TRAINING MANUAL FOR AGROFORESTRY PRACTICES, TREE NURSERY MANAGEMENT, PLANTATION ESTABLISHMENT AND COOKSTOVES

LAKE VICTORIA ENVIRONMENT MANAGEMENT PROJECT II

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Summary

This training manual is intended to help Trainers of Trainers on Agroforestry practices, tree nursery establishment and management, principles and practices of plantation and woodlot management. It also covers energy saving cook stoves.

Overview of the importance of Forests in Uganda

Forests, trees and woodlands are important resources and they play multiple ecological, economic, social and cultural roles. Forestry makes a substantial contribution to the nation's economic development and well-being, although the extent of this is not fully recognized. This therefore suggests that there are many opportunities for poverty alleviation, for economic development and for environmental improvement through forest sector development. Generally, it is recognized that forestry is very important through its contributions to:

- The national Gross Domestic Product
- Provision of forestry products
- Creation of employment
- Provision of subsistence needs
- Provision of environmental services and bio-diversity
- Much of the tourism in Uganda is based on forests, woodlands and their constituent wildlife and natural beauty.

However, the main issue is how to capitalize on the economic, social and environmental opportunities in forestry without undermining (degrading and over-exploiting) the resource base. A lot of deforestation has occurred in the last 50 years. This has been mainly due to the rapid population increase which has not been coupled with parallel economic and technological development. The following activities have contributed to the environmental degradation:

- Clearing forests for agricultural development
- Cutting of trees for charcoal production
- Collection of firewood for domestic as well as for commercial purposes
- Burning of forests
- Over-grazing by livestock in some areas like in the cattle corridor.
- Degradation of wetlands

Some of the consequences of deforestation:

- Shortage of construction poles and timber
- Fuel-wood problems in some areas
- Shortage of fodder/forage during the dry season
- Silting and flooding of rivers and streams
- Declining soil fertility leading to low crop yields
- Increased soil erosion.

Efforts to reduce the rate of cutting down trees for both charcoal and firewood include:

- Agroforestry initiatives
- Energy saving stoves
- Briquette making
- Solar cookers
- Tree planting

CHAPTER ONE: AGROFORESTRY PRACTICES

1.1 What is Agroforestry?

Agroforestry is planting and managing trees on farms. It is a combination of agriculture (agro) and forestry practices on the farm. Agroforestry components include:

Trees and Livestock (bees, fish, cattle and goats)

Trees and Crops

Trees , Livestock and Crops

1.2 What can Agroforestry Provide

Due to increased human populations, gazetted forests can no longer meet the demands for tree products and services. The most possible alternative way of providing tree products and services at the farms. Some of the important tree products include: Fuel wood; Poles; Stakes; Timber; Mulch; Fruits; Fodder; Medicines and others. All these products can be utilized at household level and/or sold for income generation thus leading to improved livelihoods.

Tree services include the following: Control of soil erosion; Improving soil fertility; Protection from wind; Fencing; Boundary marking; Shade; Ornamentals and others.

The service role of trees can be utilized to increase and sustain the productivity of the natural resource base leading to increased production. In turn increased production can lead to improved and sustained livelihoods.

1.3 Why Agroforestr ypractices

Declining Land Size

Due to population increase Uganda is experiencing significant declines in land holding sizes. In some parts of the country land holding has become as small as 0.25 acres supporting a household size of 8 people. Agroforestry technologies can be used to improve and sustain the productivity of these small pieces of land.

Limited Access to Forest Products and Services

Again due to population increases forest cover has sharply declined in the country. This has reduced access to forest products and services. Agroforestry can enable farmers produce some of the tree products and services on the farm.

Declining Soil Fertility

Declining soil fertility is one of the major challenges facing farmers and the entire agriculture sector. The phenomenon has placed millions of lives in Uganda at risk as more

than 80% of the population depends directly on farming for their livelihoods. Agroforestry technologies can be used to improve and sustain soil fertility. Improved soil fertility can then lead to increased yields and improved livelihoods.

Food Insecurity

Improved fruits when properly integrated on the farm can provide fruits for domestic consumption and also for selling to generate income. Furthermore, soils can be improved through Agroforestry leading to increased productivity and improved food security.

Livestock Production

Livestock play a pivot role in the livelihood strategies of all farming communities in Uganda. Like crops, the country is experiencing declining livestock productivity. This is partly due to lack of pastures and fodder. Use of Agroforestry technologies can be used to provide fodder for livestock leading to increased productivity. This will in turn improve food security while also generating income for the farm family.

Climate Change

A change in seasonal weather patterns and parameters is affecting not only Uganda but the entire world. This is partly blamed on declining forest and tree cover in the world. If farmers can integrate trees on their farms and other landscapes, together we can reduce the impacts of climate change. Agroforestry technologies can be used to reduce the impacts of climate change and also increase our capacity to adapt to climate change.

1.4 Types of agroforestry practices

1.4.1 Scattered tree planting / growing.

Trees may be grown on farmers fields while crops /and or animals are in the same land management unit. The trees may be widely dispersed and randomly scattered or systematicallyspaced in the farmland.

Reasons for scattered tree growing in farmlands include:

- To increase crop production.
- To diversify the range of products.
- To maintain organic matter.
- To reduce soil and water loss by surface plant litter cover.

1.4. .2 Boundary tree planting/growing

Is the practice of planting/growing and managing trees along boundaries in systematic way.

Reasons for systematic tree growing along boundaries:

- For land demarcation
- Increase wood production

- As wind brakes to control wind speed
- To control soil erosion
- To maintain organic matter thru litter fall
- To maintain soil moisture
- Provision of wood products

Suitable trees for boundary planting include:

- *Grevillea robusta*
- *Maesopsis eminii*
- *Melia azedarach*
- Eucalyptus spp
- *Markhamia lutea*
- Senna spp
- *Calliandra calothyrsus*
- Cassuarina spp

1.4.3 Improved fruit tree growing

Are improved because they have been grafted or budded with material of superior qualities

Why improved fruit trees?

- **B**etter yield from the grafted or budded trees and shortened time of fruiting.
- Income generation
- Nutrition and Food security

Improved fruit tree types

- Tropical fruit trees e.g. mangoes, oranges avocadoes e.t.c.
- Temperate fruit trees e.g. apples, pears, nectarines e.t.c.

Advantages of improved fruit trees?

  - Sweeter than the local varieties
  - Fruits have more juice than the local varieties
  - Fruits are fibre free compared to the local varieties
  - The fruits are of a bigger size e.g. 1 fruit can weigh up to 1½ Kg
  - Initial time of fruiting is reduced e.g. fruiting starts between 1-2 years
  - Provide shade for humans and animals
  - Provide wood and other products from prunings
  - Act as wind breaks
- Control soil erosion

1.4.4 Woodlots

The practice of growing and managing trees as pure stands in depleted/ marginal lands.

Why tree growing as woodlots

To make use of unproductive land where agricultural crops cannot be grown

Suitable tree species include:

- *Eucalyptus spp (site specific)*
- *Pinus spp (site specific)*
- *Senna spp*
- *Terminalia spp*
- *Tectona spp*
- *Gliricida sepium*
- *Melia azedirach*
- *Grevillea robusta e.t.c.*

1.4.5 Improved fallow

Short rotation leguminous tree shrubs planted for a season and cut back and incorporated into the exhausted soil for fertility restoration.

Why improved fallows

Improved fallows are practiced because they take a short time (rotation) before cutting back to incorporate into the soil and the land can again be used for crop production

Examples of improved fallow tree species include *Crotalaria ochloreuca, Crotalaria paulina ,Tephrosia vogelli, Tephrosia candida, Sesbania sesban*

Advantages of improved fallows:

Increase crop yields thus improved food security, Income generation from sale of improved fallow seed, money saved from labour as fallows suppress weeds, fallow period to regain soil fertility reduced from 6 to 1 season, improved soil conditions ease in land preparation

1.4.6 Fodder banks

What is a fodder bank?

A farming system where legume tree shrubs e.g. Calliandra are grown together with grasses like Napier on the farm.

Why fodder banks?

For provision of livestock feed where grazing land is a constraint

Fodder bank establishment arrangements

As pure blocks of recommended tree shrubs

- Along boundaries or as contour hedge rows
- As an interplant with grass (i.e. 1 row of calliandra with 3 rows of Napier)

Benefits from fodder banks

- Improved milk production. Research has shown that milk production improves by twice as much when a cow is fed on calliandra mixed with Napier grass as fodder.
- Cheap and reliable source of livestock feed

- Source of firewood
- Provide stakes for bananas and climbing beans
- Source of construction material
- Legume trees improve soil fertility
- Soil and water conservation
- Bee forage
- Source of seed
- Income from sale of seed and stakes e.g. 1Kg of Calliandra is bought at Ush 15,000 at National tree seed centre at Namanve

1.4.7 Home gardens

What is a home garden?

Is an agroforestry practice in which different types of tree crops, agricultural crops, grasses and herbaceous plants are grown together in a garden.

Why a home garden?

To maximise utilisation of available land where land is scarce without depleting/exhausting the soil. A home garden is usually located near the homestead; is sustainable with little external in-put.

