SUSTAINABLE AGRICULTURE LAB MANUAL

Department of Agriculture and Aquatic Sciences

COMPILED BY
AARON SAKALA
P.O BOX 480195 CHINSALI
Email address: mwasakala@outlook.com

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ABOUT THIS PRACTICAL MANUAL

This practical manual provides guidelines in agricultural practices that share many technique and approaches such as nursery management, plant propagation methods, crop management, cultivation methods, pest management, mulching, post-harvest management, integration of crops and livestock. Accordingly, the production manual system is designed to:

- Enhance biological diversity within the whole system;
- Increase soil biological activity;
- Maintain long-term soil fertility;
- Recycle wastes of plant and animal origin in order to return nutrients to the soil, thus minimizing the use of non-renewable resources;
- Rely on renewable resources in locally organized agricultural systems;
- Promote the healthy use of soil, water and air as well as minimize all forms of pollution that may result from agricultural practices;
- Promote the careful processing methods agricultural products in order to maintain the organic integrity and vital qualities of the product at all stages;
- Become established on any existing farm through a period of conversion, the appropriate length of which is determined by site-specific factors such as the history of the land, and type of crops and livestock to be produced

Agriculture production practices are based on the following principles:

Principle of health

The role of agriculture, whether in farming, processing, distribution, or consumption, is to sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings. In view of this, it should reduce on the use of fertilizers, pesticides, animal drugs and food additives that may have adverse health effects.

Principle of ecology

Agriculture production should be based on living ecological systems and cycles, work with them, emulate them and help sustaining them. The management must be adapted to local conditions, ecology, culture and scale. Reducing inputs by reuse, recycle and the efficient management of materials and energy contributes to improved environmental quality and conserve resources.

Principle of fairness

This emphasizes the need of those involved in practice to conduct human relationships in a manner that ensures fairness at all levels – trainers, students and stakeholders. Natural and environmental resources that are used for training and practice should be managed in a socially and ecologically fair way and should be held in trust for future generations. Additionally, fairness requires systems of production and practice that are open and equitable and account for real environmental protection.

Principle of Care

This principle states that precaution and responsibility are the key concerns in management, development and technology choices in agricultural production. Inclusion of science is vital to ensure practice that is healthy, safe and ecologically health.

There has been an increasing demand for horticultural crops more particularly fruit and vegetables in Zambia. With this increase, the demand for good quality planting materials has gone up and the nursery industry has developed rapidly in the recent years in the country. Nursery product is no longer restricted to orchards or large parks and gardens. High demand is observed during the period of farm establishment.

Establishment of the nursery

Development of the nursery is done gradually. The mother plants reserved for vegetative or seed propagation are raised using the nursery. Most important factors to consider for establishing the nursery include agricultural climatic conditions, soil type, soil pH, location, area, irrigation facilities, availability of germplasm and skilled personnel.

Selection of the site

The site selected for raising a nursery is preferably be located near marketing centres for the convenience of transportation of the products with minimum or no damage. The site should be convenient enough for transportation of input materials for the nursery. It is important to have or develop a perennial source of water at the nursery site. If need arises, wind breaks of tall plants may be planted to provide necessary shade and protection.

Crop choice

The crop choice will primarily depend on the market demand in nearby areas. For wider market coverage, the choice may be dependent on market access in the desired areas. Varieties of various plants may be propagated in the nursery. Planting materials such as seedlings of flowers, bulbs, corms, etc. may also be produced.

Methods of propagation

Plants may be raised from seeds or by vegetative propagation. Some important aspects of propagation are summarized below along with examples of fruit crops:

Raising from seeds

Germination from seeds may not be 100% even if the seeds are sown in perfect conditions. The factors that control the germination include age, stage of maturity and viability of seeds and water, supply of oxygen and the heat or temperature. Factors that contribute to the seeds not to germinate easily are the dormancy, rest period and presence of seed coat. Seeds with hard coats might need some kind of external treatment for germination such as cracking of the coats by mechanical means, abrasion, soaking in water or acid.

Vegetative Propagation

Safe methods of vegetative propagation such as cutting, layering, division, separation, budding and grafting are adopted for multiplication of ornamental plants.

Cutting

Plant parts that are normally used for this purpose are stems, roots, leaves and modified stems such as tubers, corms and rhizomes, runners and bulbs. This method is very popular, particularly because it is the cheapest and most convenient one.

- Cutting should result in the production of new plants from pieces of stem
- The daughter plant resulting from a cutting is identical to the mother
- Primary aim is to encourage the cut tissue to produce first roots and subsequently a shoot

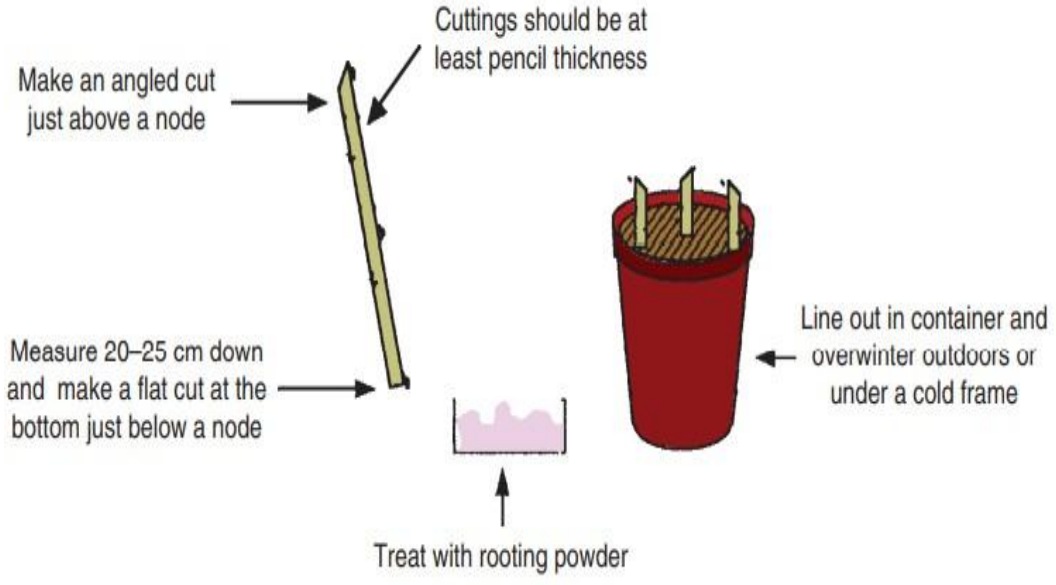

Figure 1Showing cuttings for propagation

Layering

The method of inducing roots in a stem which is still attached to the plant and then detaching it after the root is formed for transplanting is called a layering or layerage. Mostly creepers and trees are raised by this method. Some herbaceous plants such as Guava can be propagated in such a way.

