40	75
Cauliflower	35	60	60	90
Celeriac	10	15	60	90
Celery	15	30	45	100
Chard (swiss)	30	37.5	60	90
Chinese cabbage	25	45	45	90
Corn	20	30	75	105
Cucucmber	20	30	90	180
Egg plant	45	75	60	120
Garlic	2.5	7.5	30	60
Kale	45	60	60	90
Leek	5	15	30	90

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 57

RECOMMENDED SPACING (2)

Recommended spacing of vegetables (2)

Vegetable species	In row (cm)		Between rows (cm)	
	Minimum	Maximum	Minimum	Maximum
Kohlrabi	7.5	15	30	90
Lettuce (cos)	25	35	40	60
Lettuce (leaf)	20	30	30	60
Muskmelon	30		150	210
Onion	2.5	10	40	60
Parsnip	5	10	45	90
Peas	2.5	7.5	60	120
Pepper	30	60	45	90
Potato	15	30	75	105
Pumpkin	90	150	180	240
Radish	1.25	2.5	20	45
Rutabaga	12.5	20	45	90
Spinach	5	15	30	90
Squash (bush)	60	120	90	150
Squash (vining)	90	240	180	240
Tomato (flat)	45	120	90	150
Tomato (staked)	30	60	105	150
Turnip	5	15	30	90
Water melon	60	90	180	240

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 58

The soil is best dug to a depth of 20 to 25cm to facilitate good root growth, however minimum soil disturbance helps to conserve the soils. A fine tilth allows quick establishment of directly sown seeds or the transplanted seedlings. Depending on the type of crop, it may be necessary to prepare planting holes, e.g. for sweet corn/maize, or shallow and narrow furrows, e.g. for onions or carrots, to help with water retention during establishment. Banding application in the planting holes or furrows, rather than broadcasting, of well-rotted manure or compost can help to concentrate and increase its availability to the crop particularly when quantities are limited.

7.3 Application of soil nutrient amendments

To improve soil quality and provide enough nutrients to the growing vegetables, well-decomposed compost or well-rotted manure should be applied to the topsoil or to the planting holes and mixed with the soil before planting. The requirements for manure or compost will vary based on many factors including the current fertility status of the soils, the type of crop being grown and anticipated yields. Soil fertility management is discussed in more detail in later in this training manual module, and also in Module 3 of this same African Organic Agriculture Training Manual at www.organic-africa.net.

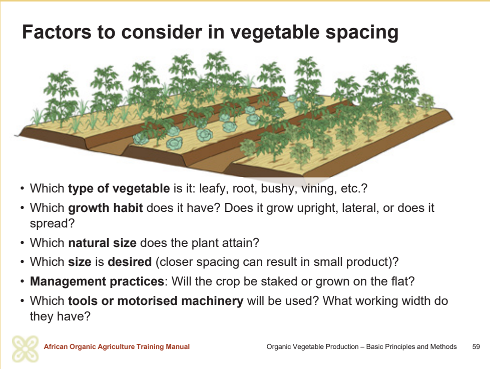
7.4 Direct sowing into the field

To sow seeds directly into their permanent growing stations, farmers can dig shallow furrows or holes into which they drill or broadcast the seed and cover. After germination, the seedlings are thinned to their required spacing, e.g. carrots, to avoid crowing and ensure that the remaining seedlings have adequate space, nutrients, water and sunlight.

7.5 Appropriate plant spacing

Suitable spacing in leafy and fruit vegetable crops is important for proper crop development and good yields, and also for better aeration and disease manage-

WHAT TO CONSIDER IN SPACING



ment. The spacing must also allow for the use of machines where this is relevant, and human movement for various field operations.

Commercially produced seeds are packaged in packets which also contain information on sowing and planting requirements including spacing. In general, small root crops such as radishes are spaced closer together (10 cm apart within a row) while larger root crops like turnips and beets are spaced at 20 cm apart. Greens like spinach, lettuce and endive can be spaced at 30 cm apart. The spacing is much bigger for peppers and eggplants and for tomatoes and squash vines. For direct seeding, it is a common for farmers to plant closer than recommended and then thin out to the recommended distances after successful germination and establishment. The recommended distances are a guide and farmers should take other factors into consideration to determine the final spacing according to their needs and situation. These factors include, among many, accessibility to the plants, weeding practices, pest scouting and control as well as harvesting practices. Consideration should also be made as to the type and size of equipment/machines to be used for field operations as these require additional space.

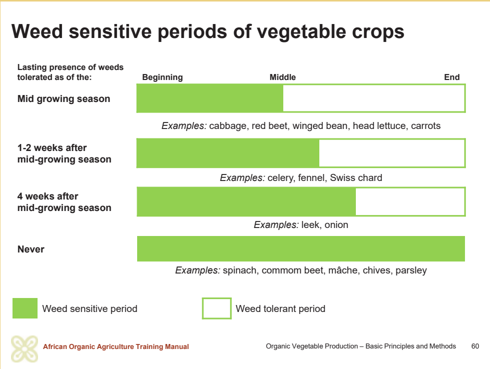
Reasons for seedling thinning in direct seeded vegetables

a) Allow good spacing for proper growth
b) Reduce competition for growth resources among the seedlings
c) Reduce disease build up by providing good air circulation among the growing plants. Poor circulation encourages moisture build up in the air surrounding the plants and this can facilitate disease spore germination and proliferation.

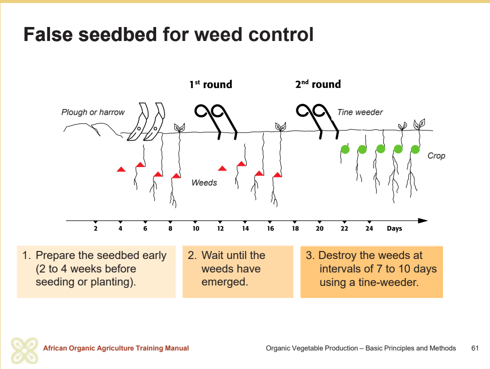
Thinning timing – when must thinning be done?

Thinning is best done when seedlings have set out the first 1 or 2 true leaves and must be carried out when the soil is moist. Thinning during the evening reduces shock to the remaining seedlings. Leafy vegetables such as spinach and lettuce can be thinned by pulling out the unwanted plants. These can be transplanted onto other sites or used to fill up gaps where germination was poor, or where seedlings were damaged by pests/diseases. Care must be taken to avoid damaging the roots of remaining seedlings as this can cause poor growth or deformations such as forking in carrots. If the risk of root damage is high, then thinning by cutting seedlings at the soil level rather than pulling them out can help to reduce this sensitivity. Not all thinned seedlings are thrown away: some like let-

WEED SENSITIVE PERIODS



FALSE SEEDBED



tuce, beets and spinach can be used for salads if not required for transplanting or gap filling.

In instances where space is limited, farmers may choose to intercrop two or more vegetables, with a closer spacing than the single species, and save on the limited space. Tomatoes are normally spaced widely, but could be intercropped with lettuce, spinach, or small root crops that can utilise some space and be harvested before the tomatoes grow fully and require the entire space.

8. Good weed management

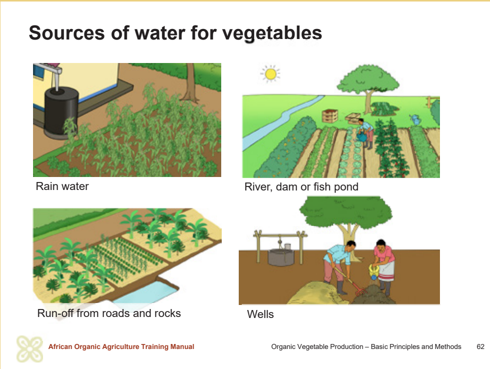
Vegetables are very susceptible to competition from weeds because most species grow short and close to the ground. The seedling stage is more sensitive to weed competition compared to the later growing stages. Direct seeded crops tend to be more sensitive to weed competition than transplanted ones. This is partly due to the fact that transplanting is done into a clean field and at a time when the seedlings have developed a substantial size of the root system. On the other hand, direct seeded vegetables may germinate and emerge simultaneously with weeds and the vegetable seedlings can be outcompeted.

Weeds compete for light, water, and nutrients and sometimes they host pests and diseases which attack vegetables. Weeding should therefore be carried out as frequently as possible, especially when the plants are still young. Farmers should ensure that no weeds are allowed to produce seeds before they are removed. Applying a thick layer of mulch made of dead plant materials like grass, straw, wood chips, crop residues or weeds can protect the soil from drying out and at the same time hinders weed seed germination to some extent. The plant residues should be free from weed seeds. A combination of regular hand weeding and alternate mulching can be effective in controlling weeds in vegetable production. It should also be noted that some weeds can actually be beneficial by repelling or distracting insect pests. Such weeds can be allowed to grow together with the crop as companions, but in a controlled manner, e.g. they can be allowed to grow, or purposefully planted, on the edges of the plots.

At later vegetative growth stages, competition by weeds may not be a problem and the benefits of weeds may surmount the disadvantages, for example *Tagetes minuta* is known to repel several pests of vegetables. In some vegetables, late weed development may therefore be tolerated.

Note
Further details on weed management can be found in Module 4 of the African Organic Agriculture Training Manual at www.organic-africa.net.

SOURCES OF WATER



THE FEEL METHOD FOR DETERMINING WATERING NEEDS

Estimating soil water condition using the feel method

Behaviour and/or appearance of sands and sandy loams	Soil moisture condition	Behaviour and/or appearance of loams, clay loams and clays
• Free water can be squeezed out of the soil	**Water logged conditions**	• Soil is very sticky • Soil oozes water when squeezed
• No free water on the soil when squeezed • Wet outline left on the hand during squeezing	**Moist soil** (100 % field capacity)	• Soil is sticky and forms a ball when squeezed, but no free water on the soil • Soil can be rolled into thin rods and leaves a wetting outline on the hand when squeezed or rolled
• Soil is slightly coherent when squeezed but only forms a weak ball	**75 % available moisture in soil** (enough for plant growth)	• Soil can still be rolled into thin but short ribbons • Soil has a sleeper feeling, and is still coherent
• Soil is less coherent and appears to be dry	**50 % available moisture in soil** (just enough water for plant growth)	• Soil is still coherent and forms a ball under pressure • Soil tends not to form ribbons except when pressed between a finger and the thumb
• Soil appears to be dry • Soil will not form a ball under pressure	**Critical** (soil needs replenishment to resume plant growth)	• Soil appears crumbly • Soil will not form a ribbon when pressed between a finger and the thumb • Soil can still form a ball under pressure
• Soil is dry and loose • Soil will flow through the fingers	**Dry** (too dry for plant growth)	• Soil looks crumbly and powdery • Soil will not form a ball under pressure

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods — 63

Creating a false seedbed helps organic farmers to control weeds. This technique consists of a series of steps whereby the weeds are allowed to grow on a prepared seedbed, then controlled before the crop is sown or transplanted into that seedbed. The farmers can prepare their seedbeds early, say two to four weeks before the expected date of crop sowing or transplanting. Within that period, the weeds will germinate and start to grow. The germinated weeds should be destroyed at intervals of 7 to 10 days until the date of planting or sowing. This way, the farmers will be able to plant into a 'weed-free' or less weedy seedbed thereby reducing the competition that normally occurs between the crops and weeds early in the season.

9. Determining vegetable water needs

Producers who have been growing vegetables over a long time will have learnt through experience and/or training about water requirements for different vegetables and their sensitivity to water stress. The amount of water needed basically depends on the type of soil, weather conditions, type of vegetable and its stage of growth/development, and whether production is in the open field or under controlled conditions such as greenhouses. Water loss from the soil and from plants is highest when plants and soils are exposed to the sun. In hot, dry and windy weather conditions, transpiration of crops is higher and more water is lost from the crops, weeds and soil and more water is therefore needed.

Vegetables differ in their peak water demands. Most vegetables are sensitive to water stress during the i) flowering period, ii) head or tuber formation and enlargement, iii) fruit set and pod/seed formation and enlargement. It is important to prevent water shortage at these stages as it retards crop growth and reduces yields. Farmers should also avoid excessive water application to prevent water logging or leaching of nutrients such as nitrates below the root zone.

An irrigation schedule aiming for efficient water use must consider the following aspects:

› Crop water requirements which depend on:
  - Type of vegetable/species
  - Stage of growth
  - Stage of development

Discussion on determination of crop water needs

Find out from the farmers, how they commonly determine the crops' water needs. What experiences have they made with these approaches? Discuss which methods they prefer to use in future.

- Rooting depth
- Canopy shape and size
- Leaf characteristics (size, shape, architecture)

› Soil moisture conditions
› Soil water holding capacity (soil depth, clay content, organic matter content, etc.)
› Weather conditions – plants and soils lose more water on hot, sunny days than on cool, cloudy days.

Deeper crop rooting means that there is a larger soil volume from which the roots can extract water. This is one of the reasons why the rooting depth determines the depth to which the soil must be wetted during irrigation. Hard pans in the soil can reduce the depth to which roots grow and hence their capacity to extract water from deeper soil layers. These hard pans need to be destroyed (through e.g. ripping, growing plants with strong roots) to facilitate better crop growth and improve moisture availability in the soils.

9.1 Soil water holding capacity

Soils with high water-holding capacity (clays and loams) generally need less frequent irrigation applications than soils that hold less water (sands). In general, loams and silt loams hold the highest amounts of available water compared to sands and those with very high clay contents.

9.2 Determining vegetable water needs using the Hand-Feel Method

The hand-feel method is a simple and quick method that a farmer can use to determine the level of moisture in a soil. A farmer obtains soil samples from different parts of the soil profile and evaluates the soil moisture by feeling the soil with the hand as illustrated on the diagram. Samples should be collected from numerous locations throughout the respective field to be irrigated as well as several depths in the soil profile. This method is only an estimate, but can be a good guide in determining whether to apply water or not. Accuracy of this method

WATER DEMAND OF VEGETABLES (1)

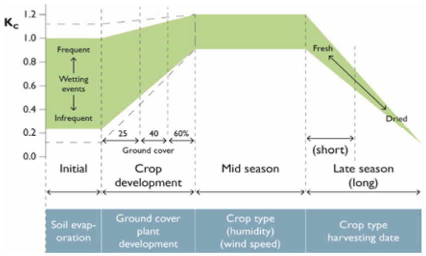
Growth periods of peak water demand of vegetables

Vegetable	Period of peak water demand
Cabbage, broccoli, cauliflower, lettuce	Head development
Carrots, turnips, radishes, sweet potatoes	Root enlargements
Tomatoes, cucumber, peppers, melons	Flowering, fruit set, fruit development/fruit enlargement
Peas	Flowering and seed development
Beans	Flowering/pollination, pod development
Spinach	Continuous
Potatoes	Tuber set and enlargement
Onions	Bulb enlargement
Sweet corn	Silking, tasseling, ear development and grain filling

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 64

WATER DEMAND OF VEGETABLES (2)

Crop Peak Water Demands



Adapted from Allen, Pereira, Raes and Smith (1998)

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 65

increases with experience of the farmer. This is the widely used method by smallholder farmers, but as technology becomes increasingly more available to the smallholder farmers, other suitable methods may become more applicable in the future.

9.3 Determining vegetable water needs using weather data

If farmers have a weather station installed in the vicinity of the vegetable growing site (within about 20 to 30 km radius), they can be supported technically on how to use climatic information to determine more precisely when to irrigate their vegetables and minimise water wastage. The method uses actual daily estimates of water lost from a field through evaporation from the soil and transpiration from plants (loss of water through leaves and other plant parts). Combined, these forms of water loss from a field are termed evapotranspiration. It also factors for rainfall received over the period when water lost through evapotranspiration is estimated. As water is lost from the soil through evapotranspiration, the amount of water held by the soil becomes depleted. As depletion continues, the remaining water will be strongly held to the soil particles and becomes less and less available to support crop growth. When moisture depletion from the soil exceeds the level at which the respective crops can draw water from the soil, it is time to replenish through irrigation to enable the crops to continue to grow normally. If there is enough rain to replenish the water lost through evapotranspiration, then there will be no need to irrigate the crops. However, the distribution and/or total rainfall amounts sometimes fails to meet the vegetable water requirements and supplementary irrigation is required to prevent moisture stress. This method is effective, but requires the appropriate tools and assistance by skilled extension staff to implement it. It could be more appealing to the younger farmers who might be inspired to apply some scientific approaches into farming.