Benefits from a home garden

- Decomposed leaf litter from trees improves soil fertility
- Controlled soil erosion and conservation of soil moisture
- Provides a variety of products e.g., food, firewood, stakes, medicine, construction materials e.t.c.
- Improved crop yield as a result of improved soil fertility
- Near the home so easy and convenient to manage

1.5 Common management practices for farm trees

1.5.1. Pruning

This is the operation of removing live branches or shoots and/or roots from a growing tree.
The common types of pruning include; coppicing, crown or branch pruning, lopping, pollarding and root pruning

1.5.2 Cutting back (coppicing)

This is an operation involving the cutting back trees or shrubs to influence young re-growth. The trees commonly managed this way include; fodder, soil fertility improvement, poles and fuelwood trees. Fodder trees or shrubs should be cut back before flowering.

1.5.3 Branch pruning:

This is the removing of the lower branches from the crown. It is done to; a) enhance vigorous growth, b) reduce shade over the associated crops, c) produce knot free timber d) produce marketable poles e) obtain fuelwood and provide organic matter (manure) to the soil. Avoid reducing the number of branches in fruit trees. This management practice is commonly carried out on most trees apart from those grown for fodder and soil fertility. Branch pruning should start when the crown starts shading the companion crops. It should be carried out before planting the crop, that is, once or twice a year.

1.5.4 Lopping:

This is the selective cutting of branches at a distance from the stem to obtain fodder, fuelwood, medicine, seeds, etc.

1.5.5 Pollarding:

This is the cutting back of the tree top or the removal of the crown. This is mainly done in order to: harvest fodder, reduce shade over crops, obtain fuelwood and provide mulch. This practice is carried out on fodder trees, boundary and scattered trees and compound trees. Lopping and pollarding can be carried out on any established mature trees when need for the tree products arise.

1.5.6 Root pruning:

This is the cutting of the roots to reduce competition with crops, avoid damage to buildings, and harvest medicine. The subsequent root pruning can be done during garden preparation before planting.

Procedure for root pruning

- a distance of 30cm from the tree is marked
- A trench measuring 30cm wide and 30cm or more deep is then dug
- After root pruning, soil is put back in the trenches and the crop planted.

The benefits of root pruning are:

- It enhances crop yields in tree/crop agroforestry practices
- It is the best option for fruit trees where shoot or branch pruning would otherwise remove the fruits as well
- It is the best option for over grown timber trees where shoot pruning is not possible
- It can be easily incorporated into the routine farm work
- Its user friendly to women as the element of climbing trees is avoided.

1.5.7 Thinning:

This is the exercise of removing some of the trees planted to allow the remaining to grow to the required sizes to meet the objectives of the planting. This operation applies in all agroforestry technologies a part from fodder bank, soil fertility improvement, live fencing and windbreaks.

CHAPTER TWO: TREE NURSERY ESTABLISHMENT AND MANAGEMENT

2.1 Introduction

Availability of good quality seed on time is a pre-requisite for all tree planting activities. The way seedlings are handled and managed in a nursery contributes to their survival rate after planting and their subsequent growth performance. Improving seedling quality correlates positively to their survival, growth and productivity.

Nursery practices must be consistent and the various techniques closely integrated. If one element in the chain is lacking there will be a negative impact on seedling quality. Good quality seedlings cannot be produced without care and tending. Nursery plants need to be protected from extremes of environmental conditions until they are strong enough. To ensure high quality of seedlings and to provide more opportunities (income, technology transfer). local people are encouraged to establish small-scale community nurseries.

2.1.2 What is a tree nursery?

A nursery is a place where seedlings are propagated, managed and grown to plantable size. To ensure a good planting programme, good nursery stock is necessary as it produces seedlings for agroforestry, afforestation and reforestation and other tree planting activities. The purpose of a tree nursery is to grow seedlings:

- Of the required plant species
- Of the required age, size and sturdiness
- In sufficient quantities for the intended tree planting programs
- At the most favorable time of planting

2.1.3 Types of tree nurseries

i. Temporary or permanent

A temporary nursery is established if the planting period is lasting for not more than 1.5 years.
It can be used for three seasons only, and is abandoned after fulfilling the aim of the planting program.

ii. Permanent nursery:

This is the type meant to serve for a long period of time. In this case, seedlings are raised from year to year, e.g. central nurseries for research and traininginstitutions. Some privately owned commercial nurseries are run on a permanent basis..

2.1.4 Tree nursery terminologies

i. **Seedbed:** An area in the nursery where seeds are sown and germinated.
ii. **Transplants:** Young seedlings which have been pricked out from the seed bed into the transplant bed.
iii. **Pricking out**: Is the operation of lifting young seedlings from the seed- bed to the transplant bed
iv. **Transplant bed**: An area in the nursery where young seedlings which have been pricked out are cared for
v.**Propagation:** Is the production or multiplication of a plant using its parts. These could be;seeds, stem cuttings, roots, branches and sometimes leaves
vi. **Viability:** Ability of the seed to germinate

2.2 NURSERY ESTABLISHMENT

When establishing a tree nursery, various aspects have to be taken into account. These include; size, location, availability of water, skilled labor force and market for the seedlings to be raised in the nursery**.** A nursery site is a very important point to consider before starting because it influences the effort that will be required to maintain it, the way in which it will be managed, and the ease of access to users.

2.2.1 Factors to be considered in selecting the site for a nursery

i) Availability of land: The selected nursery site should have enough land to raise the number of seedlings needed, and if possible, room for expansion. The size of the nursery depends on the number of plants to be produced, the time they will remain in the nursery.

ii) Land ownership: Before establishing a nursery, it is important to ascertain who owns the land. If it is institutional or privately owned land it is advisable to formalize the use of the land by obtaining a letter from the owner agreeing to its use as a tree nursery for a defined period of time. For communal nurseries, the land should preferably be public land. If privately owned, a binding agreement must be made between members of community and the owner.

iii) Permanent Water supply: A reliable and adequate water supply is always a requisite in nursery establishment. The nursery site should be located near the source of clean water either from a running stream or main pipe water supply to sustain rapid and healthy growth of the seedlings. Alternatively, a water storage tank should be installed for sustainable water supply.

iv)Topography: The area for tree nursery establishment is preferably flat with a gentle slope to allow for drainage. Contour terracing should be done if the slope is in excess of 2 per cent.

v) Accessibility: The site should be accessible all year round, so that customers are able to get seedlings easily as well as for transportation of mature seedlings to planting sites and/or markets. The site should be near to the road and as close as possible to the centre of the area to which plants will be supplied.

vi)Availability of labour: A lot of labour is required for the construction of a nursery and subsequent nursery activities. Hence nurseries should be located where labour is available. Siting a nursery on a main road near a village will also increase awareness and enhance patronage.

vii) Soils: Deep, good-structured soil is desirable. Avoid shallow soils with a hard sandstone band near the surface. A very sandy-structured soil should also be avoided because of poor moisture retention characteristics and faster leaching of plant nutrients. Soil containing too much clay has poor drainage characteristics and should not be considered for a nursery site.

2.2.2.Basic tree nursery facilities

A good nursery should have:

i) Access roads and path

Access roads and path facilitate easy movement of seedlings from seed beds to transplant beds and also for smooth movement of workers doing nursery operations such as routine watering, root pruning, sorting etc. should have pathways to all parts of the nursery

ii)Fencing

It is necessary that all animals are totally excluded from the nursery. A live fence of thorny shrubs, barbed wire or chain link fence of 1.8m high is ideal.

iii) Shelter

Shelters for tools, materials and workers should be constructed if the nursery is not located near a homestead.

iv)Seed beds

These are usually made for the seeds which cannot be easily sown directly in the transplant pots. Such seeds are first sown in these nursery beds and after germination, they are pricked out and transplanted into transplant beds where they attain plantable sizes.

When do we use seedbeds?

- When seed is old or when the germination is low or unknown, use a seedbed to test viabilitybefore filling too many containers and wasting resources,
- If seed does not store very well (that is if it is "recalcitrant"),
- If containers are not available, or not filled in time to use, seedbeds can be used until thecontainers are ready.

Some common problems associated with seed beds

- Using unskilled labour in pricking out always results in deformities,
- When plants are left in the seedbed too long (which often happens), they produce long roots that are easily damaged or twisted when pricking out,
- Many seedlings suffer a "shock" when they are transplanted from the seedbeds,

v)Transplant beds

This is where seedlings are transplanted after pricking out from the seed beds and/ or direct sown.

vi) Shading and shelter for plants

These are made above the beds to protect the delicate seedlings in the transplant beds from too much sunshine or hailstorms. Papyrus mats or elephant grass can be used

vii) Sources of soil materials

Sources of various soil components to be used in soil mixing should be put under consideration. Transportation of soil materials not at the site is a paramount

viii)Wind breaks

Trees should be planted around the nursery to guard the nursery against strong winds.

ix)A compost area

This is an area where plant remains are collected for decomposition to make manure for future use

x)Working area

A good tree nursery should have a specific reserved area where workers can sit as they do their work. It is better for the working area to have a shelter. The main activities done here include pot filling and pot cutting.

2.2.3. Nursery site preparation and layout

Materials and equipment needed for Nursery establishment include:

- Wheel barrows, Jerry cans, watering cans, rakes, pangas, hoes and spades
- A number of containers can be used, for example, polythene tubes, empty milk packets, tins and banana fibres.
- Poles, timber, grass,papyrus mats and nails are also needed for shade stand construction.