Plant layering stems are often suitable propagation material to increase plant stock

Rhizomes are underground horizontal stems growing from a lateral bud near the stem base

At each node there is a bud capable of sending out roots and shoots

Example ginger

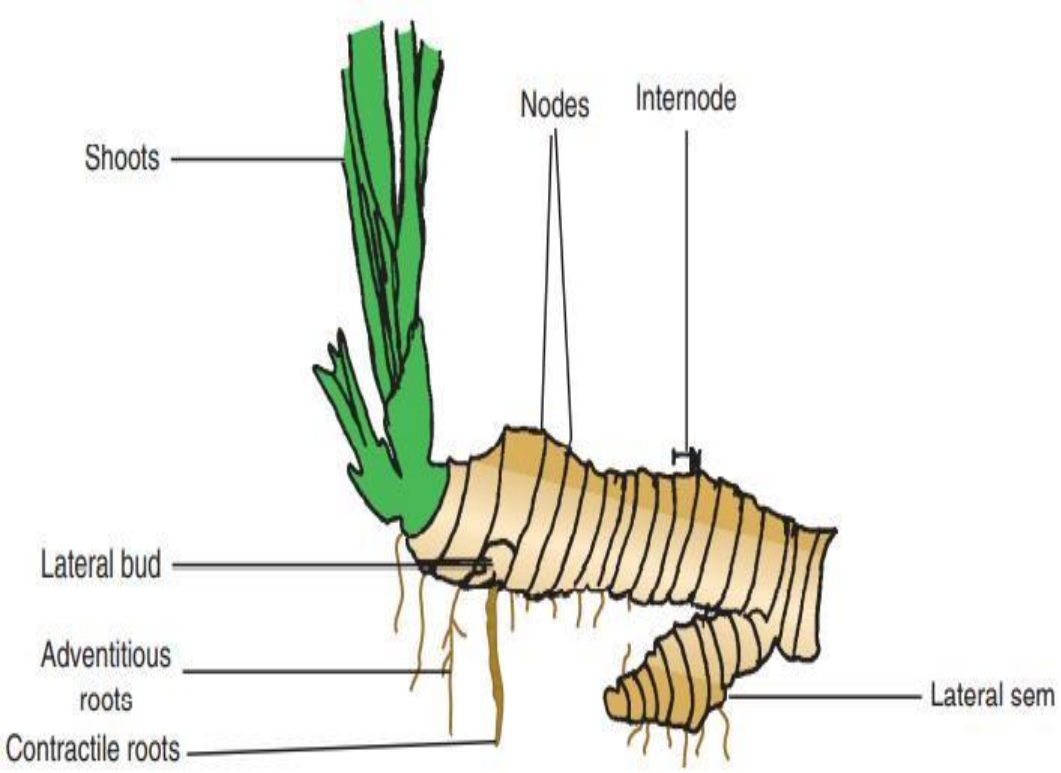

Figure 2 Showing rhizomes as a propagation material

Stolons are aboveground stems. The stems bend over and form new plants at their tips. There is a bud at each node which can produce both roots and shoots. Eventually the stolon dies, leaving an independent daughter plant. Notable example is strawberry plants.