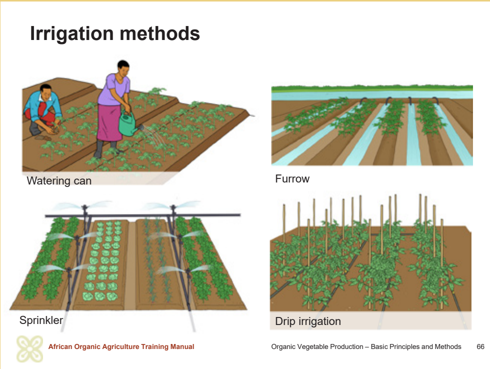
9.4 Other methods for estimating crop water needs

Another method involves the use of a reference crop for estimating the water needs of the crop being grown. More details can be obtained from the FAO Irrigation Manual (2002).

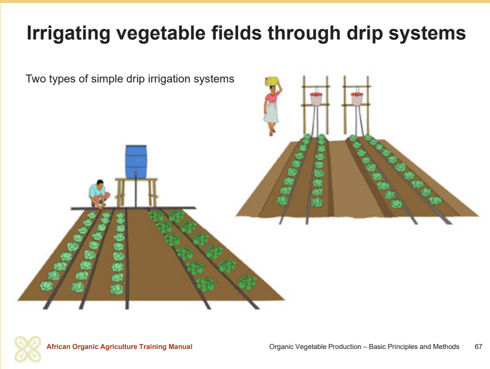
Exercise to determine the soil moisture status of soils

Determine with the farmers the soil moisture status of different soils at different intervals after irrigation (soon after an irrigation, 1 day after, 2 days after and 3 days after) using the feel method.

TYPES OF IRRIGATION



DRIP IRRIGATION



Using moisture measuring instruments
Where the facilities are available, farmers can monitor and estimate the irrigation needs through monitoring the moisture in soils using equipment like tensiometers or neutron probes. For small scale vegetable production, however, such equipment can be too expensive and also require specialised use.

9.5 Peak water demands for various vegetables

The peak water demand occurs at different stages for different vegetables. Leafy vegetables require good amounts of water throughout their growth. Fruiting vegetables are more sensitive to water stress during flowering and seed development. Fruiting vegetables require the greatest amounts of water during flowering, fruit set and subsequent fruit enlargement. Vegetables that form heads, e.g. cabbage, require more water during head development while roots and tubers are more sensitive during root enlargement. Knowing the characteristics of a crop helps the farmer to plan for her/his irrigation in a more effective way.

9.6 Irrigation practices and methods

Traditionally, farmers irrigate vegetable gardens manually using buckets, watering cans, or other suitable containers. This method is time-consuming. Unless controlled very carefully, using such manual tools for watering can result in significant water wastage as much more water is applied on a small surface in a short time. On the other hand, the manual methods, however, have the advantage of being low cost, simple and offer the possibility of precise water application to plants if well controlled. Watering by hand is therefore appropriate in small vegetable gardens.

For larger vegetable fields, efficient and water saving irrigation facilities are required. These may include overhead sprinkler, furrow, and drip and other micro-irrigation systems. Furrow irrigation can lead to high water wastage.

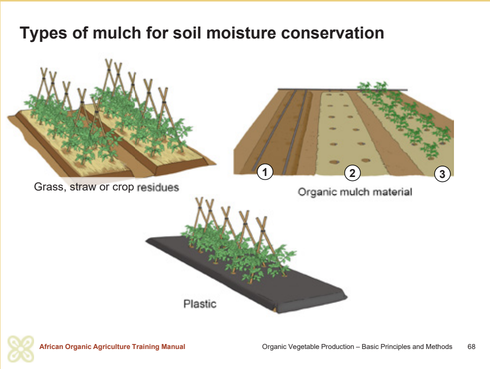
Regardless of the method used, farmers should always use good quality water for irrigation and choose the irrigation method that best suits their needs and situation taking into consideration power availability, cost, location and terrain, crop sensitivity, cropping patterns, size of field, etc.

Exchange of experiences on irrigation

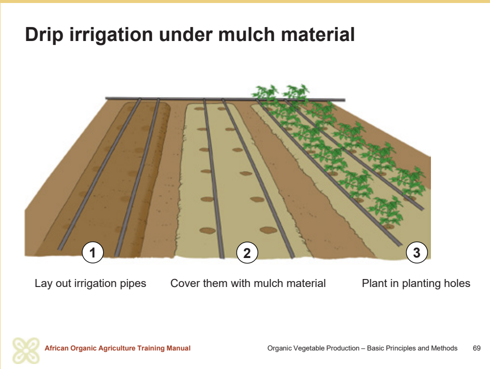
Ask the farmers the following questions to exchange information on their current irrigation practices:

- How do you irrigate your crops?
- Have any farmers developed innovations to ensure sufficient water supply for the vegetables?
- What positive and negative experiences have you made with irrigation?
- Which methods are used or known to save irrigation water and increase its usage by plants?

STRATEGIES TO REDUCE MOISTURE LOSS FROM SOIL



COMBINING DRIP IRRIGATION AND MULCH



9.7 Moisture conservation in vegetable production

Farmers can apply different strategies to conserve moisture in their vegetable gardens, for example:

Strategy	Details	Caution
Good irrigation design	A good irrigation design, management and scheduling helps farmers to enhance yields and production as the right amounts of water are applied according to crop needs.	Avoid overwatering the vegetables. By having a good knowledge of the soil and specific water requirements and peak water demands for the crop, farmers can apply only sufficient amounts of water.
Spot application of water	This technique limits water application only to the soil around the plant. This can be done easily for vegetables planted in individual holes or rows where containers such as buckets or watering cans can be used to apply water. Spot application can also be done for row-planted vegetables irrigated through drip irrigation or other means.	

Exchange of experiences on water loss reduction

Ask the farmers whether they have tried to reduce water losses from their vegetable plots and how. Discuss with them about their practices and experiences on mulching for moisture conservation. What types and main sources of mulch have they used?

Mulching	Mulching and application of adequate quantities of manure, compost and other suitable organic matter sources can help to conserve soil moisture. Mulch applied at the soil surface helps to prevent high soil temperatures hence lower direct water loss from the soil. Partial shading of the plants contributes to a reduction of evaporation by the plants, as do hedges that serve as wind barriers. Other types of mulches include plant residues, grass and plastic sheets. Besides protecting the soil and conserving moisture, mulches can also suppress weed growth and hence reduce competition for growing resources between weeds and the vegetables.	When plastic forms of mulch are used, care should be taken to reduce overheating in the soil when atmospheric temperatures are high, e. g. above 28 °C. Overheating can be reduced by covering the plastic with plant residues during the hot times of the day and removing them later. If the plant residues are left on the plastic for too long they can result in too much soil temperature reduction and ultimately cause poor plant growth and development.
Soil mulch	Creating a soil mulch to break the upward flow of water in the soil and its ultimate loss through evaporation: Depending on the type of vegetable, a shallow cultivation can be done on the top soil to reduce soil moisture loss through evaporation. This technique is known as breaking the soil water capillary, i.e. preventing the continuous flow of water from soil layers to the surface where it then evaporates.	The technique works out well for vegetables that grow deep roots but is not suitable for shallow rooted crops as this can result in root damage.

10. Pest and disease management in vegetable production

Pest and disease management in vegetables consists of several strategies. The first strategy is to prevent pest infestation or disease infection in the first place. If the vegetables are attacked, some curative control measures can be applied when the economic threshold level for a pest and disease has been reached.

10.1 Preventive measures

Many vegetables are easily attacked by many pests and diseases because they are tender and fleshy. This makes optimum implementation of preventive measures very important. Preventive measures include:

› Selecting varieties with resistance or tolerance to major pests and diseases,
› Using healthy seeds and other planting materials,
› Ensuring a conducive growing environment for the crop by ensuring good soil and nutrient, water and crop management,
› Creating a diverse cropping system that interferes with pest and disease cycles and other processes, including the promotion of a suitable habitat or home/shelters and food for natural enemies to pests and diseases (broad spectrum sprays of pesticides inadvertently kill these natural enemies and should be avoided)
› Ensuring good crop hygiene and sanitation including that of the farm operators,
› Timely detection of pests and diseases and intervention in case of an attack requires daily and careful monitoring to enable farmers to act before they can incur losses – this can be achieved by conducting regular field monitoring or scouting for disease/pest occurrence and/or their build up to threshold levels which then call for action to be taken,
› Covering seedlings and growing crops with a net or other appropriate materials or structures to prevent direct contact with pests or disease-causing agents and transmitting vectors,
› Mulching helps to reduce the transmission of diseases from the soil to the leaves and fruits (e. g. in tomatoes and eggplants). This prevents direct contact between the soil and above ground plant parts, hence reduced contamination from soil borne pathogens.

Exchange of experiences on pest and disease management

Invite the farmers to discuss challenges and successes in pest and disease control in organic vegetable production. What importance do preventive measures have? Which are the main preventive measures?

AGENTS AND PRODUCTS FOR DISEASE CONTROL (1)

Examples of agents and products for disease control (1)

Name	Derived from	Diseases controlled	Examples of crops sprayed	Application stage of plant growth	Comments
Ampelomyces quisqualis **(e.g. Bio-Dewcon)**	Fungal	Powdery Mildew disease caused by pathogens like *Erysiphe* sp., *Blumeria* sp., *Oidium* sp., *Sphaerotheca* sp., *Microsphaera* sp., *Uncinula* sp., and *Leveillula* sp.	Wide range of crops	All stages	Available both in liquid and powder formulation
Chaetomium globosum **(e.g. Con-Blight)**	Fungal	Late blight, Leaf blight, Head Blight, Botrytis and Root rot diseases caused by pathogens like *Phytopthora* sp., *Fusarium* sp., *Erwinia* sp., *Xanthomonas* sp.,	Tomato, potato	All stages	Available in liquid and powder formulation

This is a guide only; farmers are recommended to contact their local extension services and organic farming certifying agents in their area or country to get an accurate list of the disease control products that are allowed in their area and for the particular crop in question.

AGENTS AND PRODUCTS FOR DISEASE CONTROL (2)

Examples of agents and products for disease control (2)

Name	Derived from	Diseases controlled	Examples of crops sprayed	Application stage of plant growth	Comments
Pseudomonas fluorescens **(e.g. Bio-Cure-B)**	Bacterial	*Pyniculasa oryzae*, Alterneria spp., *Mycosphaerella grasicola*, *Pythium* spp., *Rhizoctonia solani*, *Fusarium* spp., *Botrytis cinerea*, *Sclerotium rolfsii*, and *Sclerotinia homoeocarpa* which cause root rot, root wilt, seedling rot and color rot diseases	Wide range of crops	All stages	Available both in liquid and powder formulation
Trichoderma viride **(e.g. Bio-Cure-F)**	Fungal	Disease-causing pathogens such as *Pythium* spp., *Rhizoctonia solani* *Fusarium* spp., *Botrytis cinerea*, *Sclerotium rolfsii*, and *Sclerotinia homoeocarpa* causing root rot, root wilt, seedling rot and color-rot diseases	Wide range of crops	All stages	Available both in liquid and powder formulation

For proper monitoring, good knowledge of pests and symptoms of diseases on plants is necessary. Some of the reports, tools, books, etc. which provide information on pest identification, and disease symptoms include: The CABI Crop Protection Compendium: The world's most comprehensive site for Crop Protection Information (http://www.cabi.org/cpc); Infonet-Biovision – Plant Health: Pests/Diseases/Weeds (http://www.infonet-biovision.org); Snowdon, A.L. 2010. Post-Harvest Diseases and Disorders of Fruits and Vegetables: Volume 2: Vegetables; Module 4 of the African Organic Agriculture Training Manual, and others.

Farmers are encouraged to practice good moisture management and optimum plant populations to reduce the chances of plant infection by bacterial and fungal diseases like damping off, leaf spots, wilts, mildews and foliage as well as feeding insect pests like aphids, caterpillars, etc. With appropriate nutrition, plants develop stronger cell walls and plant sugar levels which make them less attractive to pests. Farmers who want to reduce their use of curative measures are advised to learn more about the specific nutrient combinations that lead to increased plant sugars and stronger cell walls.

10.2 Curative measures

If all preventive crop protection measures and practices fail to sufficiently prevent economic losses to the vegetables, it may be necessary for the farmers to take curative action once the plots have been infested. Curative control measures in organic agriculture include:

- Biological control with natural predators or antagonistic microbes – these agents can be introduced into the growing crops, however regulations governing their importation/introduction should be observed and followed.
- Spraying natural pesticides based on herbal preparations or other locally available natural products.
- Mechanical control with traps (sticky traps, light traps, pheromone traps, etc.) or through hand picking or removal of pests or infected plant parts.
- Flush off or wash off the pests by spraying clean water on affected plant parts where this is feasible (consider water availability, crop sensitivity, etc.).

Botanical or mineral sprays can be applied curatively. These applications must be repeated as the need arises to ensure good protection. However, it should be not-

Exchange of information on products for pest and disease management

Ask the farmers the following questions to find out about products used for direct pest and disease control:

- Do you know of or use any of the products listed in the slides?
- If so, what are the sources?
- What do you think about the cost of the products?
- Are the products effective in controlling the pests and diseases?
- Besides the sprays, what pest and disease management strategies do you use in vegetable production?
- Do you use local sprays, too? If yes, which farm-made products have proved effective?
- How do you prepare them?

ed that there is restricted use of synthetic chemicals for pest and disease control in organic production. Leaf and seed extracts of the neem tree *(Azadirachta indica)* are some of the most popular botanical pesticides used by farmers against foliage feeding pests in organic vegetable production. The neem leaves and seeds are harvested from trees growing in the wild or on homesteads. In case of infection, rapid reaction (timely spraying) is needed to prevent further spreading of the pathogen or insects. To prevent disease spread, infected plant parts or plants should be removed from the field and disposed of properly.

10.2.1 Commercial disease control products and agents that can be used in organic vegetable production

This section describes some examples of commercial pest control products permitted in organic vegetable production. However, their use should be in accordance with national regulations and legislations. Certified organic farmers are also encouraged to consult with their certifying agencies before using these materials, if available in their area or local sources.

10.2.2 Commercial pest control products and agents that can be used in organic vegetable production

The list on the table is a guide only for certified organic production. Farmers are recommended to contact their local extension services and organic farming certifying agents in their area or country to get an accurate list of those pest control products that are allowed in their area and for the particular crop in question.

A step-by-step exercise for preventive and curative procedures for the control of selected common pests and diseases

Step 1: Decide on two or three pests and two or three diseases to be controlled.

Step 2: Identify the crops and crop stage at which the farmers should carry out the control. Use pest/disease scouting techniques to determine, if the pest or disease is approaching economic threshold levels which necessitate control.

Step 3: Select a small group of participants to address one pest or disease each. Each small group is encouraged to carry out scouting for the assigned pest/disease, they will conduct and record all the necessary preventive measures

AGENTS AND PRODUCTS FOR PEST CONTROL (1)

Examples of agents and products for pest control (1)

Active substance	Derived from	Pests controlled	Examples of crops sprayed	Plant application stage	Comments
Azadirachtin – cold pressed (e.g. Nimbecidine)	Plant extract	Whitefly, aphids, thrips, mealy bugs, caterpillars and leafhoppers in a wide range of crops	Cabbage, broccoli, cauliflower, onion, carrot, coriander, tomato, eggplant, okra, pumpkin, cucumber, water melon, sweet corn	At all stages	• Apply preferably in the early morning or late evening hours. • Add water to Nimbecidine (do not add Nimbecidine to water). • Safe to natural enemies like beneficial parasites and predators
Beauveria bassiana (e.g. Bio-Power)	Fungal	Borers, cutworms, root grubs, leafhoppers, whitefly, aphids, thrips and mealybug	Pulses, plantation crops, vegetables, fruit crops, cereals, flowers and nurseries, green houses	At all stages	• Available in liquid and powder formulation • Apply preferably in the early morning or during the late evening hours. • Safe to natural enemies of pest

This is a guide only; farmers are recommended to contact their local extension services and organic farming certifying agents in their area or country to get an accurate list of the disease control products that are allowed in their area and for the particular crop in question.