Nursery site preparation

Steps followed for site preparation:

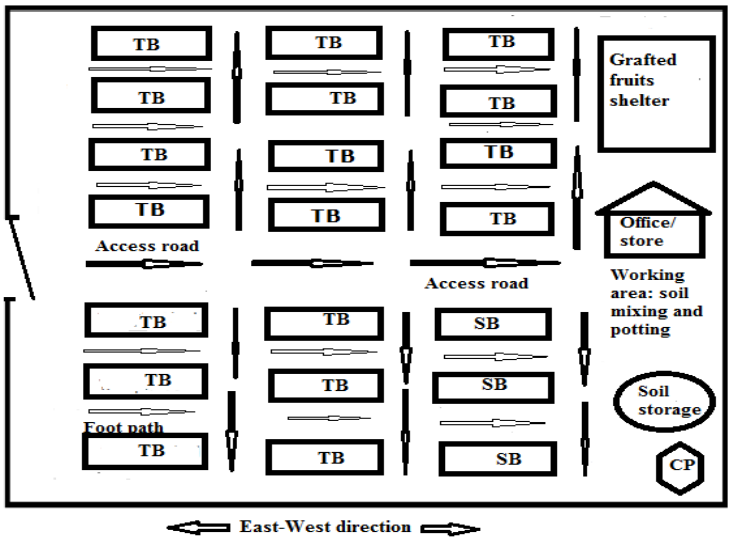
- Cut all the trees to a radius of 10m beyond the proposed boundary
- Remove all the stumps and burn all the trash that was left behind

- Destroy any termite mounds and remove all clay soils that was associated with them
- Dig up or plough the area thoroughly well, removing any large stones and roots
- Peg out the location of blocks and alignments of roads and beds within the area
- Level each block using a leveling board, you can bring in soil from nearby areas to fill deep depressions
- You can establish short grass to stabilize the soil
- After sometime, a certain amount of settlement may take place and if this has happened, level the blocks again using discarded soils.

To obtain the maximum effect of the shade, beds should be orientated to run East- West to avoid direct sunshine. During March to September when the sun is in the northern hemisphere the shade should slope towards the north and the rest of the year when it is in the southern hemisphere, it should slope towards the south. If the sun is strong in the morning or evening, vertical shade can be constructed at each end of the bed.

Nursery layout

This should be in such way that commonly frequented areas like offices, water sources, pot filling area and seed beds are centrally located. Transplant beds can be located around these for easy accessibility as shown in Figure 1. It is more convenient for beds to be 1 m wide and preferably not more than 20m long for easy management. It is better when beds are arranged in blocks. Width between beds may be 1M. Roads can be 4.5 m wide depending on the size of the nursery.



SB= Seed bed
TB= Transplant bed
CP= Compost pit

Figure 1:Nursery layout

2.3. STANDARD NURSERY OPERATIONS AND MANAGEMENT

Most nurseries adopt operations which are standard ; some operations are common to all nurseries although there could be some modification from one nursery to another.

Good hygiene of the nursery site is quiet important. This will lead to healthy and quality seedlings produced in the nursery.
Good nursery hygiene practices include;

- Disinfect the tools (knives) used in root pruning and drums used for collecting water
- Regularly overhaul the substrates in the seedbed mixture to ensure continuous nutrient supply to the young germinating seedlings
- If you are using grass or papyrus as shade, do not allow it to get rotten before you remove it
- Control of the weeds in the nursery might reduce the invasion of some pests to the nursery

- Always remove discarded and used old materials from the nursery to maintain the cleanliness and to avoid these materials to be used as entry points for pests and diseases.

2.3.1 Soil mixing

Good seed bed soils have two attributes: Ability to drain freely but retain enough water

i. Standard seed- bed soil mixture (SSM):

This is composed of 50% sieved black forest or top soil and 50% sieved sand. Therefore the ratio of soil to sand should be 1:1. The forest soil gives sufficient moisture holding capacity to promote good germination whereas the sand gives very porous, textured soil which allows good penetration of the roots of the germinating seeds and easy lifting when pricking out.

ii. **Standard transplant bed mixture (STM**)

This is the mixture of soil that is used in the transplant bed or polythene tubes and gives the seedlings the most favourable growth conditions. The recommended mixtures are as follows;
60% Un-sieved forest soil, 10% sand, 10% small stones (1cm diam), 10% clay and 10% composite manure. Sand and small stones give good root penetration and drainage characteristics, Clay and top forest soil assists to bind near the roots to improve on the moisture intake and nutrient retaining qualities. Composite manure, supplies organic matter and nutrients to the soil.

In addition to the above mixtures, 20% of Mychorrhiza soil should always be added whenever Pinus tree species are to be raised. Mychorrhiza soil is got from a well-established pine plantation. The above mixtures can be left to mature for 2-4 weeks before use. However it should be kept moist. Note: soil mixtures above are adjustable depending on the availability of soil types at the nursery site.

2.3.2 Pot filling

This is the filling of polythene tubes with soil. It should be done under a shade near the heap of the soil at the site of the transplant bed. The soil must not be too dry or too wet but moist enough to run freely into the tube and can easily be firmed to form the bottom of the tube. Soil mixture should be pressed into containers to a depth of about three-quarters of the height of pots. Pots should then be loosely topped up with soil mixture and pressed down lightly to about 2 cm below the top. Heavy compaction should be avoided at the top of pots because it will inhibit root penetration.

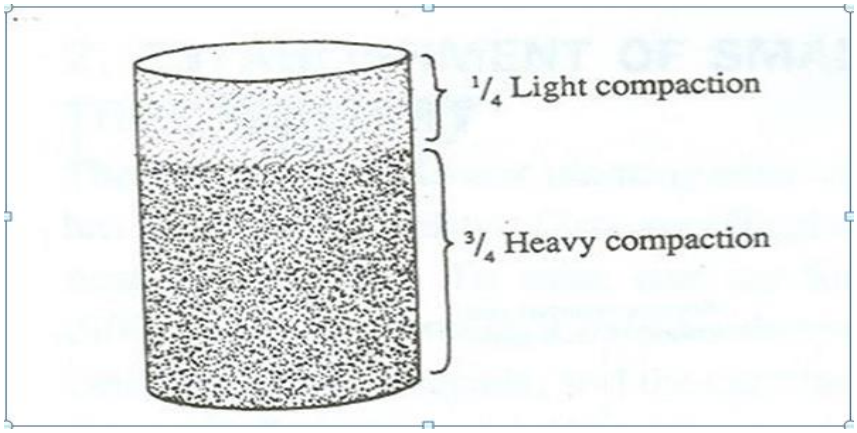


Figure 2: Example of good pot filling

2.3.3 Sowing seed

Methods of sowing seed

Seed sowing varies according to the size of the seed.

a. Broadcasting:

This applies to small sized seeds. The seeds are spread on top of the SSM, either by hand or mechanical broadcast.

b. Drill sowing:
This is the method of making shallow lines or drills in the SSM into which seeds are linearly dropped and lightly covered with SSM.

Procedure for sowing seeds in the seedbeds

- Level the seed bed,
- With fine seed such as *Eucalyptus spp* or *Bottle brush*, mix seeds with about twice its own volume of clean dry sand
- Spread the seed/ sand mixture evenly over the whole area
- Cover the seed with a layer of clean dry sand twice its own depth
- Firm the covering and water lightly using a can with a fine rose or sprinkler
- If any seed shows through the covering of sand, use another light layer of fine sand to cover the seeds.
- Continue watering twice a day, very early in the morning and late in the evening until the seed germinates
- Do not sow seed too thick.

c. Direct sowing:
This method isused when sizeable large seeds are directly sown into containers.
Direct sowing of seeds saves time, labour and money, because the extra step of preparing a seedbed and transplanting is eliminated. Even if it takes a little longer to plant small seeds directly in the containers, it is easier and cheaper than pricking out. Direct sowing allows undisturbed seedling growth and thus reduces stress of the seedlings.

When using direct sowing into containers, follow steps bellow:

- Prepare containers and shade in advance
- Test seed for viability before sowing. If less than 70% germinate, plant more than one seedper pot. If both germinate, prick out one into another container
- Pre-treat seed if necessary to speed up germination

Whenever possible, directly sow seed into containers to avoid root deformities.

2.3.4 Watering

The regular supply of clean water is essential to plant growth. When seedlings are grown in containers, they have only limited volume of substrate and cant access water from far below the soil surface.

The amount of water for watering depends on:

- Seedling age,
- Amount of sunlight,
- Soil type
- Turbulence (presence of wind).

Avoid the following type of water in the nursery

- Dirty water as it contains many plant diseases,
- Salty water as it has high concentration of dissolved minerals including possibly toxic elements from natural deposits containing oil.
- Very acidic or very alkaline.

Occasionally clean water tanks and disinfect with a disinfectant i.e. Clorox to remove plant diseases.
Ensure uniform watering of all the seedlings including those on the end rows and along the sides of the seed beds.

Some of the good nursery watering practices include:

- Regularly check the water status of the leaves to determine when to water,
- Water in the early morning and / or late in the evening,
- Water the substrate thoroughly and not the leaves,
- Water slowly and check that the water penetrates to the bottom of the container.

Some of the poor nursery watering practices include:

- Directing the water to the leaves and not the soil
- Watering during mid-day
- Watering quickly and only wetting the soil surface.

Other points to note:

- Over watering weakens plants and causes many diseases,
- If the soil is covered with green moss or algae that means you are watering too much.

NB: Be prepared for diseases like dumping off which can wipe out thousands of pine seedlings in a few days. Copper oxychloride is the standard precautionary treatment. Avoid too much dampness in the nursery to control spread of dumping off.