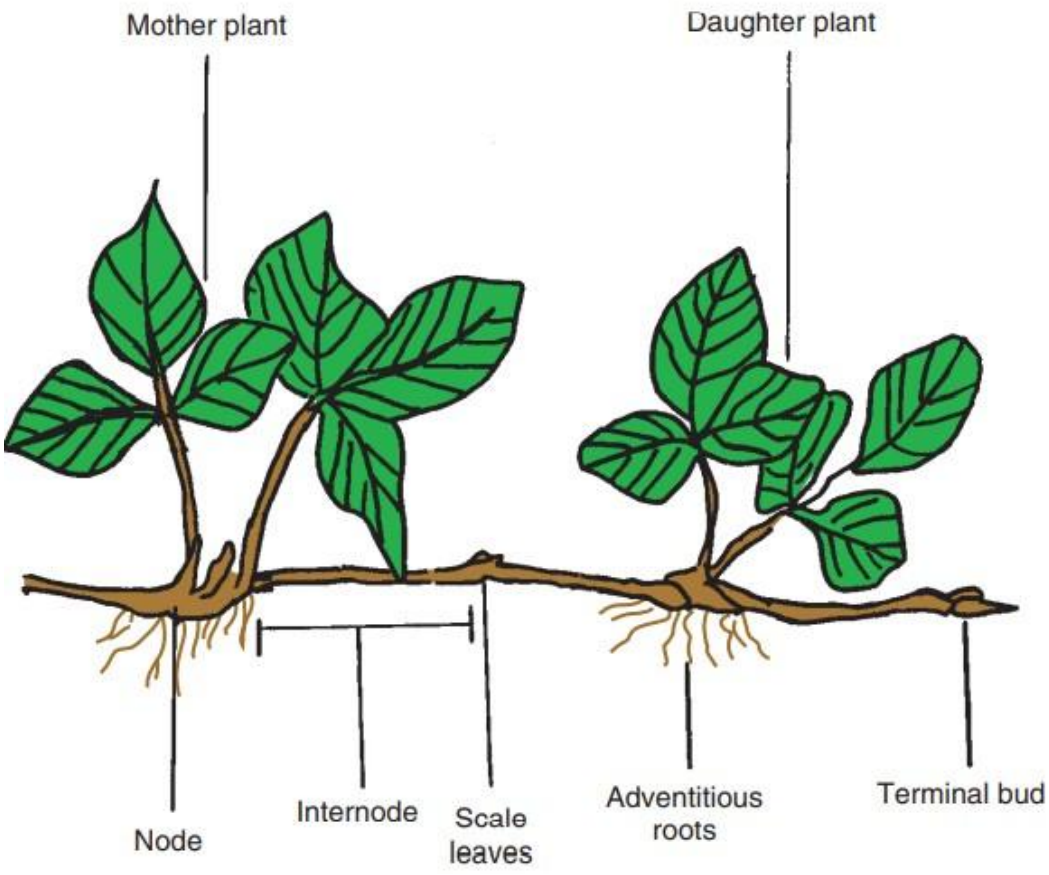

Figure 3 Depicting stolons used in plant propagation

Division and Separation

The type of plants that produce masses of stems at ground level, each having own root system are lifted from ground and divided into individual plants. This practice is known as division. In the system of separation, rooted or unrooted plant parts usually detach themselves at the point of maturity and start or develop as a new individual in the following season.

Grafting

Principles of grafting

This is a technique used to unite two different parts of plants by bringing the cambium of each into contact to become one plant. The technique of grafting involves two important stages of preparation of the grafting surfaces and the procedures for aftercare. The benefits of grafting include reduced plant height for easy picking, improved fruit quality and early fruiting usually one season or two.

Rootstock raising

For grafting a single stem is allowed to grow for 6 to18 months depending on the species. It involves the formation of a union between scions taken from desirable source and rootstocks that grow as young or healthy seedlings established in the nursery. When grafting is done correctly, it shortens the period of field establishment and tree flowers to fruits. This is an advantage to for fruit trees, since early maturity means quick revenue realization by horticultural farmers. Normally, scions and rootstocks should march in diameter to align cambium layers. This is important for the formation of the graft union and to allow effective transportation of the nutrients and water required for plant growth in roots and shoots.

Scion selection

The quality scion to use in grafting comes from shoots grown the previous season. Scions should be cut using sharp, clean secateurs or knives to prevent disease transmission and immediately the scion should be placed in moist plastic bags or tissue papers. During the harvesting of scions it is a good practice to clean the cutting utensils regularly. It can be done through dipping them in a sterilizing solution such as alcohol or methylated spirit. To achieve best results, harvest only the scions to be used for grafting during the same day. Only select healthy scion free from insects, disease or damage.

Procedure for grafting

Start by harvesting scions from the desired mother plant and cut them to about 15cm long. Carefully, remove all the leaves from the scion. Ensure that scions are the same thickness as the rootstock stem. With a very sharp utensil cut the bottom of the scions with two sloping cuts about 3cm long. Cut off the top of the rootstock about 30cm above the soil. Make one straight cut about 3cm deep in the top of the rootstock to form a wedge. Push the scions firmly into the rootstock cut. Leave about half centimetre of the cut scions outside the rootstock. Use clear plastic tape to firmly wrap around the graft centre. Do not remove the tape until the time when the scion begins to grow to indicate successful graft growth. Finally, remove any buds which have grown below the graft union.