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   72

AGENTS AND PRODUCTS FOR PEST CONTROL (2)

Examples of agents and products for pest control (2)

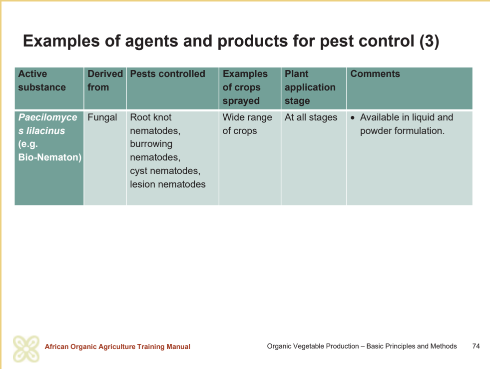
Active substance	Derived from	Pests controlled	Examples of crops sprayed	Plant application stage	Comments
Verticillium lecanii (e.g. Bio-Catch)	Fungal	Sucking pests such as aphids, jassids, whitefly, leaf hoppers, mealy bugs and root mealy bugs	Wide range of crops	At all stages	• Available in liquid and powder formulation
Metarhizium anisopliae (e.g. Bio-Magic)	Fungal	Leaf hoppers, root grubs, borers, cutworms, termites, palm weevils	Wide range of crops	At all stages	• Available in and powder formulation • Safe to natural enemies of pest such as beneficial parasites and beneficial predators
Paecilomyces fumosoroseus (e.g. Priority)	Fungal	Acarine pests like Brown Wheat Mite, Rust mite, Blue oat mites, Red Spider Mites, Pink Mite, Purple Mite, Pale mite, Scarlet mite	Wide range of crops	At all stages	• Available in and powder formulation • Safe to natural enemies of pest such as beneficial parasites and beneficial predators

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   73

Exercise on procedure for pest and disease control

Invite the participants to carry out the exercise on the left.

AGENTS AND PRODUCTS FOR PEST CONTROL (3)



Examples of agents and products for pest control (3)

Active substance	Derived from	Pests controlled	Examples of crops sprayed	Plant application stage	Comments
Paecilomyces lilacinus (e.g. Bio-Nematon)	Fungal	Root knot nematodes, burrowing nematodes, cyst nematodes, lesion nematodes	Wide range of crops	At all stages	• Available in liquid and powder formulation.

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 74

from planting (up to harvest point) and determine when the pest populations or disease infections has reached levels where curative measures should be applied.

Step 4: When the curative stage has been reached, each small group will be given the opportunity explain to the rest of the participants the reasons why they think that curative techniques must start. At this stage, all the small groups will discuss possible curative options to be applied and provide key reasons for their choice of curative measures.

Step 5: For any liquid or powder mixes, each group will demonstrate to the rest of the farmers on the following:

- How best to collect or obtain the ingredients indicating the possible local sources
- Quantities required for successful control
- Any pre-treatments required before the ingredients are mixed (e.g. drying, separation, extraction, etc.) and how this is done
- Mixing procedure (ratios, timing of preparation in relation to expected time of use, containers/tools/equipment required, etc.)
- Application rates and timing, including repeat applications and the basis for this decision
- Disposal of the remaining mixtures, etc.

Step 6: Evaluating the effectiveness of the preventive and curative measures: each small group will report back to the larger group on the following:

- The process undertaken
- Successes/failures/challenges met
- How the challenges (if any) were addressed
- How they will do it differently in the future to improve the effectiveness and efficiency

10.3 Nematode control strategies in organic farming

Nematodes are a common pest across different regions of Africa. They build up quickly when one or more susceptible crop/plant species is/are grown consecutively on the same soil. Once they are established in a site, they are usually persistent and affect growth and yields of many vegetables. Good management will be required on a regular basis to keep nematode populations low. It should be noted, however, that root-knot and lesion nematodes have a wide host range and this may not give the farmer much choice in their crop rotations. The root-knot nematode larvae infect plant roots. This compromises the plant's ability to take up water and sufficient nutrients. Because of their microscopic size, the nematodes go unnoticed until serious symptoms appear. The pathogenic nematode infection points provide easy entry into the plant by root-rot wilt diseases. A plant infected with root-knot nematodes often exhibits the same signs like those of nutrient deficiency. It may be stunted, yellowed, or wilted, and can lead to premature death of the plant. Below the ground, the roots of infected plants are swollen or knotted with root galls and this is a visible sign of the nematode infection. Unless a plant is uprooted for examination, the cause of the poor plant growth remains undetected. The appearance of the galls on the roots can be confused with nitrogen-fixing nodules common in the legume family. However, it is easy to distinguish between them, as the nitrogen nodules can be rubbed off the roots easily while the nematode galls cannot be removed.

There are different strategies that farmers could use to manage nematodes in their vegetable gardens or fields.

Preventive measures:

i. Avoid soil transfer between fields. Farm machinery and equipment such as rippers, hoes, can transfer soil from one field to another. They must be cleaned between use in different fields.

ii. Transplant healthy seedlings and discard the weak ones.

Reducing infestations:

i. Fallowing can starve off nematodes and reduce their populations in the soil. However, this practice may not be feasible where land is limited.

Discussion on nematode problems

Since nematodes occur in the soil, farmers may not readily appreciate their presence and the damage that they cause. The following exercise can help the farmers to distinguish between nematode affected roots and nitrogen fixing nodules. Since tomatoes and potatoes are not nodulating plants, if galls are observed on the roots, these are likely to be nematode galls. Ask the following questions to the farmers:

- Have you experienced nematode problems on your farm?
- Do you know how to identify nematode problems on your farm?
- How have you effectively controlled them?
- Have you tried out growing non-host crops or green manures in rotations or intercrops to reduce nematodes?

ii. Crop rotation and/or use of nematode suppressing plants – some plants commonly used as cover crops are naturally suppressive to certain nematode species. Other plants create an unconducive environment and prevent the nematodes from reproducing. Plant species like marigold and asparagus are known to exude chemicals from their roots that are toxic to nematodes. The incorporation of large amounts of organic matter into the soil reduces populations of plant-feeding nematodes as the decomposition products of some plants can kill nematodes. These products include butyric acid which is released during the decomposition of rye and timothy grass *(Phleum pratense* L. – a grass species native to Europe, northern Africa and Asia), and isothiocyanates, released during the decomposition of rapeseed and other mustards in the genus Brassica, e. g. *Brassica juncea*. Maximum benefit of these 'natural' nematicides is derived when the plant material is incorporated into the soil as green manure. Green manures are not equally effective against all plant-parasitic nematodes. Therefore, a diagnostic lab or extension agent should be consulted to make sure they are appropriate for the nematode species.
iii. Using rotations and/or intercropping – some cultivars of cowpea and black-eyed peas are known to reduce population levels of some nematodes. Velvet beans or mucuna is also a good rotation crop that supresses nematodes. Other suitable rotation crops include onion, baby corn, sweet corn, sorghum, sudan grass, sesame, cassava, and sunhemp.
iv. Incorporating neem cake into the soil
v. Soil solarisation can kill nematodes due to high temperatures generated.
vi. Maintaining high levels of organic matter in the soil
vii. Using virgin nematode-free land for seed beds
viii. Nematicides can be used to control nematodes if the nematodes reach damaging threshold levels. Certified organic farmers must always consult with their certifying agents before using any nematicides.

Minimising nematode damage to crops:

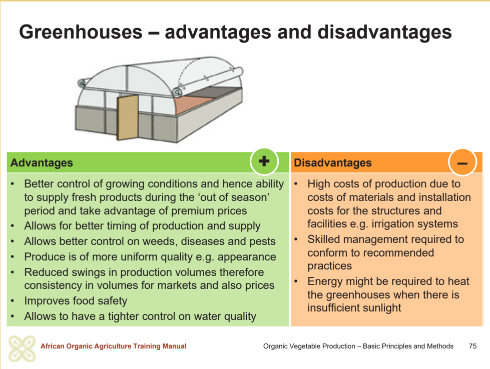
i. Tolerant varieties should be used if available. Vegetable crops that have reasonable resistance to root-knot nematodes include broccoli, Brussels sprouts, mustard, chives, cress, garlic, leek, groundcherry, and rutabaga. Others like globe artichokes, Jerusalem artichoke, asparagus, sweet corn, horseradish, some lima bean varieties, onion, okra, melons, and rhubarb are considered to be tolerant.

Identifying nematode problems

Carry out the following exercise with the farmers using monocropped and intercropped fields.

1. Identify weak tomato or potato plants with signs of unexpected wilting.
2. Dig out a few plants with the roots.
3. If galls are observed on the roots, these are likely to be nematode galls. Nitrogen fixing nodules are normally pink in colour inside.
4. Uproot a legume plant e.g. sugar beans so that farmers can identify nodules and be able to differentiate them from galls on affected tomato or potato plant.

ADVANTAGES AND DISADVANTAGES OF GREENHOUSE PRODUCTION



ii. If crops are not sensitive to cool climates, farmers can adjust their planting dates to cooler times of the year when nematodes are less active.
iii. Ensure that the plants are provided with optimal growing conditions to increase their tolerance to nematodes.

11. Protected vegetable production

11.1 Advantages and disadvantages of producing vegetables under protection

Intensive vegetable production in protected environments such as greenhouses, tunnels, or under shade (controlled culture), is gaining importance in many African countries. Such protected production enables farmers to have a better control of the production conditions (temperature, solar radiation, strong winds, hail, heavy rains, pests, etc.) and also saves on water. Vegetable production under protection can help extend the production season for crops which normally would not be grown successfully at certain times of the year due to harsh weather and challenging conditions faced with open field production. Globally, examples of vegetables that have been produced successfully in greenhouses include tomatoes, cucumbers, peppers, lettuce and herbs. It is worth noting that different crops have different production requirements under greenhouse production. While advantages exist for greenhouse production, there are some disadvantages associated with the practice.

Disadvantages of greenhouses

Despite the several advantages of protected vegetable production, the greenhouses and other structures also have some downsides as follows:

- high cost, especially to low resourced farmers
- diseases and pests can spread fast under greenhouse environment if good preventive methods are not practiced
- requires good technical knowhow and skills for effective management
- relies on irrigation – can use water obtained from dams, rivers, boreholes, or runoff collected from roofs

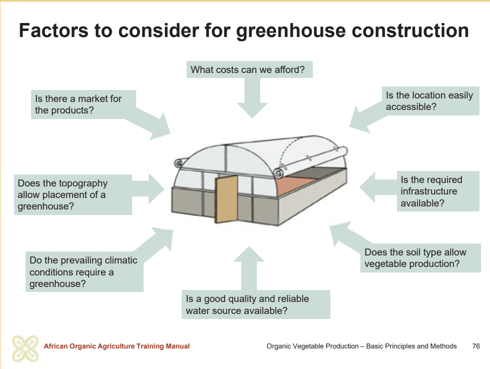
Exchange of experiences on vegetable production in greenhouses

Discuss with the farmers about their experiences with greenhouse production or production under protection. Find out which vegetables they have grown successfully and which ones are problematic. Ask the following questions:

- What do you think are the advantages and disadvantages of greenhouses?
- What challenges, if any, have you encountered?

If the farmers have never used greenhouse before, try to find out the reasons why, and also find out if they consider greenhouses to be beneficial for their future production.

FACTORS TO CONSIDER BEFORE CONSTRUCTING A GREENHOUSE



11.2 Factors to consider before constructing a greenhouse

For successful greenhouse production, farmers are encouraged to consider key economic and environmental factors before constructing the greenhouse. Some key factors to consider are described in the next sections.

11.2.1 Types of products to produce and their market potential

Before investing into the construction and management of a greenhouse, farmers are encouraged to do an assessment of the market and marketing system for their intended products. To do this, they can ask fellow farmers and consult their extension agents or organic certifying agents about the products which are in high demand and at which markets the products are needed. The farmers themselves can also visit different markets and talk to potential buyers about the products. An assessment of the prices offered is also necessary to enable the farmers to establish whether their investment will make good returns for them or not. Transport and accessibility to the markets is also an important factor to consider. With all the necessary information gathered, the farmers must develop a business plan for their greenhouse project. When farmers have an idea of the types of vegetables required at the markets they can then consider other factors as described below.

11.2.2 Prevailing climatic conditions

Temperature

Extreme temperatures beyond the normal growing range for specific crops will affect growth and yields. It is important that farmers consider the seasonal fluctuations in atmospheric temperature, e. g. in the subtropics where seasonal differences in temperature can be pronounced. They can then make plans to control the impacts of this fluctuation when constructing the greenhouses. If farmers are located in areas where temperatures fluctuations are high it will also be necessary to install equipment which monitor temperatures inside and outside the greenhouse so that appropriate regulation of the inside temperature can be done accordingly. High fluctuations in daily temperatures within the greenhouse must be avoided. Temperature regulation measures include good ventilation to allow good air circulation, cooling, or provision of heat (to protect the crops against very low temperatures where this may be necessary). High temperatures, such as those occurring during the middle of the day, can result in high loss of water from the crops and soil through transpiration and evaporation) particularly if the atmospheric relative humidity is low. Accumulation of heat within the greenhouse to excessive amounts must therefore be avoided through proper ventilation and/or cooling.

Relative humidity
The prevailing external atmospheric relative humidity must be taken into consideration when planning to construct a greenhouse. In semi-arid or arid areas where atmospheric humidity is generally low, farmers should avoid the risk of excessive loss of water from the greenhouses by using practices like water sprinkling or misting to prevent plant desiccation. High and excessive relative humidity inside the greenhouse though promotes rapid development of diseases as the high moisture levels will be conducive for spore germination and disease pathogen growth. Ventilation during early morning hours may be necessary to reduce the amount of water vapour that settles (condenses) on the crop leaves.

Rainfall
Although greenhouses can protect vegetables from extreme rainfall events, the greenhouse roofs must be constructed in such a way that excess water can easily drain off. This can be done by harvesting the water into large containers. The water can be used for irrigation or other household purposes. Similarly, plans should be made to drain away excess rain water from around the greenhouse base to prevent water logging and associated problems. If farmers are located in areas where heavy rainfall events are common then proper drainage facilities must be put in place to avoid the risk of rising temporary or permanent water tables near the greenhouse. This measure will help to control water logging and build-up of plant disease which thrive under wet or moist conditions.

Solar radiation
Greenhouses can prevent intense solar radiation from damaging vegetables. This is because the greenhouse covers intercept part of the radiation before it reaches the crops. It is therefore important for farmers to select an appropriate

type of greenhouse cover, particularly in sites where high sunlight intensities occur. The farmers can consult their extension officers or agriculture input suppliers for the suitable types of polythene to purchase.

Sunshine hours

Vegetable growth and yield are affected by the amount of sunlight that the vegetables receive during their growth as this influences photosynthesis. The number of sunshine hours experienced in an area at different times of the year can determine whether or not the vegetables are receiving adequate sunlight. For vegetables which are sensitive to fluctuations in sunlight hours, the regulation of light is important to either increase or reduce the hours during which the vegetables are exposed to light depending on whether the vegetable requires longer or shorter daylength hours. The annual rainfall pattern and accompanying cloudiness experienced in different areas are also critical factors in determining the amount of sunshine received by the crops. Similarly, topography e.g. the presence of mountains has an effect on the quantity of clouds experienced in an area, and the amount of shade posed by the topographic features. It is necessary that farmers consult their extension agents before constructing a greenhouse in order to get advice on whether it is necessary to use greenhouses in the first place, and if so, to then get advice on proper location and construction of the greenhouse. When required, to decrease the number of sunshine hours, the farmers can cover the greenhouses with a dark cloth or similar materials for a certain amount of time corresponding to the number of desired dark hours. In commercial production, farmers often use blinds to block away the sunlight and hence reduce the number of hours that the crops receive light. If farmers need to extend the number of sunshine hours, they can provide artificial lighting inside the greenhouse. However, these practices can be expensive and farmers should ensure that they are necessary for their situation before they invest in them.

Wind

Both the direction and speed of wind are important factors that can affect the performance of a greenhouse. Strong winds can damage, tear down, or blow away a greenhouse particularly if the covering material is poor or not strong enough and also if the poles and covering material are not well anchored into the ground. If strong winds prevail in an area, farmers must construct their greenhouses in such a way that the greenhouse faces the direction of the wind.

The sides of the structure should be slanting to the outside (at the base) so that the wind can move smoothly over the structure rather than hitting against the sides of the structure.

11.2.3 Good quality and reliable water source

Farmers need to ensure that they have a good and reliable source of water for their greenhouse vegetables. The water must be of good quality (drinking level quality). A sample of the water must be sent to a laboratory for analysis so that any corrective measures are done properly. Harvested rain water is often of good quality especially where the levels of air pollution are within acceptable ranges.

11.2.4 Type of soil

Vegetables prefer different soil types as discussed in earlier sections. For greenhouse production, farmers are encouraged to have their soil tested by a soil-testing laboratory before growing crops. Based on the results, the farmers will be more informed and aware of the nutrient status of their soil and pH, in relation to the type of vegetable to be produced. Soilless production can help control soil borne diseases and pests in greenhouses. The limitation, however, could be the lack of or limited availability and/or high costs of the soilless materials, and in some cases this type of production may be considered as not organic.

