Tree Nursery Manual

Prepared by:

Dr. Teshome Tesema.....Team Leader
Dr. Efrem Garedew.....Member
Dr. Yigardu Mulatu.....Member

June, 2017

Addis Ababa

Table of Contents

List of figures

List of tables

Foreword

Tree planting has become one of the national agendas as deforestation and climate change continues to pose a threat and as the need for reforestation and afforestation is becoming pertinent. In order to respond to huge demand of the society for wood and wood products, the government has launched a huge tree planting program and this demands seedling production in adequate amount and in the required quality.

Seedling production is the basic requirement for launching tree planting and forest development. By setting-up forest nursery, it is possible to produce seedlings. Seed propagation is the principal mode of plant production in tropical silviculture. In managing nursery operations based on seed propagation, the main objective is to obtain good germination and provide optimum conditions for their survival and growth into strong healthy trees and seedlings to grow vigorously.

The objective of this manual is to provide information and guidance on how to start and manage a tree nursery and on how to produce seedlings for different purposes. The manual is therefore of special interest not only to nursery workers and nursery supervisors but also to foresters, horticulturists and those involved in planning and managing the production and use of tree seedlings for any of the above mentioned roles and benefits.

This manual has been prepared by a team of three dedicated researchers; Dr. Teshome Tesema (Team Leader), Dr. Efrem Garedew (member), and Dr. Yigardu Mulatu (member) who are members of the research staff of the Ethiopian Environment and Forest Research Institute (EEFRI) and these team members deserve sincere appreciation.

Kebede Yimam

State Minister, MEFCC

Acknowledgement

The team which has been established for preparing this manual has produced this manual at the request of the Ministry of Environment, Forest and Climate Change (MEFCC). We would like to thank and appreciate MEFCC for trusting us and providing us this opportunity to contribute to the on-ongoing effort of forest development and management in addition to our regular forestry research activity. We have a strong conviction that together we will bring the renaissance of forestry in this country.

The Team

CHAPTER 1: INTRODUCTION

Forestry is one of the economic sector that plays a vital role in the development of a country. Forests are essential to our lives and are an integral part of our landscape. This can be asserted by the economic benefits that forests provide for the rural poor for their livelihoods and in times of adversity. They play many roles and confer a multitude of benefits to society such as food, shelter, shade, timber, natural beauty to the countryside, conservation of our soil and water resources and improved air quality. In fact next to food, wood is the most basic necessity and important commodity requirement in the country.

With the growing recognition of the role of forestry for climate change mitigation and the greater awareness of forest and tree values, indications are that, there will be an increased demand for tree seedlings to ensure that these benefits continue to contribute to the nation's well-being. That is the basic reason why the Ethiopian Climate Resilient Green Economy (CRGE) strategy puts sustainable forest development and management as one of the four basic pillars of the strategy. The strategy aims at enabling forests to properly contribute to the national economy and ecosystem services.

Despite their economic and environmental value, Ethiopian forests are under threat. In recent decades deforestation has become one of the critical national issues in Ethiopia because it has grown to unacceptable level and triggered an extensive environmental crisis and social instability. The loss of forest resources in Ethiopia has been both in size (*deforestation*) and quality (*degradation*) and as a result there is a wide gap between wood supply and demand. To fill the supply gap, the country is forced to import wood and wood products from abroad.

Curbing the above mentioned problems, the forest sector is expected to play a great role in the on-going effort to attain economic growth in general and assure food security and poverty reduction in particular. Forest lands should be clearly demarcated and objective based extensive tree planting should be carried out across regions and ecologies.

Seedling production is the basic requirement for launching tree planting and forest development. By setting-up forest nursery, it is possible to produce seedlings. Seed propagation is the principal mode of plant production in tropical silviculture. In managing nursery operations based on seed

propagation, the main objective is to obtain good germination and provide optimum conditions for their survival and growth into strong healthy trees and seedlings to grow vigorously.