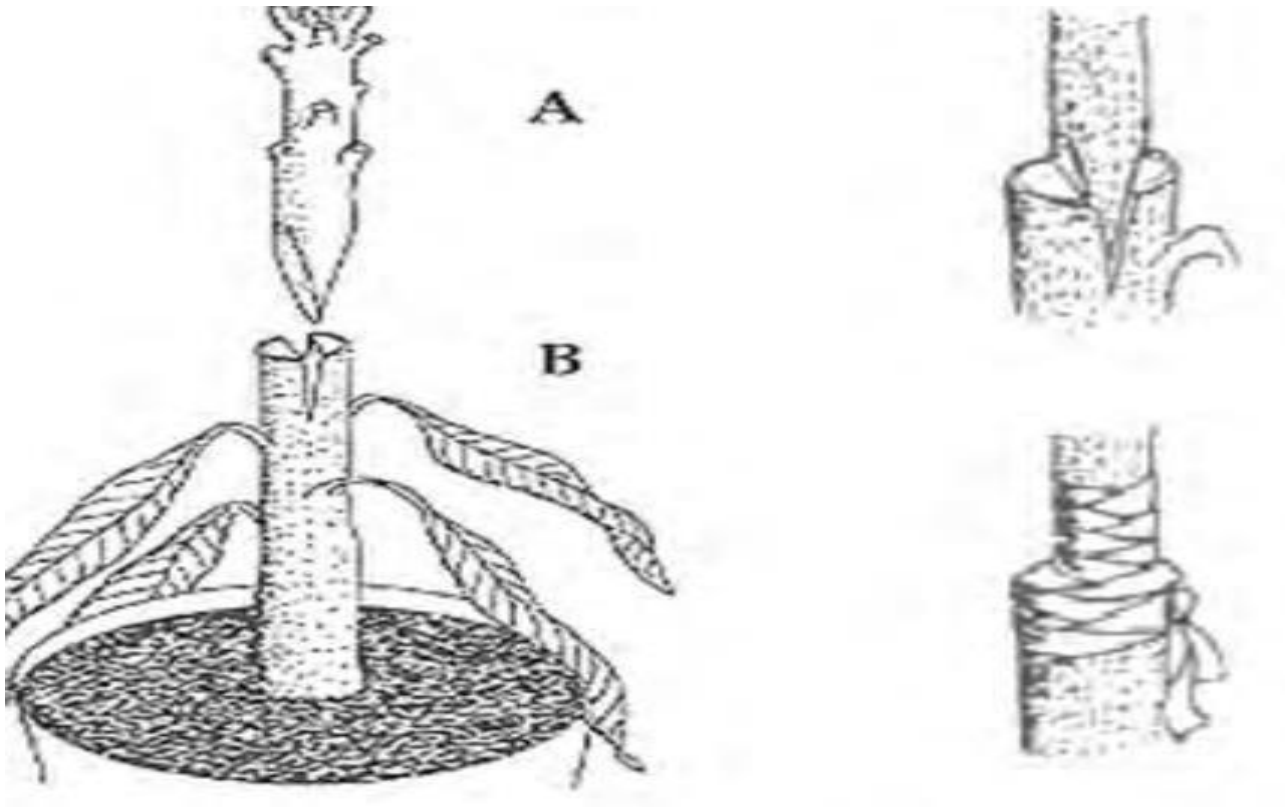

Figure 4 Showing a grafted plant

Budding

Principles of budding

Budding is a method of asexual propagation which involves inserting a strip of bark containing a bud from the branch of the desired clones to the stem of the root stocks. This is a type of grafting that is based on the same principles for successful union in grafting. Techniques applied depends on the bark slipping and the condition that determines the ease or difficulty of removing the bud from the wood. Like in the case of grafting, budding uses healthy and disease-free rootstocks and scion. The process can be done using T-budding or patch budding.

The basic principle in budding is the replacement of the shoot system of a plant with that of another plant with desirable traits. Patch of bark of the rootstock is replaced by a patch of scion with a dormant bud taken from the clone intended to be multiplied. Therefore, scion gets attached to the stock permanently and becomes part of it. Afterwards, rootstock is cut off above the budded portion to allow the grafted bud to develop into a shoot carrying the characters of the plant from which it was taken. This new tree is a two-part tree, consisting of a root system belonging to the rootstock and a shoot system contributed by the scion.

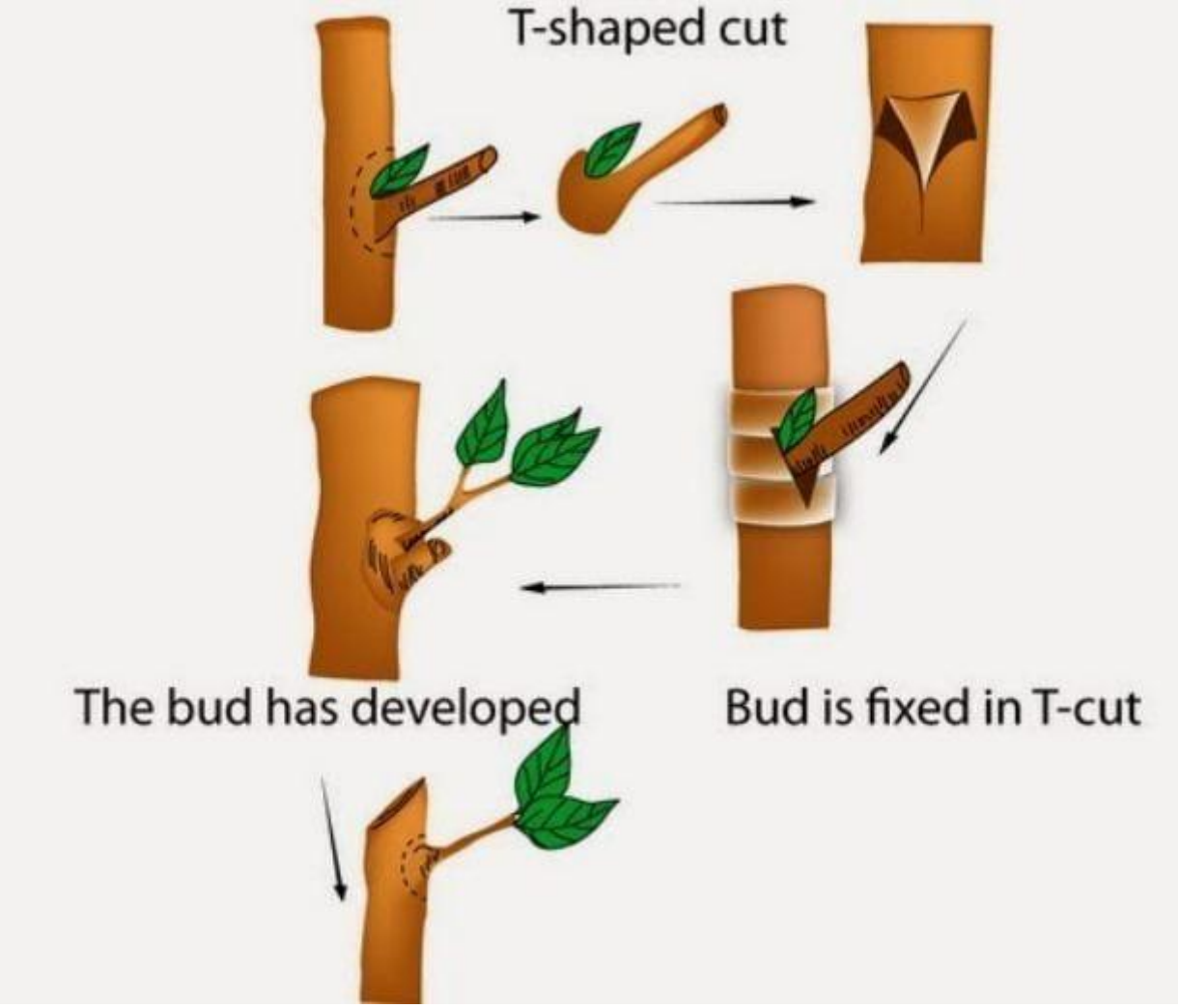

Figure 5 Showing different methods of budding

Compost making

Composting is the process of breaking down of organic material for a period of time through the action of micro-organisms into a crumbly, dark, soil-like product that none of the original material can be easily identified. Most of organic waste materials produced by farming such like husk, effluent, vegetable waste, and stubble can be used to produce compost. The benefits of using compost include, increased organic carbon protection of soil from erosion, increased soil structural stability, improved soil moisture holding capacity, increased water infiltration, reduced water runoff and addition of nutrients and Enhancing growth of a wide range of soil organisms.