11.2.5 Location of the site and accessibility to major infrastructure

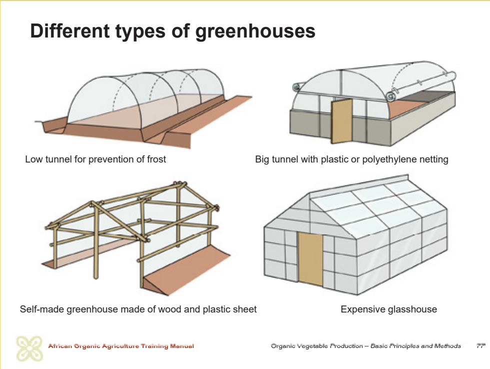
Greenhouse site location must be considered in relation to roads, sources of power or electricity (if artificial lighting or heating is required, or if automated irrigation is to be used) and other services. Farmers can also explore the possibility of using solar or wind power for lighting the greenhouses, or for pumping water for irrigation. However, a proper feasibility assessment will be necessary to determine if this is possible. Availability of private or public transport is another important factor. If transport is unreliable, timely marketing of the vegetables could be jeopardized leading to quantitative and qualitative losses.

Exercise: development of a business plan for greenhouse production

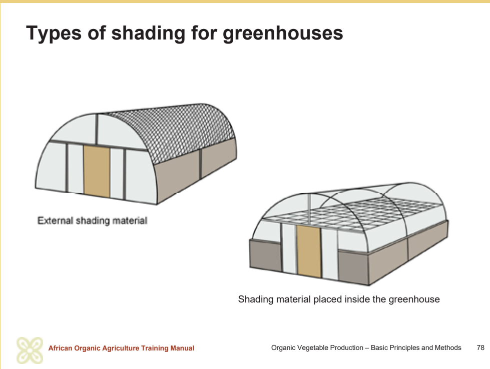
Undertake an exercise whereby the participants can develop a business plan for a selected greenhouse vegetable. The farmers will collect all the information required for them to come up with a good business plan. The business plan must show the following main components:

- Reasons why the greenhouse must be constructed (environmental or socio-economic factors to be addressed, indication of the potential benefits/profits)
- Type and size of greenhouse to be constructed, reasons for the choice
- Management plan (planting, irrigation, rotations, timing, responsibilities, etc.)
- Marketing strategy
- Records to be taken
- Any other relevant information

TYPES OF GREENHOUSE



SHADING OF GREENHOUSE CROPS



11.2.6 Topography and drainage

Land topography (e.g. features such as hills, mountains, slope, valleys, rivers, etc.) affects accessibility of an area, drainage mechanisms, irrigation practices and other characteristics of the site. A flat area or horizontal surface is best suited for locating a greenhouse.

11.2.7 Socio-economic considerations

The following socio-economic factors must be considered before establishing a greenhouse and incorporated as part of the business plan

- Labour requirements for intensive production, including availability during peak harvesting periods
- Good skills to manage the greenhouse and other infrastructure and special operations
- Cost of constructing and managing the greenhouse in relation to projected benefits: farmers can assess the feasibility of their investment through a cost : benefit analysis of protected production before they embark on such an intervention
- Investments and repayments for any loans which the farmers may take up to finance the greenhouse project

11.3 Types of greenhouses and construction materials

Greenhouses can range from simple homemade designs to sophisticated prefabricated structures. They can be very low tunnels (30–60 cm high) for short vegetables (e.g. for protecting beans, lettuce, etc. from frost and pests), medium height (60-100 cm), or tall (up to 2 m high or more). Wood, aluminium and polyvinyl chloride (PVC) poles can be used to construct the structure. Glass, ultraviolet (UV) light resistant polyethylene plastics and netting material can be used for covering the structures. The materials selected must not cast shadows on the crops as this will affect proper growth. Polyethylene and shade net are preferred to glass because they are cheaper to buy and to install, and are also easier to work with. The strength and durability of covering materials should be considered when buying. Cheaper materials may require more regular replacement compared to the more expensive stronger types. If farmers have limited starting capital then they could begin with cheaper materials and change to stronger ones later if the production proves to be profitable.

In hot climates, it might not be necessary to construct a greenhouse with the objective of increasing heat to vegetables. It would be necessary, however, to protect sensitive vegetables from frost in susceptible areas. Additionally, it would also be necessary to provide a screen or reflective material to reduce the light intensity. The types of reflective materials to use ought to be checked with the organic certifiers.

11.4 Plant growing medium for greenhouse production

In the greenhouse, crops can be grown directly into the soil or in containers using soilless mixes. A third method called hydroponic production involves the use of nutrient film technique (NFT) and all nutrients required by the plant are supplied through the irrigation water. This third method may not be suitable for organic farmers since nutrient application from e. g. compost through the irrigation system will be a challenge unless if their liquid forms (e. g. leaf or manure teas) are used. Some proponents consider hydroponics as not being an organic compatible production practice. Again the farmers are encouraged to consult with their extension agents and organic certifiers if producing for certified organic markets.

11.5 Managing water in a greenhouse

In general, greenhouse production uses less water, about 30 % less depending on management practices, compared to open field production. To reduce water wastage, farmers can install a drip irrigation system in their greenhouse. This method, however, requires high levels of management including good water filtration to prevent blockage of the drip holes. In arid areas, loss of water due to evaporation is much higher and irrigation demands are higher compared to tropical areas. Irrigation scheduling is important and must take into consideration the crop type and water loss levels as discussed in earlier sections. Greenhouse

Exercise for the construction of a modest greenhouse

Undertake an exercise with the participants to plan for constructing a modest greenhouse. The farmers will go through the process of:

- Selecting the site (taking into consideration various factors as discussed above)
- Determining the size of the greenhouse
- Determining the different types and estimating the quantities of materials required for construction

production can therefore help farmers in arid areas to reduce evaporation and transpiration losses hence save water and increase production efficiency.

11.5.1 Controlling salt build up in greenhouse soils

Good quality water with acceptable levels of salt must be used for irrigation. If farmers use salty water for their greenhouse, the salt will accumulate in the soil and will need to be washed out of the top soil layers to prevent harmful effects to the crops. This can be achieved through applying large amounts of water to leach out the salts. It is therefore, recommended that farmers prevent this problem by using good quality water.

12. Harvesting vegetables

Most vegetables, particularly the fresh leafy and fruit types, are highly perishable. They quickly grow and as soon as they reach the peak maturity (i. e. right harvesting stage), they start to deteriorate at a fast rate. This normally depends on the environmental conditions – warm weather encourages quicker maturation and also deterioration. Harvesting practices should minimize mechanical damage to the produce as much as possible. Due to their high sensitivity to mechanical damage, vegetables must be picked or dug (if toots/tubers) and handled as gently as possible to reduce postharvest problems.

Food safety is a major concern in vegetables, particularly considering that some vegetables are consumed raw without being subjected to heating temperatures which can help to destroy some pathogens. Farmers and others in the vegetable value chain (from production to distribution and marketing) must observe and practice good hygiene to avoid contamination with harmful pathogenic microorganisms, harmful chemicals and lubricants, insects, animal waste (including human), and other contaminants such as dirt, dust/sand, wood chips, plant debris, etc. as discussed already in earlier chapters.

Exchange of experiences on determining the stage of harvest

Find out from the farmers how they determine when to harvest the vegetables which they grow. Discuss difference in harvest timing as influenced by types of markets (fresh fruit or processing), market distances from their gardens, availability of cold storage facilities, etc.

DETERMINING WHEN BEST TO HARVEST VEGETABLES (1)

Harvest indices for vegetables (examples) (1)

Vegetable type	Examples	Harvest indices
Leafy	Kale, spinach	• Days from transplanting, leaf appearance (marketable size, changes in shape, changes in surface characteristics)
	Cabbage, lettuce, Brussel sprouts	• Days from transplanting, solid feel of the head
Flower	Broccoli, cauliflower	• Days from transplanting, shape and compactness of the head
Fruit	Tomato	• Days from flowering, external colour change (may require special equipment in order to be accurate and avoid missing the right stage of harvest) • Appearance (changes in internal structure e.g. development of the jelly layer in the fruit)
	Honeydew melons, eggplant	• Appearance (development of a glossy/waxy surface on the skin)
	Some pumpkins, okra; peas	• Texture (feel) – development of a hard skin
	Water melon	• Appearance (internal colour change)
	Musk melon	• Easy to detach from main plant (abscission layer)

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 79

DETERMINING WHEN BEST TO HARVEST VEGETABLES (2)

Harvest indices for vegetables (examples) (2)

Vegetable type	Examples	Harvest indices
Root/Tubers	Carrot	Days from sowing; shape (e.g. uniform root tapering)
Bulbs	Dry onions	Days from transplanting, when the tops start to collapse
	Green onions	Anytime when the leaves are still green

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 80

12.1 Timely harvesting

12.1.1 Determining the stage of harvest

Vegetables need timely harvest in order to obtain the best quality at harvest and thereafter. Too early or too late harvesting can result in poor quality and affect the shelf life of vegetables and their ability to be transported to distant markets. Depending on the type, harvesting can be done before physiological maturity provided that the vegetable has reached horticultural maturity. In general, farmers use different types of methods to determine when to harvest a particular vegetable. These may vary from simple techniques to sophisticated methods which may require special types of equipment to be used. For example, tomatoes can be harvested at the mature green or pink stage as a way of prolonging their storage and/or transportation period before they become fully ripe. For fruit vegetables that require ripening before consumption, too early harvesting can result in failure of the fruit to ripen well after harvest and this will affect quality attributes such as colour, texture, taste and general appearance during the postharvest life.

Different methods, known also as maturity indices (index), can be used by farmers to determine when to harvest different types of vegetables. These methods include:

i. Changes in chemical composition (e. g. accumulation of sugars in fruit vegetables, change in acid content (sources), loss of bitterness, change in starch content, production of certain gases e. g. ethylene, etc.). These indices require suitable equipment for their proper determination
ii. Changes in physical or visual appearance (e. g. weight and size changes, change in colour, disappearance of surface structures such as hairs, development of a glossy or shiny appearance, e. g. eggplant)
iii. Development of an abscission point (a weak layer of tissue called the abscission layer develops at the base of each leaf stalk (or petiole) or fruit stalk and allows the leaf or fruit to fall easily during harvesting or when they fall naturally from the parent plant)
iv. Aroma development
v. Other characteristics or strategies – here the farmers can add their own methods of how to determine maturity or when to harvest certain crops

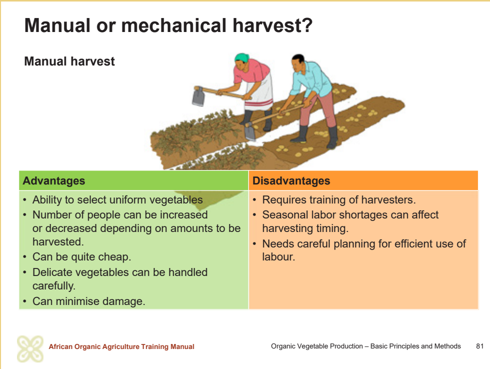
Ethylene

Ethylene is a gas produced to varying extents by some ripening vegetables and fruits, and other products. It is one of the major factors influencing shelf life and postharvest quality of harvested products. The gas causes both desirable and negative effects to vegetables depending on the type and their sensitivity to ethylene damage. For example, ethylene hastens ripening of tomatoes and many fruits and enhances their flavour, taste and other attributes such as colour development. However, if such fruits are intended for long distance markets, ethylene production can actually reduce the keeping time of such products by causing them to ripen prematurely before they reach the market. Farmers should note, however, that exposure to ethylene can cause undesirable disorders like browning or accelerated deterioration in certain vegetables. While ethylene is produced naturally by plants, it can also be produced by rotting vegetables. It is also present in products such as smoke and can cause unintended effects. It is important that damaged and rotting vegetables are removed before they spoil others in storage (this is where the old saying that 'one rotten apple spoils the bushel' is derived from). Farmers need to know and take into consideration the differences in ethylene sensitivity of vegetables and avoid mixing high ethylene producers like cantaloupe and tomatoes (and fruits such as bananas, apples and pears) with sensitive vegetables like eggplants, lettuce, spinach, carrots, cucumbers and others during handling and in storage. A general guide on compatibility of vegetables during storage should be understood by the farmers to avoid losses. Some of the desirable and undesirable effects caused by ethylene during storage include the following:

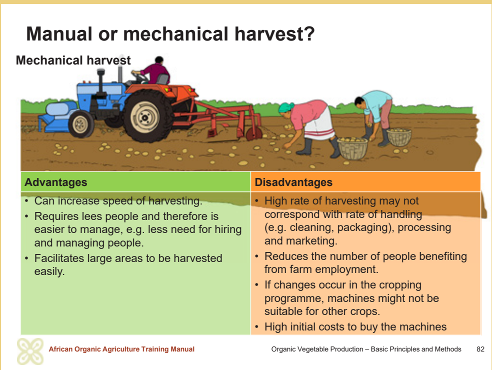
Note:

1. Not all effects of ethylene exposure are detrimental. In conventional production, ethylene can be used to accelerate ripening and to achieve uniform ripening of fruits like bananas and fruit vegetables like tomatoes that are harvested at the mature green stage.
2. In organic, the use of ethylene is regulated. Before farmers use any ethylene producing products to enhance ripening, they should consult with their extension agents and/or certification bodies in order to get the right information and act accordingly.

ADVANTAGES AND DISADVANTAGES OF HAND HARVESTING



ADVANTAGES AND DISADVANTAGES OF MECHANICAL HARVESTING



12.1.2 What is the best time of the day to harvest vegetables?

Harvesting is preferably done in the early morning hours, preferably before the sun comes up, because at this time the vegetable leaves and/or fruits will be very firm and can store longer. This high firmness is a result of greater moisture absorption than loss by the plants during the cool night environment. Harvesting late when it is hot and the vegetables are warm or hot may speed up wilting and reduce shelf life. Suitable harvesting tools and containers must be used to reduce any form of damage to the produce. Poor harvesting practices and timing can result in higher levels of bruising and other types of physical damage as well as wilting of the harvested produce.

12.2 Methods of harvest

Most smallholder farmers commonly harvest their vegetables by hand. With large scale production, it may be necessary for farmers to use mechanical methods of harvest. Both methods have advantages and disadvantages related e.g. to the speed of harvest, resultant quality of harvested produce and loss of this quality, and other factors.

12.3 Harvesting tools and containers

Knives, pruning shears and other sharp-edged tools can be used for harvesting different types of vegetables without much damage. Some vegetables are easier to harvest as they develop natural break points at the junction of the stem and the stalk when mature. Vegetables can be harvested into small containers like baskets, tins, trays, boxes, bags or other suitable types. From these, the harvested products are frequently emptied into larger field containers. In some cases, harvesters can pick vegetables directly into the large field containers. The following are some ways which can help to reduce physical damage during harvest:

› Ensure that harvesters' fingernails are well trimmed
› Remove jewellery (it may cause scratching)
› Wear gloves when harvesting delicate vegetables

Discussion on harvesting methods

Discuss the methods of harvest for different vegetables which farmers in the locality use. For each vegetable, outline the advantages and disadvantages including the challenges/constraints faced by the farmers. Discuss how the farmers overcome the stated constraints or how they think that the challenges can be addressed.

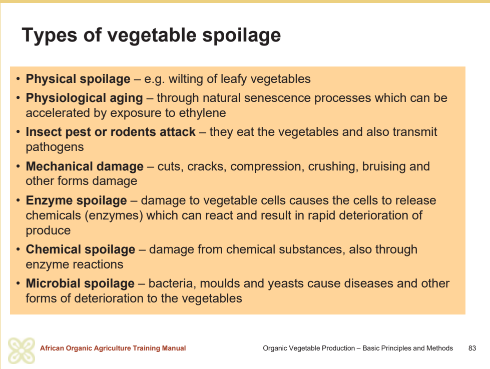
- Use sharp harvesting tools. Knives must have rounded rather than pointed tips to avoid poking or scratching the produce
- Avoid holding the delicate plant parts during harvesting
- Careful emptying of picking baskets, bags or other containers into the large field containers
- Avoid overfilling both the picking and/or field containers especially if they are to be stacked
- Use picking and field containers which have smooth insides and edges
- Reduce the amount of produce handling: e.g. practice field packing where possible. This means that the harvested produce undergoes selection, sorting, trimming and packaging in the field soon after harvest instead of transferring them to packing sheds where they will be offloaded and undergo a number of handling steps before they are packed and sent to the markets.