The objective of this manual is to provide information and guidance on how to start and manage a nursery and on how to produce seedlings for different purposes. The manual is therefore of special interest not only to nursery workers and nursery supervisors but also to foresters, horticulturists and those involved in planning and managing the production and use of tree seedlings for any of the above mentioned roles and benefits.

CHAPTER 2: NURSERY SITE SELECTION AND ESTABLISHMENT

2.1. Factors to be considered for site selection

The criteria for choosing the nursery site will be affected by the type of nursery to be established. For the purpose of this manual, two broad types of nurseries are recognized, namely:

- Small-scale nurseries
- Permanent nurseries

Small-scale nurseries, sometimes called ‘temporary nurseries' are needed to meet small reforestation and tree planting targets, often in remote forest reserves and rural communities.

Some benefits of small-scale nurseries are:

- Nearness to planting site improves survival because transit time between nursery and plantation is short and plants suffer less from overheating, windburn, soil loss and vibration caused by long journeys
- Better provision for the range of species and numbers of seedlings required by different farmers
- Transport cost is less and capital investment is low Isolation of disease is mu ch easier
- Isolation of disease is much easier
- A wider distribution of the economic benefits to be derived from raising seedlings is promoted

Permanent nursery, it is a nursery, meant for supplying nursery stock for a long time on permanent basis. The duration of service life of permanent nursery is long and it is maintained till seedling can be raised in it at reasonable cost.

The main advantages of permanent nurseries are:

- High production levels and high seedling survival rates resulting in a more efficient, reliable operation and consequently lower unit cost per plant

- The availability of permanent installations, propagation techniques and suitable modern equipment favoring higher quality seedlings and the production of a wide range of difficult species
- Risk of damage and theft minimized due to better on-site supervision

Although the contents of this manual deal mainly with permanent nurseries, much of what is written applies equally to small-scale nurseries.

The most important factors to be considered in selecting a good nursery site are discussed in the following sections.

2.1.1. Environmental/ecological factors

Water

A reliable and continuous supply of water should be available throughout the year. Since the need for water is greatest during the dry season, it is necessary to check the source during the most critical period to see if the flow of water at that time is adequate for the quantity of plants being produced. Regardless of the source, it is advisable to have adequate facilities for storage of at least 3 of days' supply.

The quantity of water required depends on the size of the nursery, the kind of soil, the species, the number of seedlings and the irrigation method employed. More water, for example, is needed for sandy soils which have a low water holding capacity. In the case of a nursery of one hectare in full production using overhead irrigation, it is estimated that 60,000 litres of water per day will be required on average during the dry season. This is equivalent to approximately 2.4 liters per second during a seven hour period.

Equally as important as the quantity of water is the quality of the water. It is necessary to measure the pH which should be between 5.5 and 7. Water with pH greater than 7 favours attacks of 'damping off' fungi in the seed beds and tends to raise the pH of the soil which in turn can reduce the growth of seedlings.

Location

The nursery should have a central location as near to the planting site or demand centre as possible to avoid the transportation of seedlings over long distances. In order to reduce the problems of transport, food and accommodation, and to encourage better supervision, most forest nurseries are located close to or within population centres. This avoids the need to construct dwellings and living facilities for nursery workers thus reducing costs. Sites with exposure to excessive wind should be avoided as well as valleys and old water courses that may be liable to flooding.

Topography

Ideally, the nursery should be on a gentle slope sufficient to allow excess water to run off without causing soil erosion. Where necessary, a proper drainage system must be built to avoid water logging and damage during periods of heavy rainfall. The exact design of the drainage system will depend on the requirements of the site. The general principle is to direct excess water to the sides and keep the main pathways dry. At Mt. Airy Forest Nursery, in the hills above Golden Spring in St. Andrew, the permanent nursery is constructed on sloping ground and the terraces are efficient and could serve as a model for similar sites on gentle slopes.