Compost making phases

- Heating phase
- Cooling phase
- Maturing phase

In the hot phase of composting the digestive processes of the micro-organisms increase the temperature of the compost pile. These temperatures are hot enough to denature some disease organisms and weed seeds. At the cool down phase fungi become more active in the composting processes and cause stems, stalks and other tough fibrous materials to break down. The final phase of maturation begins after the compost has cooled down. In some cases living organisms move in to breaking down some of the materials and mixing the compost. The compost is ready to use as soon as most of the original material is no longer recognizable.

Compost preparation

Mostly, compost is be made in pits of about 2m long by 1m wide and 1m deep that could produce enough compost material to cover up to one hectare. The lowest layer in the bottom of the pit is made up of 10cm forest soil. The second is made up of 10cm of leaves or grass which is compacted by stepping on top of it. Another layer is made up of 10cm of manure. With the exception of the first layer, each layer should be watered before adding the next layer. The layers are then repeated in similar order until the pit is full. Usually, there will be three repeated layers of each material in a 1-metre-deep pit. The compost pit is completed by adding 10cm layer of soil which is compacted by stepping on it, and the finished compost pit is levelled with the surrounding ground.

Good quality compost takes about 8 weeks. It is essential not to use compost before getting ready because beneficial organisms will not have established, and nitrogen content is temporarily taken by the decayed organisms and could be unavailable to plants. Signs of compost that is ready include nice and earthy, with no bad (sour or rotten) smells, feeling of moist and earthy, not wet and sloppy or dry and powdery, original organic materials cannot be distinguished in appearance, compost contains dark soil sized particles, temperature of the compost gets cool and carbon to nitrogen ratio is between 15:1 and 30:1. The composting process might take long in an event that the water supplied was not enough or too much of carbon materials.

Management of Nursery

Seedbed and nursery beds

For raising flower seedlings, some permanent or temporary structures for seed bed may be prepared. These beds will be minimum 0.5 to 0.75 m high from ground level. The beds may be 0.75m to 1.00m in breadth and length may be as per the availability of land. The nursery beds will be prepared for storing of perennial plants or the plants that should be kept for sale.

Collection and planting of mother plants

The plantation of mother plants is an important work for developing a nursery. The mother plants must be true to the type and true to the variety. The plants should be properly labelled. Collection of exotic type of mother plants is a continuous process or job. The mother plants may be maintained properly for their vigorous growth; otherwise, number of propagated plants will get reduced.

Storage of dried, cleaned soil and compost manure

For raising flower seedlings during rainy or early winter season, the soil and compost would be stored during hot or summer months. In rainy season, collection of dried soil and manure is very difficult. Without these, the seedlings cannot be raised during rainy season.

Production of flower seeds

Production of flower seeds is highly specialized job. The seeds should be produced carefully. If the quality of seed is good, the percentage of seed germination, seedlings vigour, vegetative and reproductive growth of the crops will be good. After harvesting of quality seeds, germination percentage of seeds and seedling vigour should be checked before marketing of seeds.

Storage of propagated plants in nursery beds

The propagated plants are planted in nursery beds for better growth or hardening the plants. In general, this type of nursery bed is prepared under partial shade.

Manuring

Manuring is to be done very carefully. Vigorous growth of plant is always attractive to the buyer. Again, heavy manuring is not beneficial for storage of plants.

Watering

Like manuring, watering is also vital in the nursery. Moisture provision to the plant is done according to need of the plant. For the plants to be maintained health, the nursery should have a water source nearby. Sprinkler type of irrigation system is not advisable at the initial stages.

Drainage

For sufficient vegetative and reproductive growth of plants, good drainage system must be developed in between the beds and around the nursery. Adequately gentle slope in the pot bed surface is also desirable. It is extremely important to ensure that water logging does not occur in and around the pots and beds.

Plant protection

Keen observation on attack of different pests and diseases is required. If the mother plants are infected, the propagated plants will be infected also. Necessary control measures should be taken immediately on observation.

Harvesting

Seeds and bulbs need to be harvested at the required stage. Only completely ripe seeds are ready for harvesting. Seed capsules should be covered with muslin cloth or by the paper bag before ripening in cases of light seeds which may blow off due to wind or those species the fruits of which may burst while ripening in order to prevent loss of seeds.

Corms and bulbs are generally harvested when the leaves start yellowing or when they dry up. These are dug out carefully without imparting any injury.

Before harvest, nursery stock should be mature. The tissues are hardened against water loss and shrinkage. It is a common practice to defoliate shrubs and trees some days before they are to be dug out. This can be done by chemical defoliants, by withholding water or by hand. Live plants intended for transport are sent with a ball of earth around their roots.

Soil health in agriculture practices

In some areas, materials such as plastic sheets or even stones are used for covering the soil. However, in this manual the term ‘mulching’ refers only to the use of organic, degradable plant materials.

Protecting the soil from wind and water erosion

In the presence of mulch, soil particles cannot be washed or blown away. Improving the infiltration of rain and irrigation water by maintaining a good soil structure: no crust is formed; the pores are kept open.

Keeping the soil moist by reducing evaporation

When mulch is applied plants need less irrigation or can use the available rain more efficiently in dry areas or seasons.

Feeding and protecting soil organisms

Organic mulch material applied on the bed is an excellent food for soil organisms and provides suitable conditions for their growth.

Suppressing weed growth

Putting sufficient mulch layer on the bed, weeds will find it difficult to grow through it Preventing the soil from heating up too much

Laying of mulch on the bed provides shade to the soil and the retained moisture keeps it cool

Providing nutrients to the crops

In the process of decomposing, organic mulch material continuously releases nutrients, thereby fertilizing the soil

Increasing the content of soil organic matter

The parts of mulch material will be converted to humus

Selection of materials to use for mulch

The kind of material used for mulching will greatly influence its effect. Material which easily decomposes will protect the soil only for a rather short time but will provide nutrients to the crops while decomposing. Hardy materials will decompose more slowly and therefore cover the soil for a longer time. If the decomposition of the mulch material should be accelerated, organic manures such as animal dung may be spread on top of the mulch, thus increasing the nitrogen content.