13. Vegetable postharvest handling and management

Once harvested, farmers should strive to maintain vegetable quality and prolong its useful time. The activities involved in vegetable postharvest include i) field and post-field handling, ii) cooling or shading, iii) curing, e.g. for onions and potatoes, iv) cleaning, v) packaging, vi) storage, vii) processing, viii) transportation, ix) and all activities which happen during the marketing stages until the vegetables are consumed. The postharvest performance of vegetables depends on many factors which include:

- Type of vegetable and perishability characteristics
- Variety type, e.g. skin thickness
- Prevailing environmental factors during field production and during harvesting e.g. soil type, temperature, and wind during fruit set, sunlight intensities, frost and rainy conditions during harvest can also influence the overall quality, shelf life and suitability of the vegetables for transportation.
- Field husbandry practices – e.g. protection from high sun intensities during the field stage, earthing up for potatoes and carrots (green sections on potato tubers, green shoulders and green cores in carrots due to exposure to the sun if the roots are not well covered with soil)
- Harvest timing and practices
- Cooling or shading

TYPES OF VEGETABLE SPOILAGE



Discussion on harvest-related topics

Discuss the following harvest-related topics with the farmers:

- How do you normally harvest the vegetables (use specific examples of the most commonly grown vegetables)?
- What types of tools are available for harvesting different types of vegetables?
- What types of containers do you use for picking, for bulking, and for transporting the harvested produce to the farm sheds or to the markets?
- Are there any problems or challenges associated with the harvesting methods, tools and/or containers used? If yes, discuss these and provide possible solutions.

DON'T'S FOR FRESH PRODUCE STORAGE

Don'ts for fresh produce storage

- **Do NOT** handle crops for storage when they are wet.
- **Do NOT** overload storage rooms or stack containers too close together.
- Avoid lower than recommended temperatures.
- **Do NOT** stack containers beyond their stacking strength.
- **Do NOT** store onions or garlic in high humidity environments.
- Avoid storing ethylene sensitive vegetables with ethylene producing vegetables.
- Avoid storing produce known for emitting strong odors (apples, garlic, onions, turnips, cabbages, potatoes) with odour-absorbing commodities.

Source: Adapted from Kitinoja and Adel, 2015

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 84

DOS FOR FRESH PRODUCE STORAGE

Dos for fresh produce storage

- Know the requirements for the vegetables you want to put into storage.
- Store produce of proper maturity which is free of damage and decay.
- Cure root, tuber and bulb crops before storage.
- Provide shade for storage structures with a roof overhang of at least 1 meter, or paint buildings white or silver to reflect heat.
- Keep the storage room dark.
- Keep the storage facility clean and free from rodents by keeping the immediate outdoor area clean, and free from trash and weeds.
- Ensure proper air circulation leaving air space between the stacks and the walls, and place produce upon pallets.
- Provide adequate ventilation in the storage room.
- Place thermometers at several locations to monitor storage room temperature.
- Inspect stored produce regularly for signs of injury, water loss, damage and disease.
- Remove damaged or diseased produce to prevent the spread of problems.

Source: Adapted from Kitinoja and Adel, 2015

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 85

- Handling methods for produce
- Postharvest treatments
- Storage conditions
- Transportation to markets (including distances to the markets and other factors.

During the post-harvest stage of organic certified produce, any kind of contamination e.g. by pathogens, pesticides, disinfectants or other chemicals must be avoided. Practicing good hygiene has high importance. Organic farmers may harvest and market their produce just before or at peak ripeness; therefore, timeliness and handling assume even greater importance. Most small-scale farmers lack suitable storage facilities to help them to maintain quality. The following general practices can help organic farmers to maintain the quality of their produce after harvest:

- Avoid harvesting during hot times of the day. Harvesting during the coolest time of day will help to lower respiration and water loss from the vegetables.
- Take care to avoid or minimise produce damage such as wounding, bruising, crushing, cuts.
- Avoid prolonged exposure of the harvested produce to the sun. When available, the harvested produce must be moved to cooling or cold storage facilities as soon as possible.
- Keep the harvested produce cool and minimise respiration and water loss by providing shade to the harvested produce
- All damaged or decaying produce must be disposed and never allowed to mix with the undamaged or healthy produce.
- Clean site before handling produce.
- Use only clean water to wash vegetables, or for removing field heat which can otherwise accelerate deterioration of the produce.
- Wear clean clothes and always wash hands before handling foods.
- Do not eat or smoke while handling produce.
- Avoid contamination - use clean packages and containers.

Exchange of experiences and discussion on postharvest practices

Ask the farmers the following questions:

- What is your understanding of the term postharvest? Do you perceive it as inclusive of the harvesting stage to consumption?
- What are the major postharvest practices, treatments, handling and storage applied to different types of vegetables? Discuss the differences, similarities and why the differences exist. Discuss the appropriateness of the techniques applied for the different types of vegetables.
- What are the major postharvest problems that you experience for the different vegetables?
- How do you think that postharvest life of the vegetables can be improved under the prevailing situations?

14 Vegetable postharvest handling and management

14.1 Postharvest handling practices/procedures

Cooling and precooling

Similarly, to other production methods, cooling is one of the most important handling practices for organically produced vegetables. All harvested produce must be kept under shade. Types of shade in the field can include the following:

- Clouds in the sky: if possible harvest on a cloudy day
- Trees or large plants such as bananas under which the harvested produce can be kept pending transfer to the farm shed or markets. In other cases, the large banana leaves can be used to cover the harvested produce.
- Simple sheds constructed from simple materials at different places in the field
- Covers, e.g. light-coloured canvas cloth, plant leaves (e.g. banana) or branches, straw
- Inverting an empty container on top of the one filled with vegetables – this allows good ventilation or air circulation to avoid/reduce the built up of heat within and around the produce.
- For leafy vegetables, a tub containing water can be brought to the field if harvested quantities are small.
- At the field, farm or community levels, simple cooling structures can include grass thatched structures with straw/charcoal insulated walls. Others include below ground structures constructed to preserve root/tuber types of vegetables like potatoes and sweet potatoes.

Care should be taken to avoid heat build-up in the shaded produce especially when polythene-based covers are used and with little or no ventilation. Leafy vegetables can be sprayed or sprinkled regularly with clean water to reduce loss of water from their surfaces and hence protect them from wilting. If cooling facilities such as a cold room are available, the harvested vegetables must be transferred from the field to the cooling place as soon as possible. Depending on the context and facilities available, farmers can apply some of the following techniques:

Discussion on cooling practices for vegetables

Discuss with the farmers about the following issues relating to cooling of vegetables:

- Heat sensitivity of different types of vegetables
- Cooling practices for harvested vegetables and cooling techniques used
- Access to local and distant cooling facilities: Do they construct their own (temporary or permanent) cooling facilities? Which types of materials are used and how is their cooling effectiveness?
- Challenges faced with cooling practices used and possible solutions

SUITABLE STORAGE CONDITIONS

Suitable storage conditions for selected vegetables

Vegetable	Optimal storage temperature (°C)	Optimal relative humidity (%)	Estimated storage period
Asparagus	0 - 2	95 - 100	14 - 21 days
Broccoli, Brussels sprouts	0	95 - 100	
Cabbage	0	98 - 100	3 - 6 weeks
Carrot (mature)	0 - 4.4	98 - 100	7 - 9 months
Cauliflower	0	95 - 100	
Egg plant	7.8 - 12.2	90 - 95	1 week
Kale	0	95 - 100	2 - 3 weeks
Lettuce	0	98 - 100	2 - 3 weeks
Okra	7 - 10	90	7 - 14 days
Onion (green)	0	95 - 100	
Onion (dry)	0	65 - 70	1 - 8 months
Potato	4.4	90 - 95	4 - 5 months
Spinach	0	95 - 100	10 - 14 days
Sweet corn	0	90 - 98	5 - 14 days
Tomato (ripe)	7.8 - 10	90 - 95	4 - 7 days

Sources: Hardenburg et al., 1986; Kader; 1992; Saltveit, 1993

PROLONGING SHELF LIFE OF VEGETABLES

Prolonging shelf life of vegetables through icing

Vegetables which can be iced (examples)	Vegetables which should not be iced (examples)
Asparagus	Cucumbers
Beets	Garlic
Broccoli	Green beans
Cauliflower	Okra
Green onions	Onion bulbs
Leafy greens	Romaine lettuce
Radishes	Squash
Spinach	Tomato

a. **Hydrocooling:** when available, cold water (hydrocooling) can be used to remove the field heat by immersing the harvested produce, like leafy vegetables, into the cold water for some time. For some produce like snap beans, hydrocooling leads to rapid cooling, however significant postharvest decay can occur if the snap beans remain wet afterwards.
b. **Forced-air cooling:** Forced-air cooling is a better method for cooling, e.g. packed snap beans as optimum cooling can be achieved without leaving free moisture on the products. However, the forced air cooling will need to be done in a place with high humidity to avoid excessive water loss from sensitive products. Perforated plastic wrapping can help to reduce water loss.
c. **Precooling through vacuum cooling**, and various combinations of cooling methods, can also be applied.
d. **Ice:** Ice in packs or added into cartons in liquid form can be used to maintain the quality of some vegetables, e.g. during transit. This technique, however, is not applicable to all vegetables due to differences in sensitivity to damage by the ice.

Examples of suitable precooling methods for selected vegetables are explained below. The usefulness of the techniques discussed depends on the type of smallholder farmers in question. Some of the higher technology types suit farmers who are working in groups and aggregate their produce for sale, or farmers who are producing at a larger scale and engage in commercial horticulture.

Table: Commercial precooling methods for selected vegetables
(adapted from https://rvpadmin.cce.cornell.edu/uploads/doc_500.pdf)

Category	Examples	Precooling requirements and cautions
Headed types	Broccoli	Injecting liquid ice into field-packed broccoli packaged in waxed cartons. Hydrocooling and forced air cooling are also possible if low temperatures can be maintained during the process.
	Cabbage	Hydrocooling is needed before storage. When harvested under cool conditions, cabbages can be placed in storage and cooled without precooling first. Forced air-cooling in storage can be used to quickly to remove field heat from cabbages.

Activity on simple cooling techniques for vegetables

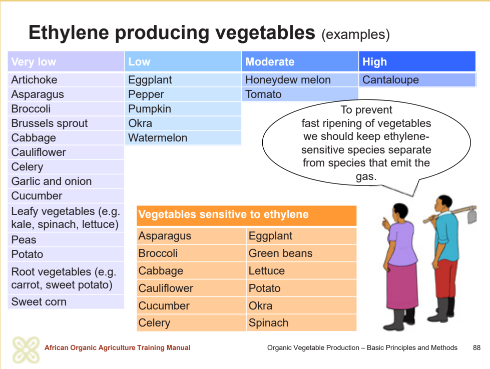
Construct a sand or charcoal coated cooling shed for storing fresh vegetables (or another appropriate type of structure depending on available raw materials). For details see i) Kitinoja L. and Kader A.A. 2003. Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition), Postharvest Horticulture Series No. 8E; University of California, Davis; ii) Nenguwo N., 2000. Appropriate Technology Cold Store Construction and Review of Post-harvest Transport and Handling Practices for Export of Fresh Produce from Rwanda, Chemonics International Inc.).
Evaluate the effectiveness of the structure in prolonging the shelf life by comparing the vegetables stored/held in the coolers and those held under normal conditions as practiced by the farmers.

Headed types (conti-nued)	Lettuce and other greens	Quick cooling to 0 °C is important for lettuce and other greens. Vacuum cooling with of the produce in perforated or water permeable film wraps is preferred. Hydrovacuuming can reduce water loss during cooling. If hydrovacuuming facilities are not available, clean water can be sprinkled onto the produce before closing the cartoons to help with cooling if the lettuce heads are dry and warmer than 25 °C at harvest. For non-heading lettuce types, hydrocooling can be used, but with heading lettuces this precooling method leaves some water retained in the head and this promotes decay and deterioration.
Fruits	Tomato	Forced air results in more uniform ripening compared to room cooling.
	Eggplant	Rapid pre-cooling to 10 °C is needed. Hydrocooling, forced-air cooling or room cooling after washing are possible.
	Bell peppers	Forced-air cooling, hydrocooling, or vacuum-cooling can be used.
	Cucumber	Hydrocooling and forced-air are suitable. However, the cucumbers should not be held at chilling temperatures for more than 6 hours as this causes chilling injury.
Roots	Topped Carrot	Should be washed and cooled immediately after harvest to <5 °C in order to maintain crispiness and freshness.
	Beetroot	Hydrocooling, forced-air cooling, and package icing can be used. Bunched beets should be precooled rapidly to below 4 °C.
	Turnip	Hydrocooling, but if the water is too cold (>10 °C difference with the root temperature) cracking of the turnips can occur.

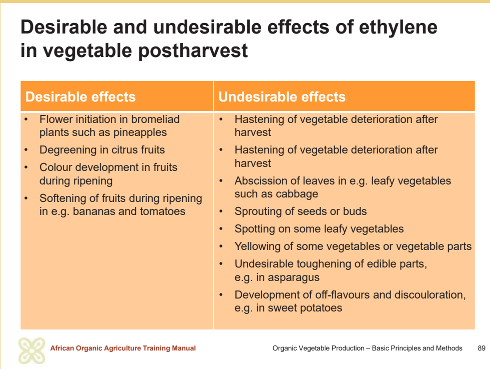
Exchange of experiences on icing

Find out if the farmers have ever heard about the icing method before. If they are aware of the method, find out if they have ever used the method, and for which vegetables, the sources of ice, and discuss any challenges faced and possible solutions.

ETHYLENE PRODUCING VEGETABLES



EFFECTS OF ETHYLENE TO VEGETABLES



	Onion (dry bulb)	Precool the bulbs to 0 °C soon after drying or using cool air. The speed of precooling is important – rapidly cooling the bulbs inhibits rooting and sprouting during storage while the slow natural cooling enhances storability when the onions have a long rest period and weather conditions are conducive for curing.

Cleaning

Some vegetables should be cleaned before storage to remove, soil/dirt, dust, plant debris, insects, and other unwanted materials adhering to the vegetables. In most cases, the cleaning before storage should be dry, because wet treatments can help to spread bacterial or fungal pathogens on the vegetables resulting in rapid deterioration of the produce. After storage and shortly before marketing, a final cleaning step is made. It they have to be washed, drinking quality water must be used. Dry vegetables (e.g. bulb onions) must not be washed.

After cleaning, the produce is sorted/graded, inspected for damage and kept under cool conditions (at least under shade) in order to increase shelf life. If no cooling facilities are available on site, most vegetables, particularly the leafy types, should be delivered to the market within hours on the same day that they are harvested.

Other postharvest treatments

Some vegetables require some treatments before storing. For example, onion and potatoes require curing. Potatoes intended for long term storage (up to 12 months) should be first stored at around 15 to 20 °C and 90 to 95 % relative humidity for about 10 days to cure them before storage. Curing stimulates wound healing on the potato skins and helps the skins to thicken thereby reducing water loss from the tubers during storage. These wounds may have been caused by damage during digging at harvest and bruising or cuts during handling after harvest. If not cured, the tubers will lose a lot of water through the wounds and result in economic weight loss. The wounds will also provide entry to pathogens and hasten rotting during storage.

Exchange of experiences on cleaning

Find out from the farmers if they clean any of their vegetables. If so, ask them the following questions:

- How do you clean the different vegetables?
- Where do you get the water from and what do you think about the water quality?
- Have you ever sent the water to a laboratory for quality testing?
- What are the challenges, if any, faced with vegetable cleaning?
- What are possible solutions?

SYMPTOMS OF ETHYLENE INJURY

Symptoms of ethylene injury in vegetables

Species	Symptoms	Species	Symptoms
Asparagus	Increased toughness	Garlic	Off-flavours, sprouting
Broccoli	Yellowing, florets abscise, off-flavours	Lettuce	Russet spotting
Brussel sprouts	Yellowing	Onion	Off-flavours, sprouting
Cabbage	Leaf yellowing, leaf abscission or fall	Okra	Loss of green color
Cauliflower	Leaf yellowing and/or browning, leaf abscission	Potato	Sprouting
Carrot	Bitterness	Tomato (ripe)	Tissue softening, decay
Cucumber	Yellowing, accelerated softening	Spinach	Accelerated yellowing
Egg plant	Brown spots, browning of flesh and seed, decay	Sweet corn	Can cause husk yellowing

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 90

Handling

From the time when vegetables are harvested until the time that they are consumed they undergo different forms of handling and environments. Handling happens during the following processes: i) picking or harvesting, ii) cleaning, iii) grading and or sorting, iv) packing v) transfer to storage, vi) cooling, and vii) transporting from the field to packing places in shed houses, or from the farm to the markets. This intensive handling can result in damage such as bruising, cuts, cracking, and compression. Other forms of injury, e.g. of a physiological nature, can also occur during handling, for example through exposure to ethylene gas which can cause damages to sensitive vegetables. Bruising is known to result in undesirable quality attributes such as browning of produce, e.g. in lettuce, and this renders the produce unattractive to consumers. Any physical damage to harvested produce also provides entry points for disease pathogens such as fungi and bacteria. These can hasten deterioration of the produce before it is marketed or consumed.