Soil

Adequate sources of good quality soil are required in the preparation of the potting mixture and to a lesser extent for seed beds. One of the major components of the recurrent cost in a nursery with container grown plants is the provision of suitable soil. Obviously, the nearer the nursery is to the source of this material, the less will be the cost. A high demand for sand in soil mixtures has developed due to the availability and use of heavy soils. Sand particles however, do not hold moisture and they tend to be inert, conferring few, if any, benefits to the plant. This over-reliance on sand could be avoided with adequate supplies of top soil and a ready supply of compost. Five of the more important soil properties that affect plant production are:

- Particle size
- Organic matter content
- Soil porosity

- Moisture content
- pH

Although each can be evaluated separately, they are all interrelated. The presence of organic matter is perhaps the most obvious indication of a healthy soil and is an essential ingredient in maintaining satisfactory moisture relationships necessary for plant growth. Soil that is not porous encourages water-logging, hence oxygen, which is essential for root development and respiration, becomes unavailable to the plant.

2.1.2. Socio-economic factors

Size of a nursery

The size of the nursery will depend on the number of seedlings required each year and the availability of water. Large nurseries tend to be more efficient and easier to provide the necessary supervision. It is anticipated that in addition to the few large-scale nurseries, the country will be requiring a number of small nurseries to take care of the demand for seedlings for fuel wood and agro forestry in rural communities. Such nurseries can vary in size and could be as small as one quarter of a hectare.

2.1.3. Evaluation against factors and deciding on the site and type of the nursery

Evaluation of sites against the above-mentioned factors can be made by giving different weights for each factor and by rating and scoring the site against these factors. Once we finished the rating, the site that scored the highest can be selected for the nursery site.

2.2. Design and Layout of a Nursery

In general, the average permanent nursery should be designed to accommodate the administration, operations and the agreed production areas. Figure 2 shows an example of a layout for a permanent nursery. This layout will need to be modified to meet the needs of small-scale nurseries but most of the principles involved will apply. There should be no waste ground where weeds can accumulate and grow although unused land has to be included if expansion is planned.

2.2.1. Administration area

The inclusion of an office and storage facilities depends on the size and useful life of the nursery and the availability of funds. Generally the office and the storage area occupy the same building with the exception of fuels and other inflammable or toxic materials for which separate storage facilities should be arranged. The office should be located close to the main entrance to avoid routine movement of personnel, visitors and vehicles from disrupting nursery activities. It would be an advantage if the location overlooked the production areas to facilitate management and supervision. Very often washing and toilet facilities and a lunch room are overlooked when nurseries are being planned. These are essential to ensure high standards of personal hygiene as most workers are in daily contact with soil and chemicals and sometimes have to work at very close quarters with each other in large numbers.

2.2.2. Operation area

Adequate space should be provided to accommodate the following operations:

- Extracting, drying and processing of seed: The surface of this area should have a concrete floor close to covered facilities and could have multiple functions as it is usually suitable for other operations
- Preparing germination trays and potting mixtures
- Screening compost and soil
- Filling pots
- Soil shed with compartments for screened soil, sand and compost: The soil shed should allow for soil mixing and the filling of containers to be carried out under shelter throughout the year
- Composting area: Compost production should be considered mandatory in all nurseries, and a place provided for this purpose

2.2.3. Production areas

Production efficiency is achieved by locating each of the following major activities in a defined area of the nursery.

Germination Section

This area which is set aside for the germination of seeds is best located near the office, to enable the supervisor to maintain a close watch on the activity. It is customary to sow the seeds in elevated metal or plastic trays erected waist high above the ground level. Round wood is commonly used but a more permanent foundation is recommended to avoid frequent replacement. One alternative is to build permanent seedbeds of concrete blocks with an internal measurement of 1 metre wide. Ten metres is the standard length but this varies with location and production targets. The beds may be subdivided into 1 metre quadrants to facilitate sowing smaller quantities of seeds. Since dogs, birds, rodents and insects have been known to damage seedlings during this stage, the germination section may need to be fenced and a 'roll on' cover provided for use when required.