Sources of materials

Weeds or cover crops, crop residues, grass, pruning material from trees, cuttings from hedges, wastes from agricultural processing or from forestry

Soil moisture management

Scarcity of water for agriculture is a common problem in most countries. For some regions it is difficult to grow crops without irrigation. Even in areas with adequate rainfall in the rainy season, crops may get short of moisture during dry periods.

Keep soil moisture

In dry periods, some soils are likely to supply crops with water while other soils are unable to supply crops with water. The ability of a soil to absorb and store water is dependent on the soil composition and on organic matter content. Soils with high clay content can store up to three times more water than sandy soils. Presence of Soil organic matter acts as storage of water, like a sponge does. Crop residue protects the soil, prevents crusting on the soil surface and eventually slows soil runoff. Roots and soil biological organisms maintain cracks and pores in the soil, reduce water runoff, and more sinks into the soil.

With the availability of irrigation systems, many crops can be grown outside their typical agroclimatic conditions. It may be possible to cultivate land which would otherwise be unsuitable for agricultural activities without irrigation. Therefore, cultivation of sensitive crops can be shifted into areas with less pest or disease pressure. Among the irrigation systems there are irrigation systems with higher or lower efficiency and with more or less negative impact. If irrigation is the best alternative, it is important to carefully select a system, which does not overburden the water source, does not cause harm to the soil and has less impact on plant health.

One promising option is the drip irrigation systems. From one central tank, water is distributed through thin perforated pipes directly to the single crop plants. The system provides a continuous but very light flow of water, allowing sufficient time to infiltrate in the root zone of the crops. Therefore, a minimum amount of water is lost and the soil is not negatively affected.

Pest and disease management

Pest and disease management consists of a range of practices that support each other. Some of the management practices are long-term activities that target prevention of pests and diseases from attacking a crop. The focus is on keeping existing pest populations and diseases in the field low. On the other hand, control is a short-term practice that focuses on killing pest and disease. The general approach in pest and disease management is to deal with the root cause of a problem rather than treating the symptoms. Therefore, management practices are of a much higher priority compared to control. This document describes preventive practices, as well as control practices using biological, mechanical control and natural pesticides.

A healthy plant is not vulnerable to pest and disease infestation. Therefore, a major aim for the pest and disease control is to create conditions which keep a plant healthy.

Management practices

Prevention of pests and diseases can be accomplished by right timing of management practices, a combination of various methods, or the choosing of a selective method. Some important preventive crop protection measures include to select varieties which are well adapted to the local environmental conditions (temperature, nutrient supply, pests and disease pressure), as it allows them to grow healthy and makes them stronger against infections of pests and diseases.

Use safe seeds which have been inspected for pathogens and weeds at all stages of production.

Use planting material from safe sources.

Mixed cropping systems can limit pest and disease pressure as the pest has less host plants to feed on and more beneficial insect life in a diverse system

Crop rotation helps to reduce the chances of soil borne diseases and increases soil fertility.

Green manuring and cover crops are important to increase the biological activity in the soil and can enhance the presence of beneficial organisms.

Moderate fertilization can enhance steady growth of the plant and makes a plant less vulnerable to infection. Too much fertilization may result in salt damage to roots, opening the way for secondary infections.

Balanced potassium supply contributes to the prevention of fungi and bacterial infections

Increases micro-organism density and activity in the soil, thus decreasing population densities of pathogenic and soil borne fungi.

Regulates weeds which serve as hosts for pests and diseases.

Most pests or diseases attack the plant only in a certain life stage; therefore, it's crucial that this vulnerable life stage doesn't correspond with the period of high pest density and thus that the optimal planting time is chosen.

Scouting

Regular scouting of pests, diseases and weeds is the basis for effective pest and disease management. In order to manage pests, diseases and weeds, details are needed on the specific pests, diseases and weeds occurring in the region and the associated damage they may cause. Mostly crop pests belong to the insects, mites and nematodes and birds (like sparrows) that can also damage crops. The basic crop diseases are caused by fungi, bacteria or viruses.

Careful and continuous scouting of pest and disease levels in the field at critical times of growth of a crop is key to successful management of pests and diseases. This can be done through regular monitoring of the field. This helps to intervene early enough before the pest or disease can cause significant damage to the crop.

The usual pattern of pest and disease scouting programs involves walking along a predetermined zigzag or M-shaped route through the entire field. This pattern is mostly used because it is easy to teach, convenient to use, and helps to reach all regions of the field to be visited. In order to monitor insect pests, even traps can also be used. The simple idea is to detect the presence of the insect pests in the field especially the fast moving.