14.2 Sorting and packaging

Sorting

If no field sorting has been done, soon after cleaning the vegetables must be sorted or graded to achieve uniformity based on size, shape, weight or colour, etc. Sorting must be done regardless of whether the vegetables are destined for fresh or processed market. For fresh markets, consumers usually prefer uniform vegetables in a package. For processing, sorting the vegetables by size is especially important if they are to be dried or heated as size significantly determines the drying or heating time required. Specialized processing industries (e.g. potato crisps) have detailed sorting criteria which must be followed carefully. This means that farmers should base their grading and sorting on the requirements and specifications of the target markets.

Packaging

Packages should contain the produce and offer them good protection from damage or injury, contamination and water loss. There are many different types of packages available. They differ in design, size, type of material, and other characteristics. Bags, crates, hampers, baskets, cartons, bulk bins, and palletized types

Exchange of experiences on storing vegetables

Ask the farmers whether they store any vegetables after harvest. If so, discuss further to establish the following:

- For what purpose do you store the vegetables and in what form? Are the vegetables stored for consumption later, or for sale?
- Are the vegetables stored fresh or in processed forms? If they are stored in a processed form, discuss briefly the types of processing used.
- In which places and containers and under which conditions are the vegetables stored?
- Which challenges are faced in storage? Discuss possible solutions.

are examples of packages. Packages must have smooth insides to avoid inflicting scratching damage on the produce. The types of packages used must make the vegetables convenient for handling and distribution (including transportation and marketing). When packaged, the produce should fit well inside the container, with little wasted space. The size and shape of produce partially determines the type of package to be used. While potatoes and onions can be packaged in a variety of packages, specialised types are required for other types of vegetables such as cherry tomatoes, asparagus. Caution should be taken not to exceed the recommended weight for hand handled packages to minimise damage and reduce strain to those involved in manual lifting of the packages. For example, in the USA hand held containers should not exceed 50 pounds (slightly over 22 kilograms). Where mechanisation is possible, larger containers with much higher weights can be used with fork lifting.

Some vegetables tolerate compression damage to some extent. With proper care taken, vegetables such as cabbages, onions and pumpkins can easily be transported to reasonably distant markets at the back of a truck with minimal damage inflicted. Other produce like lettuce, tomatoes and zucchinis are more fragile and more susceptible to compression, bruising and other types of damage. However, tomatoes varieties with a firmer texture and stronger skin suffer less damage during transportation compared to other varieties.

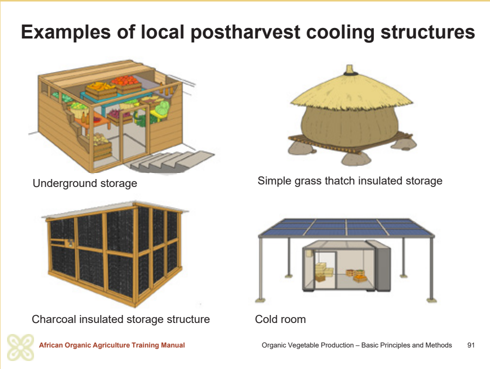
Cost should be considered in selecting the type of package to use. Environmental considerations must be taken into account also – biodegradable, renewable and recyclable types cause less harm to environment compared to durable plastics for instance. Finally, packing materials must not contain chemicals which contaminate the foods. Never use containers which have previously been used for storage of inorganic fertilisers, petrol, paints, pesticides or other chemicals. Especially with plastic materials, organic farmers are advised to buy only packaging materials which are explicitly destined for food packaging. The packages must allow for good ventilation during transportation to avoid moisture accumulation on container surfaces and around the produce as this leads to rapid deterioration.

Exchange of experiences on sorting and packaging

Ask the farmers the following questions:

- Do you sort/grade your produce? If so, which vegetables do you sort/grade? Which criteria do you use for sorting?
- Do you package the produce before sending to the markets? If yes, discuss the types of packages used, their pros and cons, including accessibility and sources, as well as perceptions on sustainability?
- Do you practice any curing for the produce? If so, which ones and how?

DIFFERENT TYPES OF LOCAL COOLING STRUCTURES



14.2.1 Storage and storage conditions

Due to their high perishability, most vegetables cannot store well without proper storage conditions and facilities. To reduce water loss and slow down deterioration in harvested vegetables, it is generally advisable that vegetables are stored at low or relatively low temperatures and high humidity. Optimal storage temperatures are higher for those vegetables that originated from the tropics and subtropics. Those from temperate climates require lower storage temperatures. The specific requirements differ from crop to crop.

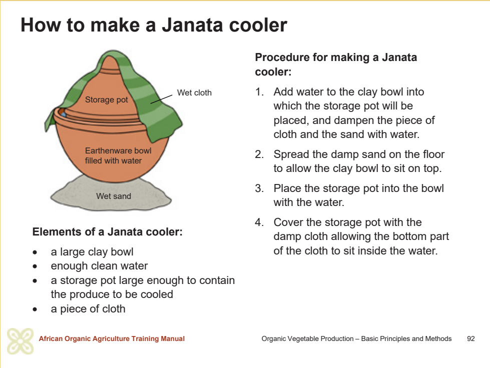
Many smallholder farmers face storage constraints due to lack of appropriate facilities for storing their vegetables and hence suffer significant losses. Severity of loss is higher if no ready markets are available, or if marketing is delayed due to various reasons such as unavailability of transport at the required time. To reduce losses and keep produce for longer periods, farmers can use several on-farm storage practices and techniques as described in the next sections. In doing so, farmers need to be aware that vegetables (and fruits) which contain a lot of water like green leafy vegetables, potatoes, cucumbers, tomatoes and others are all highly vulnerable to damage by freezing. Hence, any exposure to frost during storage can damage the vegetables and protection must, therefore, be provided. Storage structures built or set up on the farm can vary from simple to sophisticated types depending on the farmer's situation and objectives for the storage.

Examples of farm level storage strategies for vegetables

a) Pot-in-pot evaporative cooling

A small simple evaporative cooling structure can be assembled or constructed and used for storing vegetables in dry regions where the relative humidity (RH) of the air is low. It comprises two clay pots, one small one that can sit into a larger pot. The sizes, e.g. height, of the two clay pots can vary, but should be manageable. In between the walls of the two pots should be a gap that allows farmers to add sand or soil and keep it wet. If available, charcoal can be used in place of the soil or sand, but the uncontrolled use of charcoal can lead to deforestation and other environmental challenges. The dry air (with low % RH) absorbs water from the wet soil or sand, and in doing so, results in a cooling effect which benefits the produce stored in the smaller pot.

MAKING A JANATA COOLER



b) Janata cooler

A Janata cooler is another example of a simple evaporative cooler that farmers can make at home. It was developed in India and also uses the evaporative cooling effect of water, similarly to the pot-in-pot method.

The Janata cooler is suited well to drier regions where the air has a high evaporative capacity. In humid regions where the air contains high moisture levels, the system does not perform well, because the surrounding air can only absorb little water, hence evaporation is minimal, and only minimal cooling occurs.

c) Underground storage pits

Potatoes and other root vegetables (in good quality) can be stored well in underground pits. The surrounding earth protects the produce from high temperatures in warmer climates and from frosts in colder climates. Well prepared pits can maintain a more or less continuous temperature throughout the year and hence protect the produce. Delicate vegetables like leafy greens (and fruits) should not be stored in such pits. Even for the roots and tubers, the risks of rotting while in the pit storage exists, and the often-poor ventilation can pose spoilage challenges. Ventilation channels are required to allow natural air to flow into and out of the storage pit to aerate the produce.

Mixing damaged or diseased vegetables with intact ones in the storage can cause rapid deterioration and spoilage to the good quality ones. All key factors for good storage, e. g. compatibility, and relative humidity and temperature requirements, should be considered when storing different vegetables in pits.

d) Cooling buildings

Farmers can construct a number of structures to store their vegetables. These structures depend on available materials (local and purchased), affordability, and also the type of vegetable to be stored and the intended length of storage.

General characteristics of farm level storage structures

› Constructed or located in a shaded area to take advantage of natural cooling for additional benefits.
› Square shaped to keep the inside area cool, with reflective walls (white or silver painting) to reflect the sun and reduce heat build-up.
› Thick or double walls separated by a 15 cm gap to insulate from the sun's heat. The gap is filled with suitable materials like wet soil, sand or char-

coal for further cooling effect. The evaporating water adds to the cooling. The double walls and straw also help to insulate the storage structure's interior from frost. Additionally, farmers can cover the vegetables in the storage room with clean cloths, sacks or straw. A straw layer of about 15cm thickness placed on top of the vegetable heap can help to protect the vegetables from frost damage.

- Only compatible vegetables or products can be kept within the same storage structure.
- **Hygiene:** Before storage, any rotten produce (vegetables fruits, flowers, etc.) should be disposed of immediately and the room should be cleaned thoroughly. Make all necessary repairs to the damaged structure as necessary. Thereafter, the storage room must be kept clean and protected from large and small pests as well as dust at all times. Adding some non-poisonous rodent traps is recommended in areas where mice and rats are problematic. Keeping the surfaces of the storage structures free from cracks reduces infestations by cockroaches as they will not fine good hiding places to lay their eggs.
- **Caution for organic farmers:** The storage room for certified organic products should not be used for conventional products as they can cause contamination. Materials like kerosene, fuel, agrochemicals, paint, medicines, etc. which can potentially contaminate the stored products must not be kept in the storage structure.

The cooling buildings can be air conditioned in cases where power (solar, hydro or other types) is available. Such structures offer good protection as it is easier to control the atmospheric conditions like temperature and relative humidity. The downside is that in many developing countries, electricity can be expensive and is often interrupted hence can cause disruptions in the cooling with detrimental consequences to the produce. In this case a standby generator can help to ensure continuous power supply to the cooling system, but it also comes at a cost.

Activity on shelf life lengthening and quality preservation in fresh vegetables

Note that these activities can take several days, weeks or months depending on what the participants select to do.

Step 1: Ask the farmers to identify a product which is commonly grown and marketed and where post-harvest losses are generally high. List the characteristics of the vegetable according to:

- Sensitivity to temperatures during storage
- Potential damage from washing (after harvest)
- Necessary pre-treatments before storage
- Storage period under farmers' normal practice
- Common quality loss symptoms (e. g. wilting, yellowing, decay, etc.)
- Sensitivity to ethylene, e. g. loss of colour in cucumbers
- Other characteristics considered important for the type of vegetable

14.2.2 Compatibility of different vegetables within a storage room

Odour contamination of vegetables during storage
Some vegetables which have a strong odour (and some fruits too), should not be stored together with sensitive once. For example, onions and cantaloupe melons have a pungent smell and this can be absorbed by potatoes if stored together. The potato taste will be affected by the onion smell.

14.3 Preservation of vegetables through farm level processing

Once harvested, vegetables start to spoil or lose their quality unless control measures are taken to slow down the process. The loss of quality can be due to natural senescence (ageing processes) or induced by physical, chemical, enzymatic, or microbial processes. Insects and other pests such as rodents can cause and or accelerate spoilage in harvested vegetables. For example, wilting or other forms of dehydration may render the produce look unattractive.

Beside cooling (and possibly freezing if facilities are available), other preservation methods can be used to stop or reduce the rate at which vegetables become spoiled (loss of quality) after harvest. This is particularly important if there are large quantities of surplus produce than can be immediately marketed or utilised. For seasonal vegetables, preservation is also important to extent their availability beyond the normal period.

Examples of preservation techniques at farm level
Some of the common farm level preservation methods for vegetables include:

- **Boiling/blanching:** This process arrests enzymatic reactions in the produce and prevent or reduce several physiological processes which can lead to rapid deterioration.
- **Dehydration** (with and without salt, with and without grinding into powder): This can be done under the sun, in solar dryers or electric powered dryers, or using fire depending on the product. If drying in the open sun, the produce should be protected from contamination by dust and other impurities
- Purees and chutneys for e. g. tomatoes (and bottling into sealable jars)
- Fermentation (results in formation of acids which then prevent certain microorganisms from growing, hence protect the product)

(continued)
Activity on shelf life lengthening and quality preservation
Step 2: Develop a plan of how the shelf life of the vegetable can be prolonged. Indicate which new postharvest treatments or storage techniques, in addition to the normal practices by farmers, should be tried as part of the strategy to lengthen the shelf life of the vegetable. The plan must also include a list of the assessments or measurements to be undertaken and their timing in order to assess effectiveness of the proposed postharvest treatments or storage strategy.
Step 3: Ensure that all required tools, containers, materials, storage facilities, etc. for the proposed strategy are available.

› Pickling of onions and cucumbers in a slat solution or a vinegar solution
› Using vinegar

Again, the organic farmers are encouraged to consult with their advisors regarding the best preservation methods for products destined for sale as certified organic.

For many small-scale vegetable producers, preservation at the farm level is currently low due to a number of reasons like the following:

› No or low availability of appropriate preservation techniques and facilities – cold storage for raw materials and preserved products where necessary, lack of controlled conditions e.g. for relative humidity and other atmospheric conditions; lack of proper sanitary facilities, inappropriate containers, etc.
› Limited know-how and skills on the possible preservation techniques which can be used
› Labour constraints
› Limited or no preservation space (especially if the harvest is bulky)

Packaging and storing the processed vegetables

The packages and storage used for processed products depend on the type of product and processing method used. For example, bottles filled with purees or chutney can be stored at room temperature, but preferably in a cool, dry and dark place. Dried products can be placed in well sealing glass jars or packets of appropriate sizes and stored in cool dry and dark rooms. Potatoes can be placed on a straw covered floor in a well-aerated room void of rodents such as rats. Care should be taken to use clean straw as contaminated straw may introduce some pathogens and pests to the stored produce.

14.4 Pest and disease management, and food safety considerations during postharvest life of organic vegetables

A significant proportion of the harvested vegetables never make it to the plate. This is due to postharvest losses which are caused by different factors. Farmers are reminded that some of the causes of postharvest losses start during the field stage through, e.g. contamination by harmful chemicals, pathogens, dirt, and due to physiological processes, whose triggers can be from within the vegetable

(continued) Activity on shelf life lengthening and quality preservation

Step 4: Implement the shelf life lengthening strategy components ensuring that all the steps taken, treatments, etc. are properly recorded for future reference; make the necessary assessments and record properly.

Step 5: At the end of the assessments, let the participants or farmers review the process and evaluate the impacts of the improved techniques in lengthening shelf life.

Step 6: Repeat as necessary with the same or different type of vegetable. Any modifications to the plan must be documented and used to revise the plan.

itself (internal) or from external factors. Postharvest losses are often higher in the warmer, humid climates as the climatic conditions in these environments are conducive to disease development and spread in the field and after harvest. The warmer humid climates also complicate the process of removing field heat from the harvested vegetables. This is worsened by the often-long transportation distances to markets, and delays in sending the harvested vegetables to markets due to lack of reliable transport. Farmers should remember that the harvested vegetable parts are still living organs containing food and water reserves (some vegetables contain as much as 95 % water). These food and water reserves become used up during storage and the rates at which this happens depend on the prevailing environmental conditions in which the vegetables are held or stored. The rate is higher under conditions of high temperature and low relative humidity. They should also remember that any physical damage to the vegetables (bruises, cuts, scratches, etc.), besides facilitating entry by pathogens, increases water loss and therefore hastens the rate at which deterioration occurs. Cautious handling of the vegetables is of utmost importance at all stages.

Postharvest diseases and pests

Postharvest diseases can result in complete loss of the harvested produce. It is important for farmers to note that diseases which occur during postharvest may start well before harvest although the infected plants or plant parts may not even show any symptoms until during storage when the diseases start to develop. The diseases enter the vegetables through the skin or through natural openings such as lenticels on the skins and also damaged skins. Certain storage pests, like fruit flies and potato tuber moths, can be transferred from the field into storage. Aphids too can be transferred from the field into storage if present on produce at harvest. Although most diseases develop rapidly under high temperature and high humidity conditions, some can grow even at very low temperatures, e.g. *Pseudomonas* spp. – a bacterial rot.