2.2.4. Transplanting area

The nursery beds for growing bare rooted plants or for standing containers occupies the greater part of the nursery area and it is here that the transplanted or direct sown seedlings are grown until they are ready for planting in the field. Normal bed width is 1 to 1.2 metres to facilitate hand tending. Length is also important and beds should not be longer than 20 metres in order to facilitate moving from one bed to the next. Bare root production beds should be located where the soil has the best chemical and physical properties.

The only fixture in the transplant area is the watering system if one has been installed. However, in very hot and dry locations, and with certain species, better results may be obtained by transplanting and raising seedlings under a roof shed to control the light intensity. The building need not be elaborate but it should be high enough for workers to stand underneath. Pickets of wood or bamboo slats are commonly used and preservative treatment will extend their useful life. Imported polypropylene shade cloth is available in different light intensities offering a longer lasting, tidy and more efficient material. Polypropylene shade cloth comes in standard widths of approximately 2, 3 and 4 metres that provide different intensities of shade, eg, 47, 55, 63, 73 or 80 percent.

2.2.5. Other Production Areas

If nursery production includes rooted cuttings, grafting and budding, space will be required to include glass frame bins or a mist propagation unit.

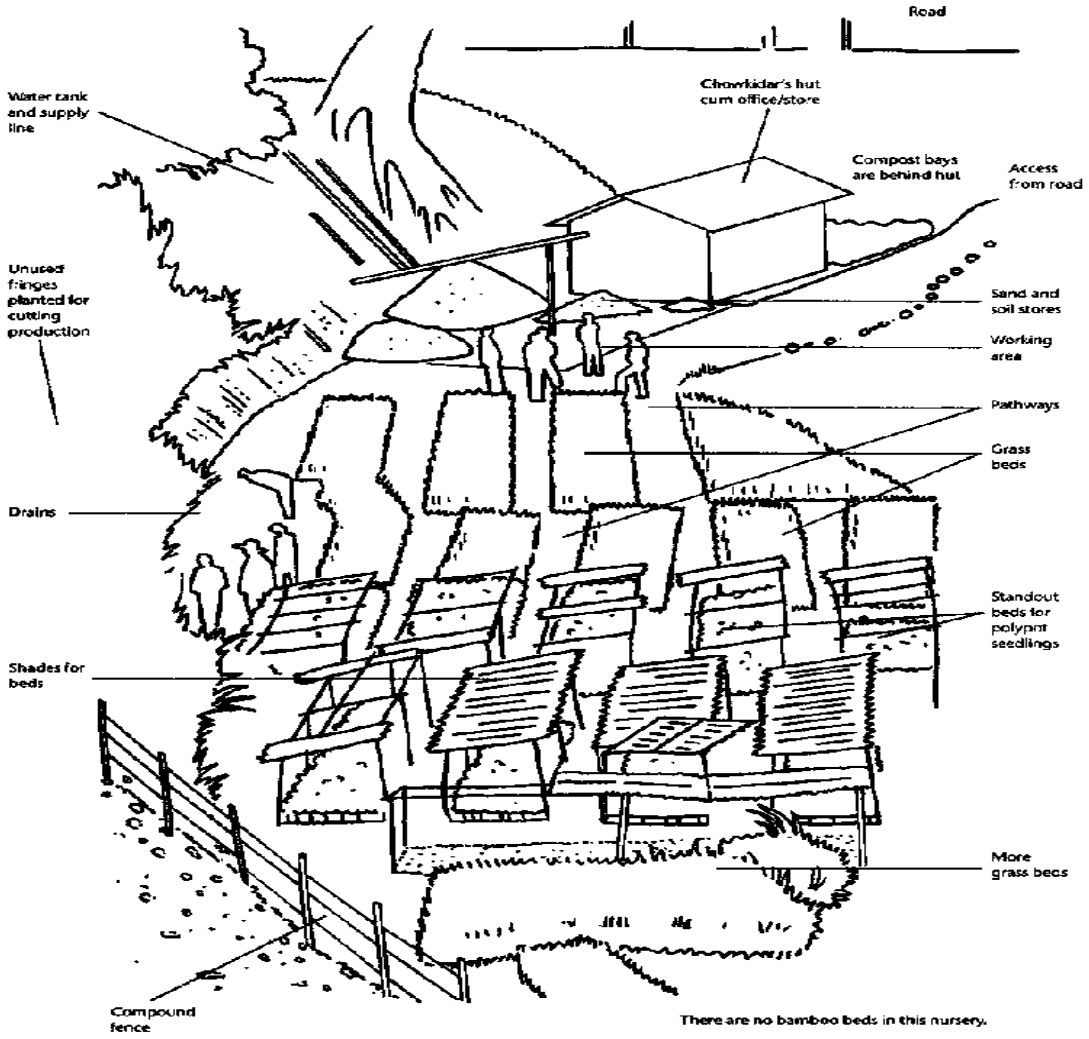

Figure 1. Well laid out forest nursery

2.3. Standard of nurseries by ownership

The basic requirements anticipated to be met by permanent and small-scale nurseries have been indicated in the preceding sections and these fundamental requirements need to be considered during the planning and establishment of nurseries that are owned by state, community or private. The following section explains the size and production capacity of nurseries that need to be fulfilled by each type of ownership.

2.3.1. State nursery

State nurseries are nurseries owned and managed by a federal or regional government. Such tree nurseries are expected to be model, demonstrative and field school for local communities as far as nursery establishment, management and production of quality seedlings are concerned. Therefore, the minimum size of such nurseries should not be below 0.75ha. The seedling production capacity should be more than 50,000 potted seedlings.

2.3.2. Community nursery

Community nursery refers to a nursery which is owned and managed by local communities, organized people, public institutions and NGOs. The minimum size of such a nursery should be at least 0.5ha. The seedling production capacity should be more than 20,000 potted seedlings.