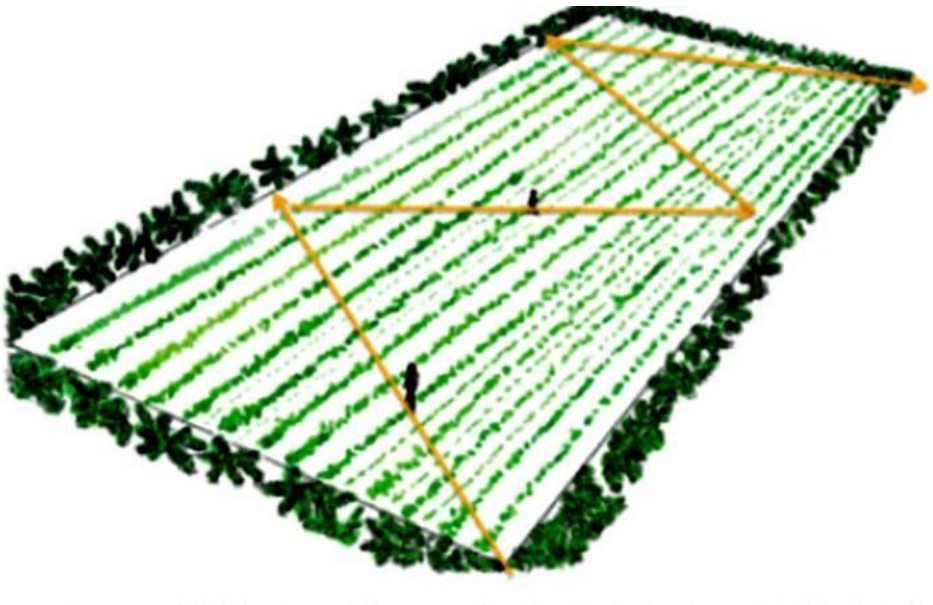

Figure 6 Showing the scouting techniques

The important pattern for pest and disease scouting programs includes walking along a predetermined zigzag or W-shaped route across a field. The pattern is usually used because it is easy to teach, convenient to use, and ensures that all parts of the field are visited.

Weed management and control

Agricultural production gives priority to prevention of the introduction and weed multiplication. Management practices target keeping the population of weeds at a level that does not result in crop economic loss or harm its quality. The aim is not to completely eradicate all surrounding weeds, since weeds also have a role to play on the farm. For instance, they provide cover that reduces soil erosion. Additionally, biological diversity in crop fields is as a result of weeds presence. Weeds provide habitat for beneficial insects used in biological control methods and mycorrhiza fungi. Some of the weeds offer pollen and nectar to allow biological control insects to maintain their population.

On the other hand, weeds alter negatively the environment of the crop. Such as creating competition for light, nutrients and air circulation. Sustainable weed management depends on creating conditions which prevent weeds from growing when not needed and in the wrong place to become a serious disturbance for the crop cultivation. The sensitive crop growth stage to weed competition is in its early growth stage. Which means a juvenile plant is vulnerable as it depends highly on high nutrient, light, and water supply for a health development. Subjecting the plants to competition with weeds at this stage, result in weak crop growth, which also makes it vulnerable to infection of pest and diseases.

Weed preventive practices

Choice of crops and varieties

Tall crops and broader leaf varieties compete well with late occurring weeds than small varieties with narrow leaves. Some crops prevent weeds through inhibiting and suppression, while others through tolerance.

Mulching

Weeds find it difficult to acquire enough light to grow and germinated weeds fail to pass through the mulch layer. Use of slowly decomposing materials for mulch keeps its effect longer than fast decomposing material.

Cover crop

The cover crop competes successfully with weeds for light, nutrients, and water to prevent weed growth by winning the competition for resources. Examples of cover crops used in preventing weeds are legumes that improve soil fertility on top of suppressing weeds.

Crop rotation

Rotating crops in the field contribute efficiently to regulate seed and root weeds invasion. Regular changing of crop conditions interrupts the living conditions of the weeds thereby inhibiting their growth and spread.

Intercropping

Intercropping using fast growing weed suppressive varieties between rows of main crop species proves effective in weed control. The notable example is growing maize intercropped with cowpeas that suppress growth of weeds and reduce weed occurrence.

Biological control

Rhizobacteria with the ability to suppress germination of weed seeds or actual distraction of the seeds are particularly promising biological control agents because they can be cheaply formulated into seed inoculants.

Mechanical control

Weeding manually is the important available method to control weeds in the field. There are various tools to dig, cut and uprooting the weeds such as hand, ox-drawn and tractor-drawn tools. It is encouraged to weed before the weeds flower and produce seeds to prevent spreading of weeds.