2.3.5. Pricking out

This is the act of lifting seedlings from the seedbed into the transplant bed or pots.
Only those who are trained in correctly pricking out should attempt it. Close supervision is necessary in order to avoid root deformities. Always check a few containers after a few days to ensure that it has been done correctly.

Pricking out process

- Ensure that the area where the transplanted seedlings will be kept is well shaded before you begin thinking of pricking out,
- Disregard any seedlings that appear sick or deformed,
- Transplant when the tap root emerges or when seedlings have shown two or three leaves, before secondary roots are formed,
- Water the pots well, one night before and one hour before pricking out so that water penetrates to the bottom of the seedbed,
- On days with strong sunshine, prick out in the early morning or late in the evening,
- Use a stick to gently loosen the soil around the seedlings by grasping their cotyledons or lower leaves – do not lift them out by the stem as it is still tender and fragile,
- Put seedlings in water and keep them under shade as soon as you take them from the germination bed,
- Prepare planting holes with a stick and ensure they are sufficiently wide and deep,
- Clip long or very branched roots to ensure they are pointed downwards,
- Gently pull the seedling upward after placing it in the hole, to straighten out roots,
- Pack the soil against the roots, starting at the bottom of the hole,
- Water the plants immediately after transplanting and continue watering as conditions demand,
- The whole operation should be carried out under shade.

Poor common pricking out practices includes:

- Waiting until plants are large and have long roots,
- Pricking out plants into dry soil and then watering them,
- Constructing shade after pricking out is done,
- Pricking out in direct, hot sunlight,
- Transplanting damaged seedlings,
- Removing seedlings by grasping the stem, as this may permanently damage the flow of water,
- Carrying seedlings in your hand or on a plate without water,
- Preparing the holes with a finger – the hole might be too small or too big depending on the sizeof the finger used,
- Allowing roots to bend upwards when inserting them into the hole,

- Leaving air pockets around the roots, plants will die.

2.3.6. Shade

After pricking out, transplants require full shade for the first 2 – 3 weeks, then ½ shade for 1 week, after which no shade should be necessary. As the shade is decreased, the intensity of watering must be increased. For the first days after pricking out, light watering is necessary, similar to that given to a seedbed. Once the plants are established and fibrous roots begin to develop, the rate of watering should start increasing gradually.

2.3.7. Weeding

This is the operation of removing weeds in order to reduce competition for water and nutrients so as to enable the transplants to grow well.

2.3.8. Root pruning

Is the cutting back of the actively growing roots of the transplants? Root pruning is carried out so as: to avoid the roots of the seedlings inter – twining, to enable the transplants to develop a well-established root system fit for easy establishment in the field and for the transplants not to penetrate into the soil and get established within the nursery site.

Procedure for root pruning

About 2 months after pricking out (depending on tree species), root pruning should done using a panga, knife or pruning saw. When using a knife, the pot is held in an upright position and the roots cut horizontally as shown figure 3 a. Alternatively, whenusing a pruning wire or panga, there is no need of lifting the seedlings off the ground. The panga or wire is moved horizontally at the soil level across the transplant bed in order to cut the roots(figure 3 b).

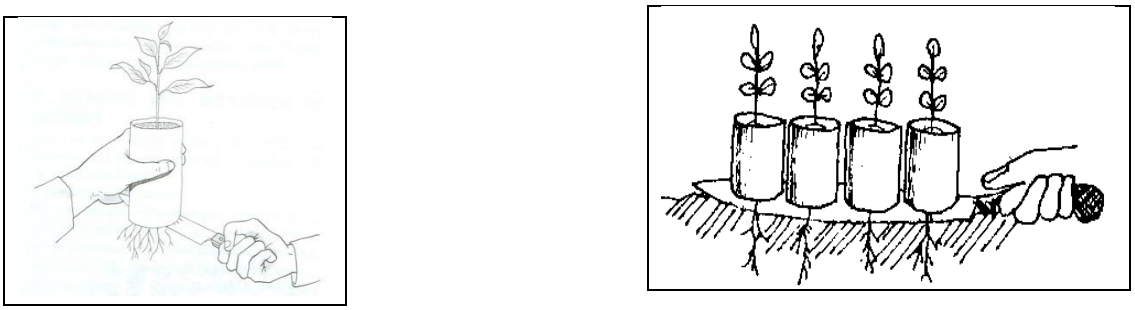


Figure 3: Root pruning using a knife and pruning saw

2.3.9. Hardening off

This is the process of creating hard conditions to the seedlings towards the planting season. Reduce the amount of water 4 weeks before seedlings are planted out. At this stage it is advisable to allow the soil to completely dry out and the plants to wilt for a day. This process should be repeated several times. Hardening off helps prepare plants for the new conditions in the field where water might be limiting. Water plants well the day or night before they are taken from the nursery. This will reduce water stress during transport to the planting site.

NB: Additional fertilizers may be applied when the seedlings show signs of weakness. The most common fertilizers are NPK and DAP. It's important to note that manure from livestock can also be used. However weakness of the seedlings can be caused not only by insufficiency of the nutrients but also by pests and diseases.

2.3.10. Sorting, Culling and grading

Sorting is a continuous process of arranging seedlings so that those of about the same age, height, species, and pot size are placed together.

Culling is the removable of diseased deformed and dwarf seedlings from the general stock and discarding them.

Grading involves ranking of seedlings of planting age into those that can be planted and those that should be discarded

2.4. Seedling protection

Seedlings are delicate and susceptible to attack by various pests and diseases as well as weather conditions. Such damages can seriously weaken or kill the seedlings. It is important that the damages be dealt with immediately. Damage and disasters in the nursery may be categorized as below.

2.4.1. Weather conditions

This is damage caused by the adverse weather conditions. We can either regulate watering or shading to comply with prevailing weather conditions.

2.4.2. Human

This is the stealing and/or intentional damaging of seedlings by human beings. Fencing and security are such options to overcome this.

2.4.3. Livestock and wild animals: Livestock and wild animals browse or graze on seedlings. Fencing can offset this.

Rodents: Field mice /rats frequently cause serious damage to seedlings in the nursery as well as in the field. Cleaning the nursery helps to reduce their population.

2.4.4. Insects: Termites are the most common insects in the nursery. They eat the roots and stems of many tree species. Eucalyptus is particularly susceptible to termite attack.

Termites may be controlled by several methods as shown below:

• Putting a thin layer of ash (2-3 cm thickness) on the bed, where the pots or tubes of seedlings will be placed. However periodic application is required since ash cannot be effective for long.

• Digging out the queen from nearby colonies (termite hills) or use of plant extracts and chemicals in severe cases.

• Using chemicals such as Dieldrin and Aldrin

• If milk packs are used as pots, wash the packs with soap water or solution of insecticide before use, otherwise termites may be attracted.

2.4.5. Fungal Disease

Although there are various diseases, which attack seedlings in the nursery, dumping off and wilt are the most common fungal diseases in the country.

2.4.5.1 Damping Off

This is a fungal disease caused by pythium spp.,Rhizoctonia salani and other various fungus. The severity of the attack usually increases with increase in soil moisture.

Dumping off can occur before germination, after germination and at pricking out.The fungi attacks the seedlings at soil level and causes rotting of the part attacked consequently killing the seedling. Susceptible species include Pinus sp, *Eucalyptus, Casuarina, Kei apples* etc.

Conditions favorable to spreading of the disease are: ;high sowing intensity, over watering, using soil with under-composed material, damaging the bark of tender seedlings

Control measures: Use of optimum sowing density, Use of appropriate quantity of water or not damaging the bark of seedlings

2.4.5.2 Wilting

This is a dying bark of the main shoot of a seedling. It is mainly caused by overcrowding. Separating the seedlings or immediate planting out can help control it.

2.4.5.3. Powdery mildew

First small white powdery patches are formed on the leaf surface and later the whole surface of the leaf is covered with white powdery mycelial colonies. Damaged leaves gradually defoliate. This affects the growth of young seedlings.

Control

Fallen diseased leaves should be buried in soil or burned and the young seedlings sprayed with Benla

2.5. Nursery planning

2.5.1. Nursery records

Keeping records helps on improvement of the nursery performance. Records on the production costs and productivity of the nursery should be kept so that it is possible to improve on the planning and operations in the future. Records about the seed source, and destinations, seed performance nursery stock should be kept.In order to have an effective nursery management you have to keep up-to-date nursery records.These are known as; Seedbed register, Transplant bed register and Nursery registers.

In the seedbed register, you have to maintain seedbed labels; on one side you have the species name On the reverse side, quantity sown, date sown and date of first and last germination.

In the transplant bed register, you have to maintain seedbed labels as well. On one side you have the Species name, on the reverse side you have the number of seedlings transplanted, date when transplanting started and ended.

In the nursery register, you have to quote the date when the seeds were received, species received, provenance, quantity in kilograms and some remarks or comments.

It is advisable to plan nursery activities well in advance of the operations. Organise all activities as per time schedules and monitor the progress of these activities and make accurate records of all the activities.

Skilled workers need to be available for different activities as need may be. You should know whether to pay workers for work done or to employ them on a permanent basis.

2.5.2 NURSERY CALENDAR

This is very important in planning nursery activities. It shows when different activities are scheduled to be done. Nursery activities are planned backwards from the planting time as this is the dead line for nursery work (Table 1).

Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Soil collection				← →						← →		
Soil mixing					←	—	→				←	— →
Pot filling	← →				←	—	→				←	— →
Sowing	←	— →			←	—	→				←	— →
Pricking out	←	— →				←	—	— →				← →
Transplanting	←	— →				←	—	— →				← →
Watering	←	—	—	— →		←	—	—	— →		←	— →
Weeding	←	—	—	—	—	—	—	—	—	—	—	— →
Root pruning	←	—	—	— →			←	—	— →			
Hardening off			←	— →					←	— →		
Planting			←	— →					←	— →		

Table 1: Nursery calendar

2 .6. Vegetative propagation

Vegetative propagation is the growing of plants from cuttings or other non-seed materials such as roots, bulbs and suckers. The cuttings can be obtained from stems, leaves and branches.

Some advantages of vegetative propagation are:

1. To get trees with desired qualities quickly
2. To get trees to mature and fruit quickly.

Some of the Different methods used in vegetative propagation include; Grafting, Budding, cutting layeringand tissue culture

Terms used in grafting and budding

- **Scion:** The aerial part of a tree that will form the crown of the new plant. This part contains thedormant buds of the tree whose desired characteristics need to be multiplied.
- **Rootstock**: The below-ground or lower part of a tree, sometimes including part of the stem andsome branches that will form the root system of the new plant. This part may also contain dormantbuds which should not be allowed to develop in the new plant since they do not have the desiredcharacteristics that need to be multiplied.

Importance of grafting / budding

- To multiply a tree that cannot be multiplied through sexual or other asexual propagation methods.
- To obtain a tree that combines both the good characteristics of one tree and the rootstock of another one

- To decrease the amount of time that a tree needs to attain maturity (flowering, seeding)
- To rejuvenate older trees through the use of young, improved material from another tree.
- To repair damage caused to certain parts of a tree.
- To detect viral diseases.

2.6.1. Grafting

This involves joining a piece of stem of a bud (scion) to another plant (the rootstock) of the same species. There are several types of grafting but most commonly used is cleft grafting.

How to do cleft grafting

1. Selecta desired mother tree. Cut ascion of approximately pencil size in diameter and about 20 cm long.Remove all the leaves carefully.

.2. Select a rootstock of about the same size as the scion. Cut off the top of the rootstock about 30cm above the soil.

3.With a very sharp knife cut the bottom of the scion with two sloping cuts of about 2 to 3cm long (A). Make one straight cut about 3cm deep in the top of the rootstock (B) to form a wedge. The longer the scion the longer the wedge.

4. Push the scions firmly into the rootstock cut. Leave ½cm of the cut scions outside the rootstock as shown.

5. Use clear plastic tape to wrap firmly around the graft. Do not remove the tape until the scion begins to grow, thus indicating that the graft has been successful.

6. Put the graft in the humid chamber to encourage rapid healing and formation of new leaves. Water the plant properly and regularly to prevent drying of the scion tissue.

7. Remove any buds which have grown below the graft. If the graft dies, you must allow one bud to grow below the graft and wait several months before trying again (Figure 4).

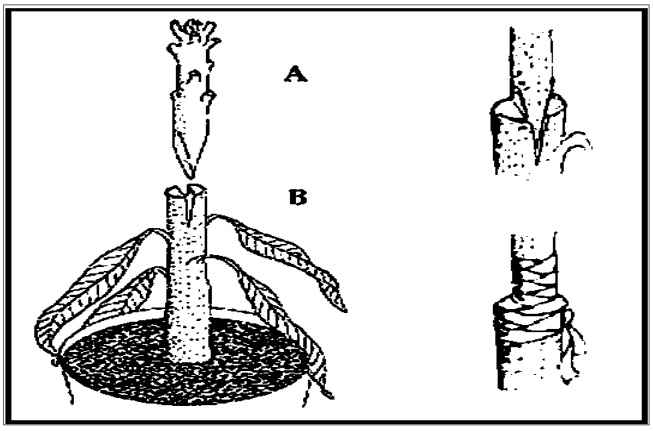


Figure 4: Top cleft grafting

2.6.2. Budding

This involves inserting of a strip of bark with bud from the branch of the desired clones to the stem of the seedling stocks. Budding is a form of grafting and is based on the same principles of and requirements for successful union in grafting.

There are different techniques that can be used depending on bark slipping or the condition which determines the ease or difficulty of separating the bud from the wood. Similar to grafting, it is important to use vigorous and disease-free rootstocks and scions. There are two commonly used Budding techniques in tree propagation. These are **T** and **patch** budding. We shall only concentrate on T-budding.

Steps in T-Budding

1. Wipe the base of the seedling stock with 75 per cent ethanol

2. Cut the shield bud from the bud stick or bud wood at about 2cm below the bud with a sharp blade

3. Make a vertical cut through the bark of the seedling rootstock at about 3 to 4 cm along a point 3-8 cm above the ground.

4. Make a horizontal cut of about 2cm in length across the top of the vertical cut

5. Gently spread the bark from the wood properly to make it ready to receive a bud

6. Gently push the shield bud into place beneath the bark flaps to makeit ready for wrapping

7. Wrap the incisions with plastic tape using 0.2mm budding tape with 2cm to 3cm width starting from the lower cut going upward.

8. Make sure that the edges of the tape overlap each other. During the first few turning of the wrapping, the lower end of the flap should be kept gently pressed over the bud patch, to prevent it from slipping off.

9. Tighten the wrapping to keep the cambium tissues of the seedling stocks and the bud patch in intimate contact with each other.

10. Open the tape after 21 days. The budding is successful if the cambium of the seedling stocks and that of the bud patch unite. A green bud patch seen through the tape indicates successful budding. If the patch is black, then it was not successful.

11. Cutback (slide cutting) the stem of the budded plants at 3cm to 5 cm from the budded part, three weeks after budding. Apply wax to the wound of the newly cut seedlings. The buds often bear shoots at 7 to 10 days from cutting and are ready for transplanting in the field.

2.6.3. Cuttings

This is a plant cloning technique where bare plant parts are removed from the parent tree and induced to form roots and shoots which later grow to form new plants. The plant part that is removed is called a cutting. Plants can be propagated from root cuttings, leaf cuttings or stem cuttings.

Cutting propagation is often the preferred method for plant propagation because it is the easiest and most cost effective way to produce a clone of a particular parent plant. Stem cuttings from less mature plants, root easily.

2.6.4 Layering

This is a form of vegetative propagation where cuttings are made to form adventitious roots while the cutting is still attached to the mother plant. Stems of the mother plant are covered in a growing medium in various ways to exclude light, increase the moisture level, and stimulate root growth. Once roots are formed the new plant (layer) is detached and either potted or can be transplanted to the desired location.

Types of Layering

2.6.4.1 Simple Layering

A type of layering where shoots from the previous year are bent to the ground (sometimes girdled) and covered in soil and “pegged down” 6-9 inches from the tip. Shoot tips are left emerging from the soil forming a U shape. Shoots are held in place using stakes.

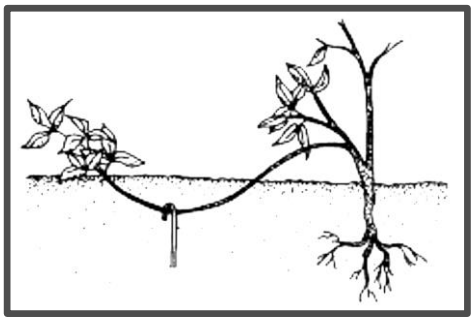


Fig 5.Simple layer with stake holding shoot in place

2.6.4.2 Compound Layering

A type of layering in which entire horizontal shoots are covered in media causing the formation of numerous rooted layers per branch rather than just one.

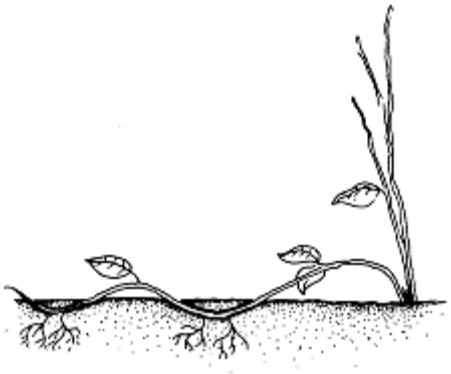


Figure.6. Compound (serpentine) layering

Just like a compound layering except that individual nodes are covered with media. Generally there is an alternation where every second node is covered. Most effective with plants that yield flexible shoots.

2.6.4.3 Air Layering

Air layering is a technique performed without placing the layered branch or shoot below the soil line of the mother plant. The stem is first girdled. Proper girdle is key to causing the accumulation of carbohydrates at the cut. Then, the girdled section is wrapped in media like peat moss that is easy to work with. Adding hormone to the media or directly applying it to the stem is very beneficial. The media is then enclosed in plastic and tied off. Once roots have formed the layer can be removed from the mother and planted.