2.3.3. Private nursery

Private nursery refers to a nursery which is owned and managed by individuals, households or investors. The minimum size of such a nursery should be at least 0.25ha. The seedling production capacity should be more than 5000 potted seedlings.

Government reports should only take into account the above mentioned nursery and seedling production standards to encourage quality and vigor seedlings and to target improved field establishment. Seedling producers (be state, community or private) should be encouraged to meet the above mentioned standards and the forestry extension service need to support the seedling growers accordingly.

2.4. Procurement of nursery equipment and materials

Nursery establishment and operation requires different equipment and materials like:-

Hoes, spades, forks, string, meter tape, watering cans, hose, wheel barrow, polythene tube, shading materials, pegs, forest soil, sand, compost, tree seed, pruning saws, trimming scissors, barbed wire, nails, hammer, wood, etc. and these equipment and materials need to be procured and ready before embarking on nursery establishment.

2.5. Development and establishment of a nursery

2.5.1. Site preparation

As soon as the site has been selected, work can start to convert the site into a more or less level area if the topography permits.

2.5.1.1. Removal of tree and vegetation cover

The first step in the preparation of a permanent nursery is to eliminate all the unwanted vegetation including trees, shrubs and small plants. It is also a convenient time to fell or save those trees either inside or outside the boundary which may either interfere with or help in future operations. For example, groups of trees on the periphery provide shelter and relaxation for nursery workers during non-working periods and fruit trees provide food. On the other hand, mature trees, particularly those of the same species being grown in the nursery which are a potential source of fungal and insect pests and those which give unnecessary shade should be removed.

2.5.1.2. Removal of top soil

Following site clearing operations, all the top soil should be removed from the site before levelling to avoid muddy conditions during wet weather and after prolonged watering. It is always useful to save the top soil for later use in the potting soil mixture or for the production of compost. Avoid creating erosion problems, pollution of nearby streams and water logging conditions. Many sites either have shallow top soil or very little, if any, so it may not be necessary to remove any soil before leveling. Terraces should be constructed on slopes of more than 4 to 5 percent.