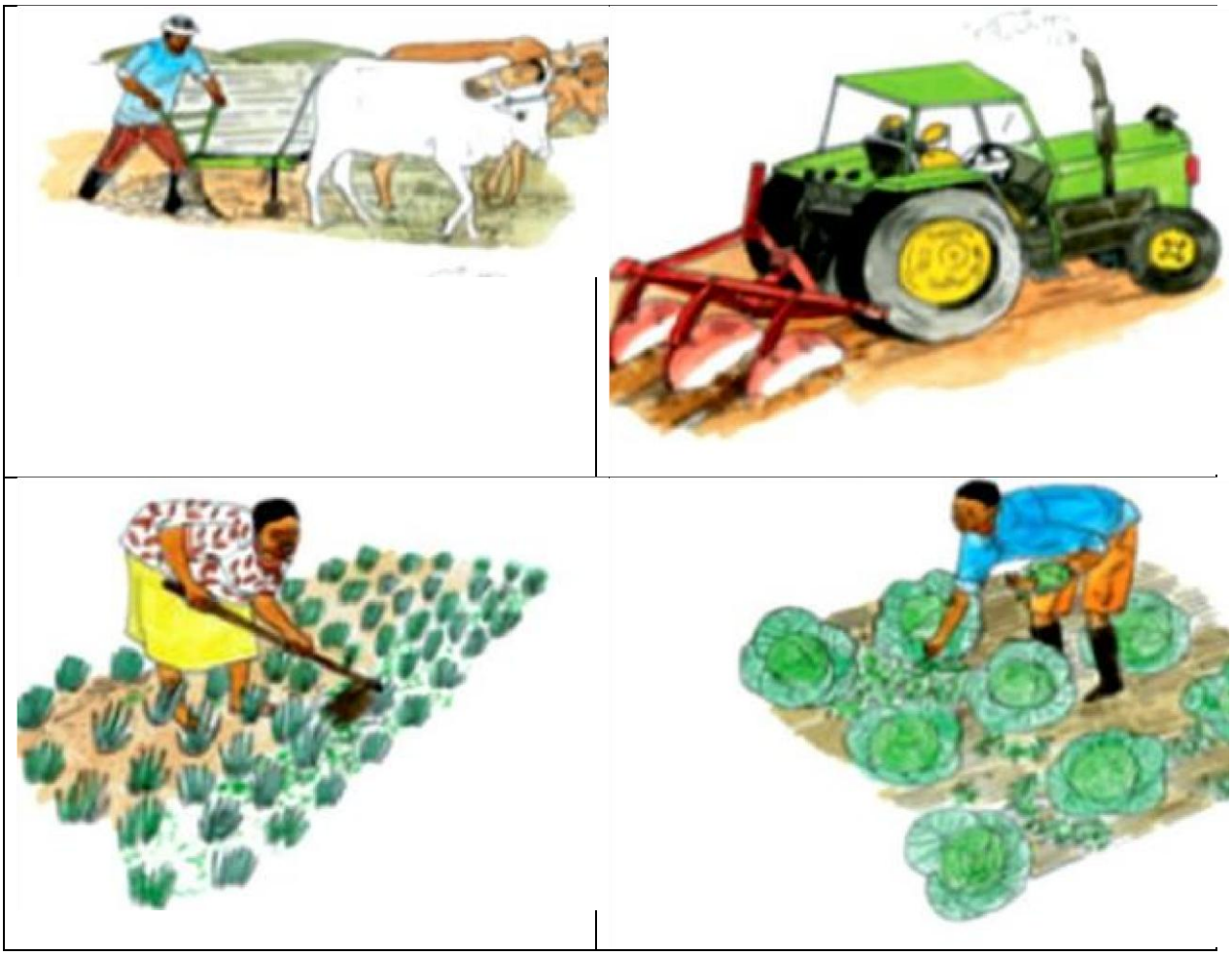

Figure 7 Depicts the weed control methods of using animals, tractor, hand and hoe weeding

Chemical control

Chemical control is the final option after exhausting the possible methods. Categories of chemicals available to control weeds include pre-emergency, post emergency, selective and non-selective herbicides. Care should be taken to avoid contamination of the environmental during the spraying and disposal.

Soil cultivation and tillage systems

Soil cultivation methods include mechanical measures to loosen, turn or mix the soil, like ploughing, tilling, digging, hoeing and harrowing. Tilling the soil can improve soil capacity in water retention, aeration, infiltration capacity and evaporation. However, soil cultivation can be harmful to soil fertility as it increases soil erosion and the decomposition of humus. Depending on the adopted cropping system and the type of soil, appropriate soil cultivation patterns must be developed in the field.

Minimum tillage

Minimum cultivation system helps to build up a natural soil structure with a top soil rich in organic matter and contains soil organisms. Loss of nutrient is reduced to a minimum due to non-sudden decomposition of organic matter and nutrients are held by a dense network of plant roots. Soil erosion is not a problem so long there is a permanent plant cover and sufficient input of organic material. Additionally, time and labour is saved in minimum tillage system.

Types of soil cultivation

Primary tillage

This type of tillage is done with a plough or a hoe to achieve a flat turning of the top soil and a loosening of the medium deep soil.

Seed bed preparation

Before planting of any crop secondary soil cultivation is practiced to pulverize and smoothen the ploughed surface. The purpose of seedbed preparation is to provide enough loose soil of appropriate clod size. In areas experiencing water logging, seedbeds can be established as mounds or high ridges.

Vegetative crop stage cultivation

After the crop establishment, shallow soil cultivation promotes weed suppression. Also, promotes enhancement the aeration of the soil and at the same time reduces the evaporation of soil moisture from the deeper soil layers. When crops are temporarily lacking nutrients, shallow soil cultivation can stimulate the decomposition of organic matter, thus making nutrients available.

Post-harvest cultivation

In order to speed up decomposition of crop residues, previous crop material are incorporated into the soil before preparing the seedbed for the following crop. Crop residues, green manure crops and farmyard manure are worked on in the topsoil layer of about 15 to 20cm because decomposition in deeper soil layer is not complete, producing growth inhibiting substances which can harm the following crop.

Simple tools for soil cultivation

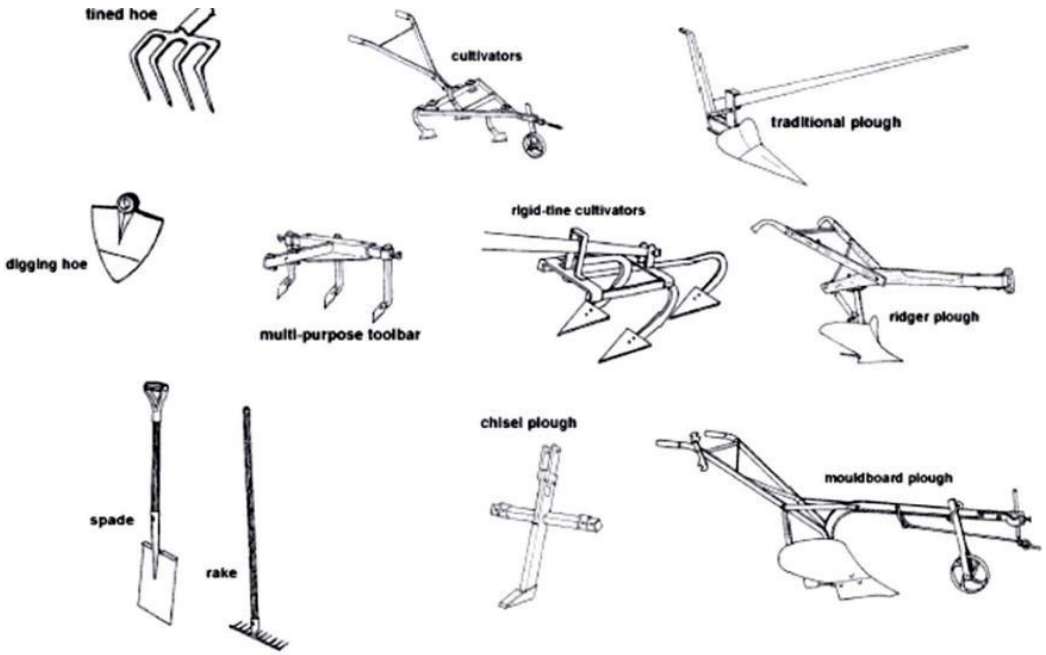

Figure 8 Diagrams of simple tools used in practical cultivation

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