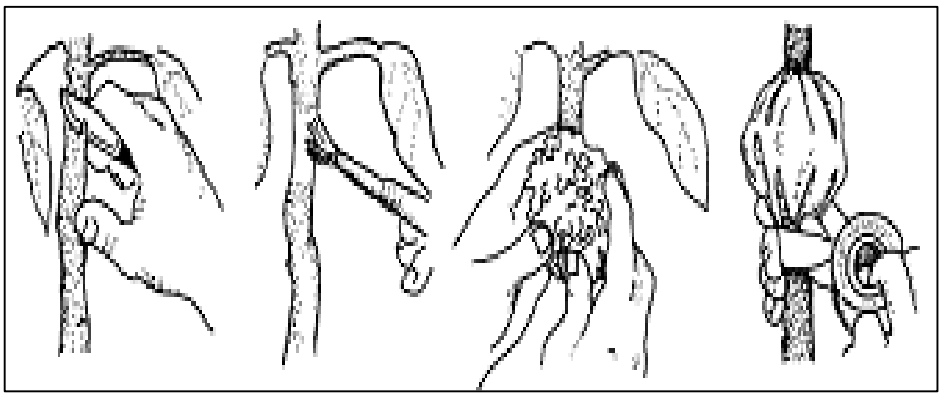


Fig 7.Sequence of air layering; Girdling, applying hormone, wrapping in media and plastic, and tying off

2.6.5 Plant tissue culture

Tissue culture involves the use of small pieces of plant tissue (**explants**) which are cultured in a nutrient medium under sterile conditions. Using the appropriate growing conditions for each explant type, plants can be induced to rapidly produce new shoots by addition of suitable growth hormones. These plantlets can also be divided, usually at the shoot stage, to produce large numbers of new plantlets. The new plants can then be placed in soil and grown in the normal manner. Tissue culture techniques are often used for commercial production of plants as well as for plant research.

2.6.6 Wildings

A wildling is a seedling that regenerates naturally from dispersed seed. Wildlings can easily be collected and replanted during the rainy season. The wildlings of desired species can be collected while they are still young and transplanted to the farm where they can be protected. They should be carefully uprooted, leaving some soil around the roots, and planted in the same way as seedlings taken from a nursery. The current year's wildlings are recommended for transplanting because they survive better than older ones. Some examples of trees that can be propagated through collection of wildlings are: Psidium guajava(guava), Mangifera indica (mango), Persea Americana (avocado) etc

2.7. Pests and diseases of fruit trees:

Citrus pests and diseases:

- Pests: Orange dog, Leaf minor, White fly, Aphids, Black ants/sooty molds, Scales.
- *Diseases:* Phaeoramularia leaf and fruit spot., Fusarium wilt, Photopthora root rot, Greening disease, Viruses , Tristezaetc)

Passion fruit Pestsand diseases:

- Pests: Mites, Aphids, leaf minors
- Diseases: Collar rot, Brown spot, Viruses, Damping off, Phytopthora

Mango pests and diseases:

Pests: Fruit fly, Aphids, Scales, Mango seed weevil

Diseases - Mildew, Anthracnose, rust, viruses

Avocado Pests and diseases:

Pests: Leaf eating caterpillars, fruit flies

Diseases: Anthracnose, Phytopthora

2.8. Sourcing tree seed /treatment

It is important to use good quality seed in planting. A poor quality seed will be poor even if it is planted in a well prepared site. Good seed improves survival rate, timber and fruit quality and harvesting period. Seeds can be collected locally from farms, forest or public land. Collectseed from at least more than 30 trees

Seeds can also be bought from suppliers. However, it is important to look at the seed and check that it appears to be of good quality, and hasn't been collected too early or contains many empty seed when getting it from suppliers.

2.8.1. Seed source (Parent trees)Seed should be selected from good parent trees as follows

a)From the natural home of the tree species
b)From where the introduced species is successful
c)From an area with similar climatic or topographic features
d)Areas with no signs of pests and disease

2.8.2. Time of seed collection

For fruits that open and release seeds when they are dry, collect the seeds just before the seeds are released, a mature seed changes colour, usually from green to brownish.

For timber and pole production, consider seed sources with the following features
a**)** straight cylindrical stem with a narrow crown
b)Small branches in relation to stem size
c)Free from diseases, pests or insect attack
d)Good vigorous growth

2.8.3. Methods of seed collection
a).Natural seed fall: This usually applies to large seeds. These can be handpicked after fall. Care should be taken to ensure that good mature and healthy seeds are collected.

b) From standing trees: In this method, fruits or cones are just picked with hands from the tree branches. Tall trees can be climbed. There is a limit to the height to which long-handled tools can be used for collecting seeds or fruit from the ground.

For heights from about 8 to 40 metres, vertical scaling ladders with several sections provide safe and convenient means of climbing the bole to the live crown. The ladders can be made of a variety of materials including wood, aluminium, magnesium alloy, etc., but each section must be light enough to be easily pulled up by the climber.

c) After felling trees: This method is applicable for bulk collection from large plantation species where collection can besynchronized with normal commercial harvesting operations. Where phenotypic quality of parent treesis more important than quantity of seed, it is preferable to select, mark, fell and collect the fruit inadvance of the main felling.

Elite trees with good phenotypes are marked as seed trees before logging. After felling, the seeds are immediately collected from the crowns of the trees. This method is widely used in plantation species in cases where sufficient improved seed is unavailable. Seed availability can be assured by scheduling logging at the time of seeding.

2.8.4. Seed extraction

Afterseed collection, seed should be removed from the fruits or cones. This is done as follows:
a) **Drying and shaking**

This applies to dry dehiscent fruits which burst open when dry; Spread fruits or cones on a polythene sheet on the ground; ensure uniform drying by frequent turning of fruits. You can as well put fruits or cones on a raised wire mesh with a tarpaulin below. Don't spread seed on corrugated iron sheet to avoid overheating.
b) **Splitting using knives**

Used on hard dehiscent fruits like Cassia species, Delonixregia, Jacaranda mimosifolia etc. the fruits are forced open using knives or knockers**c)**

Maceration

Used on fleshy fruits which are put in water and smashed, breaking down the pulp. The fruits are then constantly squeezed. The pulp will float and the seeds will settle at the bottom. The fleshy part is then poured off leaving the seeds in the container. Rinse the seeds in clean water and then dry in a cool airy place.
d) **Biological extraction**

Palatable fruits are exposed to animals which eat the fleshy part and leave the seed; care should be taken to ensure that seeds are not eaten too.

2.8.5. Cleaning the seeds

After seed extraction, seeds should be cleaned to remove the inert partwhich takes space during storage. It also results in uneven spacing and can attract pests and helps in determining plant yield

2.8.6. Seed storage

Seeds collected and extracted that are not going to be used immediately should be stored.Seeds can be stored in airtight containers such as tins, bottles, plastic containers or boxes, which are rodent free. The containers should be labeled to indicate the species, date of collection, provenance and site of collection, Seeds can be stored in refrigerators at a temperature of about 4-5^{0}c. The seeds must be dry(<14% moisture) and must be kept in moisture proof containers. Longer storage requires more ideal conditions.

2.8.7. Pre-treating seed

Sometimes it is important to treat seed before it is planted, in order to improve on the level, speed and uniformity of germination. These treatment methods can be used when seed does not otherwise germinate well.

The most common methods for pre-treatment are:

(a) **Soaking seed in hot water** Seeds are soaked in hot water until they look swollen. This is used for seeds of trees such as calliandra, most acacias, tamarind, leucaena and albizia.

Procedure:

Boil water and pour it over seeds in a container. Allow to cool and leave the seeds in the water until they look swollen

(b) **Soaking seed in cold/cool water.** This method is recommended for seeds that have soft seed coats such as sesbania, *tephrosia*, dalbergia species, gmelina,Gliricidia, and Acacia augustissima, etc. The time for soaking varies between 12-48 hours, depending on the tree species.

Procedure:1. Soak the seeds in cold water which is 2 times its volume2. Remove all floating seeds3. Sow the remaining seeds at the bottom in containers in the nursery or sow directly in the field.

(c) Cracking the seed shell This method is used for tree species with a hard coat like Melia, Podocarpus, Croton megalocarpus, etc. The cracking is done to allow water penetration for easy germination. Cracking is done using a sharp knife, a stone or a cracking machine

(d)Nicking Cut slightly the seed at one tip to allow water penetration. Seeds such as *Croton megalocarpus*, Neem, Cassia spp. and Kei apple can be sown directly into the container.

CHAPTER THREE : PLANTATION AND WOODLOT ESTABLISHMENT

3.1. Introduction

Tree growing is the process of planting and managing trees until they are finally harvested. To have good and health forest plantations, proper tree establishment (planting) and management has to be well handled.

A forest plantation is defined as "a forest crop or stand raised artificially, either by sowing or planting" (Ford-Robertson 1971 *in* Evans 1992). It covers a big area usually ranging from one hectare to several square kilometres.

A woodlot is a small forest raised by planting covering an area of less than one hectare. Woodlots are normally established to provide firewood for domestic use.

3.2 Surveying and mapping

Before plantation establishment, it is advisable to survey and map the area to be planted. The more information about the site conditions in the area being considered for tree planting, the better are the chances of selecting the tree species best suited to the area. The Information most commonly included are: Climate, temperature, rainfall, Soil depth and its capacity to retain moisture, Topography and Vegetation type. In areas which have not been degraded by man, the vegetation type can provide an indication of the site.

During surveying and mapping the land should be demarcated into blocks or compartments, access roads around these compartments should be clearly indicated and should run around each block. These serve as firebreaks as they stop fires from crossing from one compartment into another. One block can be like 10ha for big plantations.

3.3 Choice of species for planting depends on:

3.3.1The purpose of planting:

Species selected must be able to fulfill the objective for planting them; for a example fire wood and charcoal, timber, soil and water conservation , improvement of soil fertility, animal fodder, shade, fruits, etc.