Exchange of experiences on farm level preservation

Ask the farmers the following questions:

- Which vegetables do you preserve and how? Which vegetables are easy to preserve?
- What is the purpose of the preservation – home consumption, for sale or both?
- Do you use any chemical preservatives (permitted in organic)?
- Which containers do you use for storage? What are their pros and cons?
- How and where do you store the processed products? For how long?
- Are you aware of the impacts of using different preservation methods, containers, and impacts of temperature on the shelf life of the preserved products?

REMINDER: A summary of the strategies to minimise postharvest problems in organic farming

To minimise postharvest problems, organic farmers can observe the following as part of their crop management plan:

- Keeping a good record of the land use history and avoiding to plant organic crops in fields where conventional chemicals are used
- Use of good quality water for irrigation and for washing vegetables where this is required
- Good compost and animal manure management – farmers should observe safe periods (between manure application and vegetable harvesting), raw materials for composts should not be contaminated with heavy metals and other prohibited substances
- Good maintenance of equipment and tools used during production, harvesting and postharvest handling and management
- Maintaining good overall sanitation at field level and during postharvest to prevent contamination before the next crop planting
- Preventing contamination caused by human movements between or among the fields – e.g. contaminated clothes, hands, and accessories can transfer these contaminants to clean fields or harvested produce
- Maintaining good personal hygiene among the staff at all times during all field and postharvest operations
- Restricting movement of domestic and wild animals and possible contamination of produce and harvesting tools / containers from their faecal waste
- Ensuring that storage facilities are clean before and after storing produce.
- Due to the restricted use of chemicals in organic in accordance with various regulations, the use of modified and/or controlled atmospheric conditions can help organic farmers to reduce postharvest losses and maintain the quality of their produce. Provided that the vegetables can tolerate high levels (≥15 %), carbon dioxide is permitted for postharvest use in modified and controlled-atmosphere storage and packaging under organic. These levels of carbon dioxide can suppress decay and control insect pests by making the conditions less conducive for pathogens and insects. Specialised equipment is needed to introduce accurate amounts of the carbon dioxide into the storage room. The technique is suited for aggregated facilities for farmer groups, or larger scale production.

(continued) Exchange of experiences on farm level preservation

- How do you tell if the preserved products are still in good quality? Do you seek for expert knowledge and assistance in their preservation activities?
- Discuss the general challenges and possible solutions to preservation

Use of disinfectants in organic value chains

For certified organic production, farmers are encouraged to contact their local extension services and organic farming certifying agents in their area or country to get an accurate list of those permitted disinfectant products for their situation, particularly in view of the target output markets. This is because various markets have specific regulations and requirements that need to be adhered. Disinfectants may be used to disinfect equipment such as trays, table surfaces, knives, etc. during handling and processing of vegetables, but they must not come into contact with the foods being handled or processed. After disinfection, it is recommended to clean the equipment or tools sufficiently to remove any remains of the disinfectant in order to avoid food contamination. When using a commercially available disinfectant, make sure that the active ingredients are permitted for organic and specific regulations. Only use commercial products which are destined for use on food contact materials!

15. Hygiene during the production and postharvest life of vegetables

Contamination can occur during production, at harvest or after harvest. Good agricultural practices (GAPS) and/or good manufacturing practices (GMPs) are key to the integrated systems approach to food safety. This must be supported by a good record keeping and documentation of all the 'treatments', activities and procedures undertaken to help identify points of weakness in the integrated system and facilitate the farmers, handlers, or distributors to take corrective measures. In addition to observance of food safety measures outlined in earlier sections, special attention must also be given to the critical points at which known safety food hazards must be controlled which can be identified through systems such as the Hazard Analysis Critical Control Point (HACCP).

SOURCES OF CONTAMINATION IN THE FIELD

Hygiene: sources of vegetable contamination at field level

Stage	Risks	Prevention strategies
General operations	Animal faecal contamination (direct or indirect)	• Avoid access to the plots by domestic (including pets) and wild animals.
	Human faecal contamination (direct or indirect)	• Practice good personal hygiene and use toilets. • Wash hands properly before carrying out any field operations such as thinning, weeding, etc.
Fertilising	Pathogens in organic fertilisers	• Do not use raw manure - use properly composted manure/plant residues. Manure must be aerobically composted at 60-80 ˚C (note that static piles and earthworm composting do not necessary guarantee inactivation of microorganisms). • Do not use water contaminated by raw sewage.
Irrigation	Pathogens in water	• Ensure that good quality water is sued for irrigation. • Use drip irrigation - avoid water contact with the vegetable leaves/fruits.

Adapted from 'FAO Manual for the preparation and sale of fruits and vegetables: From field to market. FAO Agricultural Services Bulletin 151, 2004': Chapter 4 Hygiene and Sanitation. ISBN 92-5-104991-2

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   93

Activity: Water quality testing

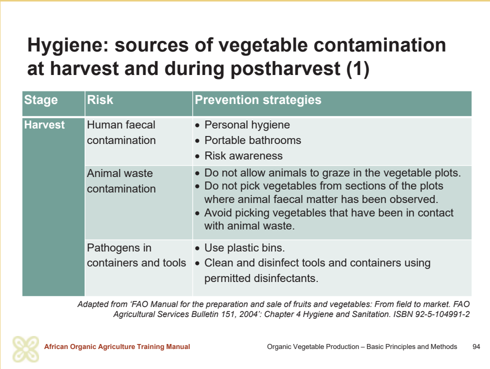
Step 1: Encourage the farmers to discuss about the quality of their water – based on the different sources.

Step 2: Encourage them to collect samples of water from various points and at different times of the year from the source of water that they use for irrigation and for cleaning their produce.

Step 3: Support them to send the water samples to a laboratory, through their extension agents or other channels.

Step 4: Assist them to interpret the results from the laboratory and identify any problems and how they might be addressed. If necessary, support the farmers to access specialist services – a specialist could come and explain to them the situation with their water and help to develop a strategy to address the existing or potential problems.

SOURCES OF CONTAMINATION AFTER HARVEST (1)

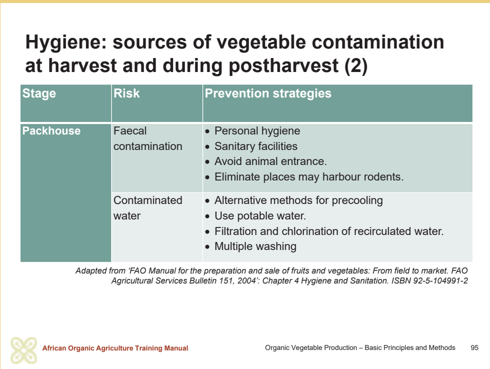

Hygiene: sources of vegetable contamination at harvest and during postharvest (1)

Stage	Risk	Prevention strategies
Harvest	Human faecal contamination	• Personal hygiene • Portable bathrooms • Risk awareness
	Animal waste contamination	• Do not allow animals to graze in the vegetable plots. • Do not pick vegetables from sections of the plots where animal faecal matter has been observed. • Avoid picking vegetables that have been in contact with animal waste.
	Pathogens in containers and tools	• Use plastic bins. • Clean and disinfect tools and containers using permitted disinfectants.

Adapted from 'FAO Manual for the preparation and sale of fruits and vegetables: From field to market. FAO Agricultural Services Bulletin 151, 2004': Chapter 4 Hygiene and Sanitation. ISBN 92-5-104991-2

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   94

SOURCES OF CONTAMINATION AFTER HARVEST (2)


Hygiene: sources of vegetable contamination at harvest and during postharvest (2)

Stage	Risk	Prevention strategies
Packhouse	Faecal contamination	• Personal hygiene • Sanitary facilities • Avoid animal entrance. • Eliminate places may harbour rodents.
	Contaminated water	• Alternative methods for precooling • Use potable water. • Filtration and chlorination of recirculated water. • Multiple washing

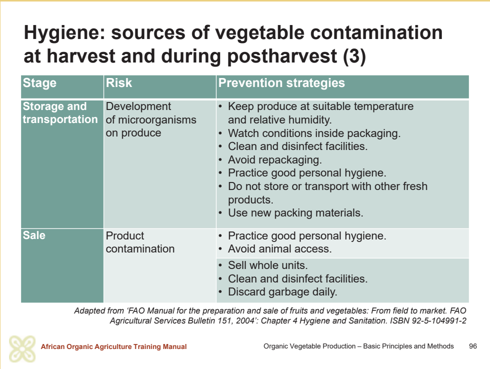
Adapted from 'FAO Manual for the preparation and sale of fruits and vegetables: From field to market. FAO Agricultural Services Bulletin 151, 2004': Chapter 4 Hygiene and Sanitation. ISBN 92-5-104991-2

African Organic Agriculture Training Manual   Organic Vegetable Production – Basic Principles and Methods   95

Table: Examples of contamination risks and preventive hygiene measures at different vegetable production stages

Production step	Risks	Prevention
Production field	Animal faecal/waste contamination (direct or indirect)	› Avoid access to the plots by domestic (including pets) and wild animals
	Human faecal contamination (direct or indirect)	› Practice good personal hygiene and use toilets to dispose human waste › Wash hands properly before carrying out any field operations such as thinning, weeding, harvesting etc.
Fertilising	Pathogens in organic fertilisers	› Do not use raw manure – use properly composted manure/plant residues. Manure must be aerobically composted at 60 to 80 °C (note that static piles and earthworm composting (vermicomposting) do not necessary guarantee inactivation of microorganisms). › Do not use water contaminated by raw sewage
	Heavy metals and antibiotics in manure and other types of biomass	› These manure and biomass sources should not be used for raw materials in organic farming › Avoid industrial waste that is contaminated › Avoid using water contaminated by sewage

SOURCES OF CONTAMINATION AFTER HARVEST (3)



Hygiene: sources of vegetable contamination at harvest and during postharvest (3)

Stage	Risk	Prevention strategies
Storage and transportation	Development of microorganisms on produce	• Keep produce at suitable temperature and relative humidity. • Watch conditions inside packaging. • Clean and disinfect facilities. • Avoid repackaging. • Practice good personal hygiene. • Do not store or transport with other fresh products. • Use new packing materials.
Sale	Product contamination	• Practice good personal hygiene. • Avoid animal access. • Sell whole units. • Clean and disinfect facilities. • Discard garbage daily.

Adapted from 'FAO Manual for the preparation and sale of fruits and vegetables: From field to market. FAO Agricultural Services Bulletin 151, 2004': Chapter 4 Hygiene and Sanitation. ISBN 92-5-104991-2

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 96

Irrigation	Pathogens in water	› Ensure that good quality water is used for irrigation › Use drip irrigation to avoid contact with the vegetable leaves/fruits
	Chemical contaminants in water	› Avoid using contaminated water, e. g. from industries that deal with or use chemicals.

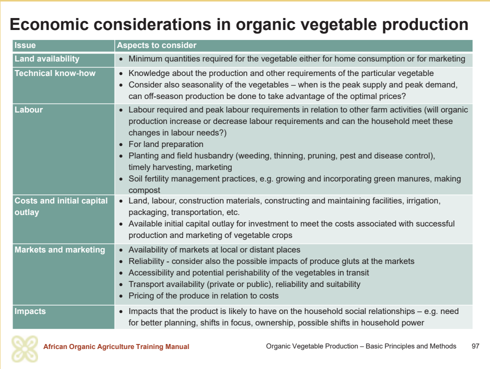
Adapted from 'FAO Manual for the preparation and sale of fruits and vegetables: From field to market. FAO Agricultural Services Bulletin 151, 2004': Chapter 4 Hygiene and Sanitation. ISBN 92-5-104991-2

Table: Examples of contamination risks and preventive measures at different vegetable harvesting and postharvest stages

Post production stage	Risks	Prevention
Harvest	Human faecal contamination	› Personal hygiene › Portable bathrooms with clean water for hand washing › Risk awareness among all actors
	Animal waste contamination	› Do not allow animals to graze in the vegetable plots › Do not pick vegetables from sections of the plots where animal faecal matter has been observed › Avoid picking vegetables that have been in contact with animal waste
	Pathogens in containers and tools	› Ensure that good quality water is used for irrigation › Use drip irrigation to avoid contact with the vegetable leaves/fruits

Pack house	Faecal contamination	› Observe good personal hygiene › Provide adequate sanitary facilities › Avoid animal (including pests) entrance into the pack houses › Eliminate places and conditions that may harbour rodents and cockroaches
	Contaminated water	› Use alternative methods for precooling instead of using water › Use portable clean water for cleaning and washing › Filtration and chlorination of recirculated water › Multiple washing of produce, but caution should be taken to avoid over wetting the produce as some are sensitive while water on vegetable surfaces can promote disease pathogens to develop
Storage and transporta-tion	Development of micro-organisms on produce	› Keep produce at suitable temperature and relative humidity levels › Watch conditions inside the packages and ensure that they do not promote pathogen development – perforations can allow good ventilation › Clean and disinfect facilities to avoid build-up of disease-causing microorga-nisms › Avoid unnecessary repackaging of pro-duce as this can introduce infections › Practice good personal hygiene at all times › Do not store or transport with other fresh products that may cause contamination, e.g. conventional produce should not be mixed with organic produce › Use new packing materials, reuse can cause contamination

ECONOMIC FACTORS TO CONSIDER



Economic considerations in organic vegetable production

Issue	Aspects to consider
Land availability	• Minimum quantities required for the vegetable either for home consumption or for marketing
Technical know-how	• Knowledge about the production and other requirements of the particular vegetable • Consider also seasonality of the vegetables – when is the peak supply and peak demand, can off-season production be done to take advantage of the optimal prices?
Labour	• Labour required and peak labour requirements in relation to other farm activities (will organic production increase or decrease labour requirements and can the household meet these changes in labour needs?) • For land preparation • Planting and field husbandry (weeding, thinning, pruning, pest and disease control), timely harvesting, marketing • Soil fertility management practices, e.g. growing and incorporating green manures, making compost
Costs and initial capital outlay	• Land, labour, construction materials, constructing and maintaining facilities, irrigation, packaging, transportation, etc. • Available initial capital outlay for investment to meet the costs associated with successful production and marketing of vegetable crops
Markets and marketing	• Availability of markets at local or distant places • Reliability - consider also the possible impacts of produce gluts at the markets • Accessibility and potential perishability of the vegetables in transit • Transport availability (private or public), reliability and suitability • Pricing of the produce in relation to costs
Impacts	• Impacts that the product is likely to have on the household social relationships – e.g. need for better planning, shifts in focus, ownership, possible shifts in household power

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 97

Sale	Product contamination	› Practice good personal hygiene at all times › Avoid animal access to the produce › Sell whole units to avoid too much handling › Clean and disinfect facilities to avoid build-up of disease-causing microorganisms

16. Economic considerations in vegetable production

Vegetables are a high value crop and offer many opportunities for market access and income generation by smallholder farmers. In general, vegetables can provide high returns to land and labour investments, and serve as significant sources of household income. Before planting a vegetable crop for income generation, farmers are encouraged to consider their economic situation and how this can influence the success of their investments.

Table: Economic considerations

Issue	Aspects to consider
Land availability	› Minimum quantities required for the vegetable either for home consumption or for marketing taking into consideration agronomic requirements such as crop rotations and intercropping
Technical know-how and record keeping	› Knowledge about the production, harvesting, handling, postharvest treatments and other requirements of the particular vegetable being grown › Consider also seasonality of the vegetables – peak supply and peak demand periods, possibility of off-season production to take advantage of higher prices › General farm management and book keeping are key assets to farmers for successful farming business

Labour	› For land preparation labour requirements and projections › Planting and field husbandry (weeding, thinning, pruning, pest and disease control), timely harvesting, marketing › Soil fertility management practices e.g. growing and incorporating green manures, making compost, etc. › The labour required and peak labour requirements for vegetable production and in relation to other farm activities should be considered. The questions whether organic production will increase labour requirements, and whether the household can meet these demands for labour in a timely manner will need to be answered. › Sources of paid labour when needed, and associated costs
Costs and initial capital outlay	› Costs associated with land, labour, and materials, constructing and maintaining facilities, irrigation, packaging, transportation › Available initial capital outlay for investment to meet the costs associated with successful production and marketing of vegetable crops – it is important for farmers to keep a farm record book for their activities including cash out- and in-flows

Markets and marketing	› Availability of markets at local or distant places and the specific needs and expectations by the markets or consumers › Reliability - consider also the possible impacts of produce gluts at the markets during peak production, or through importation from cheaper sources › Accessibility and potential perishability of the vegetables in transit › Transport availability - private and / or public forms and their reliability and suitability › Pricing of the produce in relation to costs and affordability by consumers – organic produce are often priced higher than conventional
Impacts	› Impacts that the product is likely to have on the household's social relationships –e.g. need for better planning, shifts in focus – business-oriented vegetable production, ownership, possible shifts in household power if women engage in organic vegetable marketing , etc.