3.3.2 Selection of the planting site

Selection of planting site is generally a collective decision made by a tree planter guided by relevant extension officers. For those with small land holdings, the choice of the planting site would be limited to lands which are not suited for agriculture.

3.3.3 Species selection

The aim is to choose species which are suited to the site, will remain healthy throughout the anticipated rotation, will produce acceptable growth and yield, and will meet the objectives of the plantation such as fuelwood or timber production, environmental protection, etc.

3.4 Site Preparation

Site preparation is directed toward giving the seedlings a good start with rapid early growth. In general, the methods used to achieve site preparation will vary with the type of vegetation, amount and distribution of rainfall. Additionally, the value of the tree or shrub crop to be grown is important in determining the amount of expense that may be justified in plantation establishment.

Site preparation may be: 1) Manual 2) Mechanical3) by burning 4) Chemical or 5) A combination of all.

3.4.1. Site clearance

Whatever method is used, timber trees are felled and removed by saws, pangas and axes, the remaining are cleared, stacked and burned. Much of the remaining woody material may be used for charcoal burning. Debris or trash left is burnt down to leave a good land clearance.

After clearing the area, the land may be ploughed if there is need to incorporate crops, otherwise lining out process follows.

3.4.2. Lining out (laying out planting positions)

Laying out planting positions starts with establishing a baseline with a compass or a 3 4 5 method, about 50 to 100m apart, a cross line is then cut at a right angle across the base line. Long ropes or wires marked at fixed intervals are stretched along the base line and cross line to mark planting spots on the ground. A pole of a similar spacing interval is used to measure separation within and between rows; ranging rods or poles are used for sighting to ensure planting sports are straight.

3.4.3. Spacing

Spacing depends on several factors: species, purpose for planting, availability of moisture, tolerance of the species to weed competition and economics. In Uganda, a spacing of 3.0m x3.0 m for Pinus and Cupressus tree species is commonly used. For Eucalypts, spacing depends on management objectives; Eucalypts managed for timber production may be spaced at 3.0 m x3.0 m. for Firewood and small poles. Spacing is determined by planters themselves. However, a spacing of 6.0 m x 6.0 m is recommended for fruit trees.

In hilly areas, contour trenching and terracing may be manually dug. These catch run off soil erosion and encourage infiltration.

3.4.4. Time of planting

The planting season generally coincides with the rainy season; usually, planting is started as soon as a specified quantity of rain has fallen. This amount of precipitation must be judged on the basis of local knowledge. Planting can also be initiated when the soil is wet to a specified depth (approximately 20to30 centimeters).

A common mistake is to start planting too soon. On the other hand, if planting is started too late, it may be difficult to complete a large planting programme in the scheduled time, and the plants will lose the maximum benefit of rains after planting. This can be a serious matter where the rainfall is low and erratic.

3.5. Pitting and Planting

For pitting and planting, the following general rules apply. Pitts should be, 30 cm deep x 30cm wide. When digging holes, it is advisable to separate the top soil from the sub-soil so that at planting, the top soil, with more plant nutrients, is first put back into the hole then followed by the sub-soil. Digging holes in advance reduces labour input during planting, thereby allowing the trees to be planted earlier. Also, rain water will be trapped in the holes making the soil moist.

When planting, the roots are inserted into the pit up to the root collar level, avoiding breaking, bending or crushing them. Polythene containers must be removed. The soil is gently firmed around

the roots to eliminate air pockets and bring the soil into intimate contact with the roots. Water immediately if soil is not having enough moisture.

Avoid planting seedlings which have overstayed in the nurseries because they restrict lateral root extension in pots, this can cause root malformation, coiling, and spiraling. In extreme cases, the coiling can lead to strangulation of the roots and the death of the plant. In other situations, it may reduce wind-firmness or lead to stunted growth. Unfortunately, the symptoms may not become apparent until 4 to 5 years after planting.

NB: The site should be prepared in advance to ensure that planting can proceed without delay as soon as seedlings arrive from the nursery.

The number of trees per hectare, according to the spacing between the lines in a plantation and the spacing of plants within a line, is given in Table . For example, with a spacing between lines of 3 meters and a spacing of plants within a line of 3 meters, a planting density of 1,111 trees per hectare or 440 per acre will be required.

3.6. Beating up

This is the process of replacing the dead plants or re-filling the blank spaces. Plantations should be inspected 3-4 weeks after planting to assess numbers and distribution of dead plants. With greater mortality of 20% , replacement has to be done as soon as possible so that the newly planted seedlings catch up with the rest.

3.7 Protection of trees

Trees should be protected until the objective of growing them is achieved. They should be protected from; physical damage, wind, pests and diseases.

Protection from physical damage

This can be done by erecting sticks or metal bars around the planted trees. These should be higher than the planted trees. Domestic animals should also be kept away from the trees. Fencing off the area can be done if possible.

Protection from wild animals: Damage to forest plantations by wild animals mainly takes the form of tree browsing or de-barking. In general, there are three orders of wild animals responsible for damage: **rodents** (rats, mice, and moles and squirrels); **lagomophs** (hares and rabbits); and **artiodactyls** (deer, antelopes, pigs and buffaloes). The principal methods of controlling damage by wild animals involve the use of fences, hedges or ditches, trapping and poison baits.

Protection from domestic animals: Grazing or browsing animals such as sheep, goats and cattle can be a menace to young plantations. These should be guarded from entering the forest plantations by use of hedges and fences. Where fencing costs arehigh, trespass by livestock can be controlled by guards.

Protection from Weather Phenomena: The occurrence of damaging weather phenomena is usually unpredictable. Little can be done to protect forest plantations against the damage caused by weather, except to grow tree species known to be resistant to the detrimental effects of local weather patterns, or locating the stands of trees in sheltered areas. Species susceptible to wind damage can be protected by planting wind resistant species around them.

Pests and diseases: To avoid destruction from pests such as termites, it is advisable to;

- Destroy all the termite mounds sited on the farm before planting.
- Plant during the on-set of the rain season
- Plant termite resistant species.

In general, the risk of damage from pests is higher when the plants are physiologically weakened by planting on unsuitable sites, improper site preparation, inefficient planting, adverse climatic conditions, or neglect of weeding and other maintenance operations. The main precautions to be taken in guarding against possible future damage from insects and diseases are to plant tree species that are suitable to the climatic and soil conditions of the site, and to make prior surveys of indigenous pests to ensure that none are among the known forms to which the selected species is susceptible.

Other Control measures include:

1. Chemical application

Insects and diseases can often be checked by applications of appropriate chemical insecticides or fungicides. Usually, these chemicals are available as liquids, powder, dusts, or smokes.. Only previously tested and environmentally sound insecticides and fungicides should be prescribed for use. However; indigenous knowledge should not be neglected.

2. Biological control

Biological control of insects has been employed with success in some situations. In most instances, the introduction of a parasite to control the insects is required

3. **Mechanical control**

Mechanical control, either by physically removing and destroying the pests or by eliminating the alternative hosts, can be effective.

Table 2: Main pests and diseases found in Uganda

Pest/disease	**Type**	**Notes**
BLUE GUM CHALCID (BGC) *Leptocybe invasa.*	Minute insect(<1.5 mm long)	First spotted in Uganda in 2002 and has quickly spread throughout the country. It is black with transparent wings and only female individuals are known. Forms galls on the foliage and twigs of infected plants, containing eggs inserted by adult females. Infected shoots appear deformed and heavier infestations results in severe growth malformation and even branch dieback. Affects most eucalypts in Uganda. Not present in the higher, cool regions of SW Uganda.
TERMITES *Macrotermes spp*	Insects-communal insects	High impacts found in the hotter and drier areas of Uganda. They eat roots, root collars and bark of trees up to two years old. *E. grandis* appears particularly susceptible**.** *Controlled by* physical removal of the queen followed by application of insecticides in mounds. *Preventive methods to control damage;* Using healthy and vigorous planting stock; Planting seedlings as early as possible in the rainy season; Planting species or provenances that are resistant to termites.
BLACK PINE APHID – *Cinara cronartii.*	Insect (4 mm long)	Mature is pear-shaped, soft bodied, greyish black. Just heavily attacked trees have a black appearance. Still localised In Uganda, the black pine aphid has only been a localised problem, though this could change as pine plantations expand. Extract large amounts of sap from the host trees. Research is going on

		to control it using Biological control
Animals	Rodents, primates goats, antelopes, cattle, elephants	Physical damage to shoots, barks, bole geometry. Sensitization of communities to control animal movements is an effective control.
***BOTRYOSPHAERIA* STEM CANKER** *Botryosphaeria dothidea*	Fungus	Development of stem cankers and the death of tree tops. Stems cankers are most common on trees stressed by drought and are characterized by stem swellings. Cutting badly infected trees out during routine thinning operations. Apply optimum silvicultural techniques to minimize stress.
***CONIOTHYRIUM* STEM CANKER** *Coniothyrium spp*	Fungus	Small, dark spots on young bark are the first signs, followed by larger patched of dead bark. It affects a range of *Eucalyptus* spp. and hybrid clones. Pine wilt: Yellowing and wilting leading to dieback and eventual death of young trees.
LEAF SPOTS *Cylindrocladium spp.* and *Mycosphaerella spp*.	Fungus	Leaf spots ranging from small, discrete lesions to irregular necrotic (dead) areas. Young stems can become infected and girdled, resulting in shoot blight. Widespread but generally not very serious. No eradicative treatment available.
MVULE GALL *Phytolyma lata*	Gall-fly	Causing serious damage to young mahogany and Mvule trees.
BACTERIAL WILT/BLIGHT *Pantoea anantis* or *Burkholderia solanacearum*	Bacterial	The bacteria occur in the soil and its mode of transmission on eucalypts is not known. Damage locally can be more serious: some eucalypt hybrid clones have been badly affected in Kifu nursery in Uganda. There is no known treatment. Research is needed to identify species and clones that may be more resistant to infection.