Farmers are encouraged to take their farming activities as a business in order to optimise financial benefits and ensure short- and long-term survival and development of the farm. An organic farm should not only pay for production costs, but also meet the household needs of the farmer's family. To achieve this, organic farmers are encouraged to consider the following economic goals:

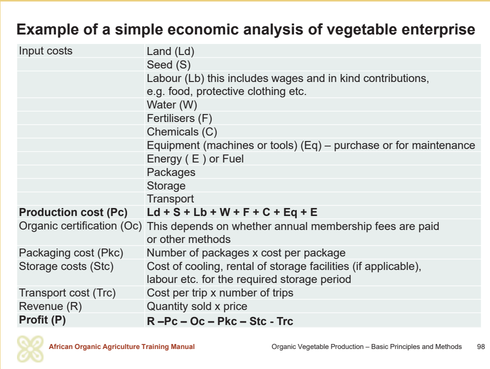
i. Satisfactory and reliable yields
ii. Lowering expenditures on external inputs and investments – organic relies more on farm-own sources, e.g. recycling of nutrients on the farm
iii. Diversified sources of income for better risk management through rotations, intercropping, etc.
iv. High value added on-farm products through improvement of quality and on-farm processing of products, provided the markets are available
v. High efficiency in production to ensure competitiveness

Discussion about profitability of organic vegetable production

Ask the farmers the following questions:

- What are the costs of organic vegetable production in relation to your prior experiences before practicing organic farming, or in comparison with your neighbours who are not organic farmers?
- Do you keep records? If so, how do you do it? What are the benefits and challenges of it?
- How do you calculate profits from vegetable production? Discuss this in relation to other farm interventions.

CALCULATING RETURNS OR PROFIT


Example of a simple economic analysis of vegetable enterprise

Input costs	Land (Ld)
	Seed (S)
	Labour (Lb) this includes wages and in kind contributions, e.g. food, protective clothing etc.
	Water (W)
	Fertilisers (F)
	Chemicals (C)
	Equipment (machines or tools) (Eq) – purchase or for maintenance
	Energy (E) or Fuel
	Packages
	Storage
	Transport
Production cost (Pc)	**Ld + S + Lb + W + F + C + Eq + E**
Organic certification (Oc)	This depends on whether annual membership fees are paid or other methods
Packaging cost (Pkc)	Number of packages x cost per package
Storage costs (Stc)	Cost of cooling, rental of storage facilities (if applicable), labour etc. for the required storage period
Transport cost (Trc)	Cost per trip x number of trips
Revenue (R)	Quantity sold x price
Profit (P)	**R –Pc – Oc – Pkc – Stc - Trc**

African Organic Agriculture Training Manual Organic Vegetable Production – Basic Principles and Methods 98

Organic vegetable production reduces the need for purchasing agro-chemicals. By being more self-sufficient in terms of seeds, manures, biopesticides, organic farmers minimize cash outlay to purchase off-farm production inputs and are therefore likely to save more resources in the long-run. For farmers to understand how their vegetable enterprises are performing, they would need to undertake some basic farm economic analysis based on inputs and outputs. Extension agents can assist the farmers to develop simple farm budgets to help monitor the performance of their farms or enterprises.

Basic farm economic analysis based on inputs and outputs

Input costs can be associated with (and can include loan repayments on the inputs):

- Land (Ld) (including land quality measurements such as soil testing)
- Seed (S)
- Labour (Lb) (including food if they are provided with food by the farmer)
- Water (W)
- Organic production permitted fertilizers (F)
- Permitted chemicals or substances (C) e. g. for disinfection
- Equipment (machines or tools) (Eq) – the cost of buying the equipment or for maintenance
- Energy (E) or Fuel
- Training and advisory (T&A)
- Packages and related (e.g. labels)
- Storage and related
- Transport
- Administrative costs

Field production cost (Pc) = Ld + S + Lb + W + F + C + Eq + E + T&A

Organic certification (Oc) = depends on annual membership fees or other methods

Packaging cost (Pkc) = no. of packages and labels x cost per package and label

Storage costs (Stc) = cost of cooling, rental of storage facilities (if applicable), labour

Transport cost (Tc) = cost per trip x number of trips

Other costs (Otc) = sum of all other costs, e. g. promotion, communication, administration, etc.

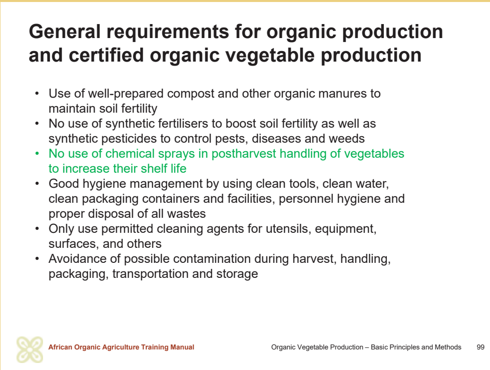
Revenue (R) = quantity sold x price

Profit = R – (Pc + Oc + Pkc + Stc + Tc + Otc) (the components used may vary from farmer to farmer depending on which costs they incur in producing and marketing their vegetables). Farmers can think of other costs to add to their analyses depending on their situation.

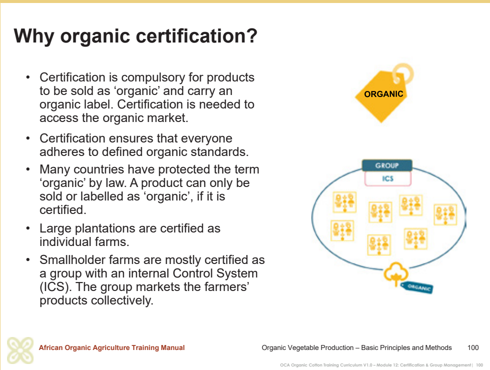
Apart from possible monetary gains from organic vegetable production, in the long-term farmers are also likely to benefit through improved soil fertility, improved resilience to harsh weather conditions, diversified availability of food for households, and other socioeconomic benefits.

For more information on the socio-economics and marketing of organic farming, the reader can refer to Modules 6 and 7 of this African Organic Agriculture Training Manual as well as the section below on Marketing and certification of organic vegetables.

GENERAL REQUIREMENTS FOR CERTIFIED ORGANIC PRODUCTION



REASONS FOR ORGANIC CERTIFICATION



17. Marketing and organic certification of vegetables

17.1 Market information, market access and certification

Vegetable marketing provides farmers with the much-needed income for their families. There is a growing market for locally grown and consumed vegetables in most African urban and per-urban markets. This implies that well organised groups of producers can produce according to organic requirements, promote and sell their vegetables in close collaboration with retailers (vegetable shops) and consumers without going through any formal third-party certification. For export markets, the farmers need to work with exporters who are well qualified and experienced in this business as it involves specific organic standards and regulations.

17.2 Certification

Organic certification tests for possible fraudulent practices within farm systems and, therefore, ensures that everyone in the organic supply chain adheres to the organic production principles, practices and laid out standards. To be certified as organic, the farm must be inspected by a representative of a certifying organization or body and assessed against an organic standard or regulation. Certification makes it possible for a customer who does not know or cannot visit the farm to get some assurance that the produce adheres to organic standards. After this, a certification label is provided for displaying on the certified products. Certification of organic vegetables is not compulsory, and is needed only if the targeted market demands it. For example, to sell in certain organic shops or on certain organic markets, the farmer may need to have some sort of certification and to export the products as organic, the farmer may often need to have third party certification by an organic certification body having the required accreditation. There are specific requirements to organic production, particularly for certified organic. However, specific national or international organic standards may define additional requirements. Therefore, interested farmers should consult the national organic movement or organic certification body operating within the region or country for further guidance.

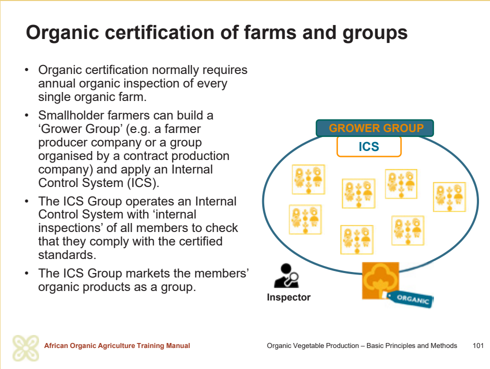
Exchange of experiences on marketing

Ask the farmers the following questions:

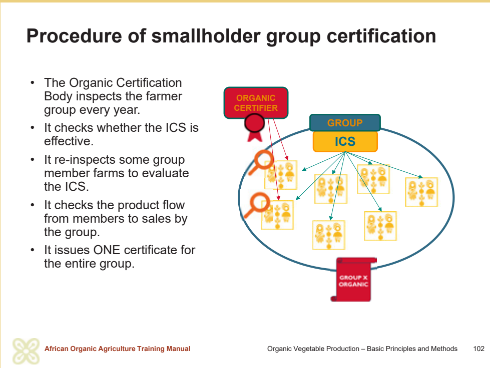
- Which vegetable species are demanded more by the market?
- Can these vegetables grow in the area during the time when the market needs them?
- Is labour and transportation to take the harvest to the market readily available?
- What opportunities and constraints for marketing vegetables exist in your area?

Suggest solutions to overcome the identified constraints.

SMALLHOLDER GROUP CERTIFICATION



PROCEDURE OF SMALLHOLDER GROUP CERTIFICATION



There are two main types of certification relevant to organic farmers.

a) a. Participatory certification through a Participatory Guarantee System (PGS): this is mainly relevant for the local or domestic market. According to IFOAM Organics International, 'Participatory Guarantee Systems are locally focused quality assurance systems. They certify producers based on active participation of stakeholders and are built on a foundation of trust, social networks and knowledge exchange.' The details of methodology and process may vary, but the key elements and features of PGS systems remain consistent worldwide. With PGS, the responsibilities for implementing sustainable agriculture practices are shared by the community. PGS enhances transparency and shared decision-making processes and prioritises a solidarity approach to organic certification.

b) Third party certification conducted by an independent (third party) organic certifier, also called certification body. This is relevant for some domestic markets, but mostly export markets. On the other hand, export of organic vegetables is better handled by bigger operators who have the certification expertise, cooling facilities and can organise efficient logistics to ensure quick delivery to the far export markets. Small farmers can still work with such export companies as out grower suppliers. In such cases, the companies will manage the certification and marketing of the products and farmers adhere to stipulated regulations.

Organic regulations are always evolving and changes may occur from time to time. It is important that farmers producing for certified organic markets are kept abreast of the developments in the industry in order to not lose on their business due to lack of compliance.

For further details on certification, the reader can refer to Module 7 on Marketing and Trade of this same Training Manual.

KEY ELEMENTS OF CERTIFICATION THROUGH PGS

Key elements of the Participatory Guarantee System (PGS)

Shared vision	Key stakeholders (producers, consumers, NGOs, traders, religious institutions, governments, and others) collectively identify and agree to support the principles guiding the objectives and goals of the PGS.
Trust	The idea of trust assumes that the individual producer has committed to the shared vision of protecting nature and ensuring consumer health through organic production.
Horizontality	PGS initiatives are intended to be non-hierarchical. This is reflected in the overall democratic structure and through the collective responsibility taken up by those involved.
Transparency	All stakeholders, including producers and consumers, are informed on how the guarantee system works, including information on standards, norms (the organic guarantee process), and decision-making processes.
Participation	The stakeholders involve actively in PGS operations.
Learning process	Through the exchange of ideas and experiences a learning process unfolds and becomes an ongoing dynamic of PGS.

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 103

KEY FEATURES OF CERTIFICATION THROUGH PGS

Features of the Participatory Guarantee System (PGS)

Grassroots Organisation	As far as possible, a PGS will be **built on local initiatives** with and for the people it is designed to serve.
Principles and values that enhance livelihoods	PGS are characterized by defined and documented principles and values that focus on **enhancing livelihoods**, and the **well-being** of farming families, **fair relations** with consumers, and the promotion of **organic agriculture**.
Farmers' pledges	Producers joining a PGS **agree to established norms or standards** via a record or document.
Norms conceived by all the stakeholders	For organic agriculture, a generally **recognised set of organic production rules** should be agreed upon by key stakeholders involved in a specific PGS.
Clear, pre-defined consequences for non-compliance	The approaches that a PGS initiative adopts to verify compliance are not only a tool for **controlling producer adherence** to defined criteria, but are also a tool for **supporting producer's improvement**.
Documented management systems and procedures	For an organic guarantee system to be transparent and deliver on a consistent and equitable basis, **systems and procedures** need **to be documented**.
Mechanisms to verify compliance	Mechanisms to verify producer compliance with established norms can include **description** of the farm and farming activities, farm **inspections**, **knowledge building**, **sharing responsibilities** and reinforcing the idea of horizontality.
Suitable to smallholder agriculture	A PGS is designed to be **affordable** for smallholder family farmers and culturally **appropriate** in terms of paperwork, procedures, and applied processes.
Mechanisms to support farmers	PGS can provide support to producers in several ways, e.g. **facilitation of market access**, **information** and **technical support**, **collective activities**.
Seals or labels as evidence of organic status	A seal is used by a PGS initiative to provide a formal endorsement of key documents, such as producer certificates.

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 104

DIFFERENCES BETWEEN THIRD-PARTY AND PGS CERTIFICATION

What are the differences between Third-party and PGS certification?

Third-party certification	PGS certification
Professional certification	Voluntary to professional certification
Independent from stakeholders	Participatory (stakeholder involvement)
In accordance with international norms	Following general international principles but locally adapted
Gives access to international markets	Access mostly to local, regional or unregulated markets
Normal guarantee system in government organic regulations	Often not recognised by governments
Deals only with certification	Combines with other functions, e.g. capacity building, marketing, etc.

Source: IFOAM

African Organic Agriculture Training Manual — Organic Vegetable Production – Basic Principles and Methods 105

DIRECT MARKETING

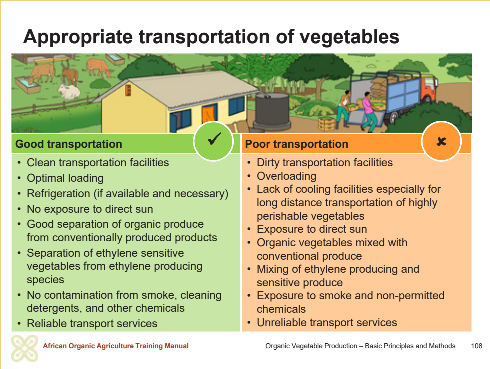
MARKETING THROUGH RETAILERS

17.3 Distribution channels

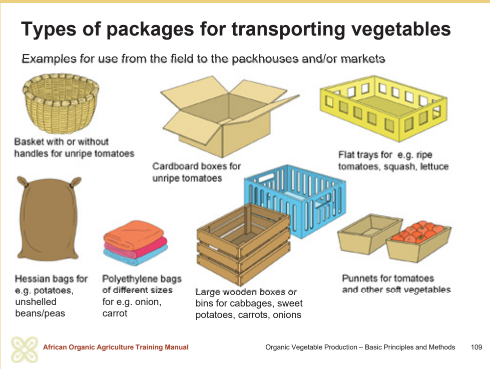
The following list provides possible channels through which farmers can sell their organic vegetables. These include:

- Farm-gate
- Road-side
- Farmer markets
- Institutions (schools, hospitals)
- Hospitality industry (hotels, restaurants, etc.)
- Retail shops
- Wholesale shops
- Social media platforms or through the internet

TRANSPORTATION



TYPES OF PACKAGES FOR USE FROM THE FIELD TO PACK-HOUSES AND/OR MARKETS



17.4 Transportation

The ideal transportation for vegetables should provide cooling facilities to help maintain optimum quality of the produce. In many smallholder farming settings in Africa, transport systems are not well developed and many different forms are used, including carrying on the head or back, bicycles, motorbikes, private cars, public buses, trucks (open or closed and with or without cooling or insulation), trains, etc. Air transportation is used for some high value export initiatives. Ideally, fresh horticultural products should be transported in refrigerated or insulated trucks or ship containers.

The special requirements for transporting organic produce must be observed. The risk of contaminating organic commodities should be avoided and the organic products must not be allowed to come into direct contact with conventional products during transportation (and earlier handling stages). Those in the shipment business need to ensure that contamination of organic produce by cleaning products or fumigants, ripening agents, pest control agents, diesel fumes, and vehicle maintenance products is prevented.

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