Fire protection : This is carried out every dry season. The most severe dry season is December to March and June to August. The external boundary should be clean hoed during the dry season. Controlled burning around the plantation should be carried out at the beginning of the dry season. For big plantations, a simple fire tower should be constructed at one of the highest points and should be manned during the dry season. People surrounding the plantation should be sensitised about the dangers associated with fires, especially the far reaching damage and losses that come with forest fires, and how to handle them. The plantation area should be regularly patrolled during the dry season.

Causes of fire outbreaks

- Natural causes, such as lightning,
- Some fires start as a result of the activities spreading from farmland on the perimeter of plantations,
- from the activities of hunters, or honey collectors
- From burning by herdsman to improve livestock grazing.

- Arson (Malicious), from people who set fire because of various reasons such as: to create employment (in the fire suppression and subsequent replanting) or to show disapproval of forest policies.

It is not possible to prevent a climatic build-up of fire hazard conditions, but much can be done to minimize the risk of fire through public education and involving local people in forestry. A main principle in protecting forest plantations against fire is to avoid combustible materials towards dry periods, to ensure there is little or no fire risk. Dangerous and damaging plantation fires can only develop when fire is able to occur at ground level.

3.8. Cultural treatments

Cultural operations are required to promote the conditions that are favorable to the survival and subsequent growth and yield of the trees in the plantation.

Weeding

After planting, weeding is the next important tending operation and it is done for the following reasons:

- It minimizes the competition for moisture and nutrients thereby boosting early growth of the tree seedlings
- It reduces the risk of fire to the seedlings and
- Proper weeding facilitates percolation of water and soil aeration for good plant development.

Trees should always begin the dry season when they are weed free.

Common weeding methods in Uganda

It involves reliance on man-power, which uses simple tools such as hoes, slashers and pangas to remove any competing vegetation.

Manual weeding can be carried out in a number of ways:

Slashing: This is normally a full cover operation whereby the entire area is slashed or a spot operation where the weeds are only high in certain areas, remove climbers from young trees during slashing.

Hoeing: Hoeing can be three different kinds:

- **Spot hoeing.**

The area immediately around the tree is hoed and the rest is left, slashed or sprayed with herbicide. It is recommended to weed a circular area of a minimum 1 m diameter (i.e. 0.5 m radius) around each tree.

- **Line hoeing**

The tree line is hoed, usually 1 m wide and the inter-row is left, slashed or sprayed with herbicide.

- **Full cover hoeing**

The entire area is hoed. This method must not be done on steep slopes as it leaves no vegetation to prevent soil erosion.

- **Herbicides**

Glyphosate kills any green plant material so it is safer to use it in the pre-plant situation. This should be done by a well-trained spray team. When using Glyphosate in the post-plant situation, it is essential to prevent it from coming into contact with the planted trees.

The trees should be protected using buckets, cones or shields. Good storage of the chemical and proper disposal of used chemical containers is also important.

3.8 Pruning

Pruning is a cultural practice in which the lower branches of trees are removed to permit formation of clear, knot-free wood.It is done to;

Enhance vigorous growth, produce knot free timber, produce marketable poles, obtain fuelwood and provide organic matter (manure) to the soil. This management practice is commonly carried out on most trees apart from those that are self-pruning such as *Maesopsis eminii* (musizi), Eucalypts and fruit trees.

Pruning is perhaps best delayed until after the first thinning. While this will mean less knot-free timber is produced, it helps to avoid cutting and removing pruned trees in the first thinning. Time of pruning also depends on the species and site conditions. The height of pruning is an important aspect in crown pruning. The recommended height for pruning for most tree species is 1/3 of the tree crown. Pinus species and Cupressus lusitanica should always be pruned as recommended. The most widely used and recommended pruning tool is the pruning saw

The effects of over pruning include; trees become highly prone to wind throws, inadequate photosynthesis due to few leaves

Effects of not pruning or under-pruning include retarded growth in tree height : the trees develop relatively broad crowns and short stems, hence low timber and poor pole production. see table 3 bellow for details:

Table 3: Pruning schedule

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Pruning schedule	**Pruning Height** (m)	**Age, years**		**Stems/ha**
		Pines	**Eucalypts**	
1st	2	3 to 4	1 to 2	1 111
2nd	4	5 to 7	3 to4	700
3rd	7	8 to 10	5 to6	500
4th	10	11to13	7to9	300

3.9 Coppicing

This is an operation involving the cutting back or felling of trees to influence young re-growth. Stump sprouts form after felling the parent tree. Factors influencing coppicing include size of the tree, season of cutting, and site characteristics as well as inherent ability of the species. Coppicing is common with hardwoods e.g. most Eucalypts.
For Eucalypts, reduce to 4 coppices per stump and when these reach 4-6 cm in diameter, reduce to two until they reach pole size, there after one pole is harvested, the other is left to develop into final crop for timber.

3.10 Thinning

Thinning (as a forest management practice) can be defined as the calculated removal of certain trees from an existing stand and is usually conducted with a specific objective in mind.

Thinning is an important part of proper plantation management and, when followed properly, the final quality of logs is very good in terms of volume and form. One of the problems, especially of the first thinning, is that there is no market for them.

Thinning promotes the growth of individual trees within a stand by removing surrounding trees, which compete for water, sunlight, and soil nutrients. Most natural and planted stands require thinning at certain stages of their development in order to sustain good tree growth throughout the life of the stand.

Thinning methods

Certain methods of thinning allow for the removal of a greater portion of diseased trees and trees that are of poor quality and form. Selection of method is usually based on stand density, stand uniformity, and owner's objective. The following are four common thinning methods:

Row Thinning
Alternate rows are removed from the stand. A row thinning might remove every third, fifth, or seventh row.
Selective Thinning
Individual trees are selectively removed from the stand. Tree selection is generally based on position, form, and general health.
Combination Thinning
A combination of both row thinning and selective thinning
Strip Thinning
A strip of trees (rather than rows) are removed from the stand following the land contours.
Refer to table 4 for more details:

Table 4.Thinning Schedules for Eucalyptus and Pinus tree species

Species	Thinning	Age (years)	Remaining stems
Pinus	1st 2nd 3rd	4-6 6-9 9-10	700 500 300
Eucalyptus	1st 2nd 3rd	1-2 3-4 5-7	700 500 300

3.11. Harvesting operations

The last part of management activities is harvesting the mature forest plantation and starting the next plantation using artificial (replanting) or natural (coppice, seedlings) regeneration.
Where a clear felling system is used the objective of the harvesting plan must be to minimize damage to the site and time of exposed soils without vegetation. Trees should be harvested once they have attained the "optimum size". From a biological standpoint, trees should not be cut until they have at least grown to the minimum size required for product utilization.

Quite often, the average annual growth rates of a forest plantation can be used as a guide in determining when to harvest wood. In general, the average annual growth of trees and shrubs increases slowly during the initial years of plantation establishment, reaches a maximum, and then falls more gradually. Trees should not be allowed to grow beyond the point of maximum average annual growth, which is the age of maximum productivity; foresters call this the "rotation" age of the forest plantation.

Economic considerations also help to determine when to harvest trees for wood products. When based solely on market factors, the time to harvest is when the profit can be maximized. Profit is maximized when the returns generated from harvesting and selling the wood minus the costs of harvesting and (when required) processing the wood into the desired products is the greatest.

The methods of felling trees, cutting the stems and branch wood into the desired lengths, and removing the wood from the plantation site should be chosen to minimize degradation of the site. Axes, saws, wedges and sledges may be all that are necessary to fell the trees and cut them into the desired lengths. Power-chainsaws are used in many instances for cross cutting; while their use makes harvesting easier, their high cost of operation can make them uneconomical.

It is important that the methods of harvesting should be selected to "match" the skills of the people who will harvest the trees or shrubs. Once again, advanced planning will be necessary to ensure that the labour and required equipment will be available for use at the time they are needed.

CHAPTER FOUR: ENERGY SAVING COOKSTOVES

4.1 Introduction

Over 90% of the population in Uganda depends on firewood and charcoal as source of energy (MEMD, 2009). The technologies used to convert firewood and charcoal to energy are highly traditional. Urban and rural dwellers use predominantly metal charcoal stoves and traditional three-stone stoves, at efficiency less than 10% (Okello et al., 2013). This puts Uganda's forests and its growing population under tremendous pressure. No-wonder, Uganda features a high deforestation rate of about 2.2% (Nampewo, 2013). Adoption of energy conserving technologies such as improved energy cook stoves could conserve energy and reduce environmental degradation.

Examples of "Firewood Saving Stoves" in Uganda

- UNICEF or DEMBE stove,
- UNICEF wood-saving stove,
- Y or LORENA stove, Institutional stove,
- Local wood-saving stove

Examples of "Charcoal Saving Stoves" in Uganda:

- Kabale stove
- Traditional metal stove (sigiri)
- Uganda Ceramic sigiri
- Black Power charcoal stove