2.5.1.3. Erosion control and wind damage

Exposed slopes and the ridges of terraces should be grassed as soon as possible and during the dry season if necessary since irrigation water should be available. If there is a threat of wind damage, a wind-break should be planted around the perimeter of the nursery. A low hedge could also be considered around key sections to further reduce wind, control or prevent wind borne weed seeds and damage from dust. The species used as a wind-break and in the hedge should be relatively free of disease and insect attacks. The species to be grown in the nursery should not be used as a wind-break since they could harbor injurious.

2.5.2. Preparation of nursery soil

Adequate sources of good quality soil are required in the preparation of the potting mixture and to a lesser extent for seed beds. One of the major components of the recurrent cost in a nursery

with container grown plants is the provision of suitable soil. Obviously, the nearer the nursery is to the source of this material, the less will be the cost. A high demand for sand in soil mixtures has developed due to the availability and use of heavy soils. Sand particles however, do not hold moisture and they tend to be inert, conferring few, if any, benefits to the plant. This over-reliance on sand could be avoided with adequate supplies of top soil and a ready supply of compost.

Five of the more important soil properties that affect plant production are:

- Particle size
- Organic matter content
- Soil porosity
- Moisture content
- pH

Although each can be evaluated separately, they are all interrelated. The presence of organic matter is perhaps the most obvious indication of a healthy soil and is an essential ingredient in maintaining satisfactory moisture relationships necessary for plant growth. Soil that is not porous encourages water-logging, hence oxygen, which is essential for root development and respiration, becomes unavailable to the plant.

Since the growth medium relates to every cultural practice in the production of nursery crops in containers, the selection and preparation of the medium is extremely important and will pay great dividends in terms of plant growth and quality. Several combinations of media with desirable physical, chemical and biological properties can be used but the goal should be consistency from batch to batch.

2.5.2.1. The best soil to use will depend on the species and what is available:

- In general a sandy loam texture and moderate to slightly acidic reaction (pH 5.5 to 7.0) represents the most favourable condition for forestry and agroforestry nursery stock although slight variations may be necessary for certain species. The Caribbean pine, for example, grows best in acidic soils ranging from pH 4.5 to 6.0 whilst hardwood species prefer pH between 5.5 and 7.0.

- In very acidic or alkaline soils certain plant nutrients are either leached or become insoluble and therefore unavailable. Acid soils below a pH of 4.5 are low in exchangeable calcium and magnesium and lack most of the important plant nutrients like nitrogen, phosphorous, potassium, sulphur and some trace elements (copper, zinc and boron) with only iron and manganese being available.

- It is always advisable to know the basic chemical characteristics of the soil being used for germination and transplanting. To avoid having to take a test with every production cycle, it is important to be able to obtain soil from the same source or soil type on a steady basis but this is not always possible. Although the sifted sand used in germination beds and container media appears clean and sterile it should be washed carefully to remove dust, harmful dissolved substances and weed seeds before use.

- Raising and lowering the pH value. The pH value of soils can be raised by adding lime or a fertilizer that reduces acidity such as sodium nitrate or calcium nitrate. An alkaline or neutral soil can be changed by the application of acid forming fertilizers such as ammonium nitrate and urea. Care must be taken with these fertilizers not to over fertilize the seedlings.

2.5.2.2. Growing media for propagation and germination beds

The physical structure of the medium in which seeds are germinated is crucial both for germination and early seedling establishment. The following growing media characteristics favour the growth of tender young seedlings:

- ✓ Good aeration which permits an adequate supply of oxygen to the root system.
- ✓ Good texture to facilitate contact between the seed and the growing medium.
- ✓ Large spaces between the medium particles should be avoided.
- ✓ Little physical resistance so that the emergence of the seedling is not restricted and root penetration is fairly easy.
- ✓ Infiltration capacity that permits easy watering and avoids crusting on the surface as often occurs with fine sand and silt.
- ✓ Absence of fungi, bacteria, nematodes and weeds.

- ✓ In view of the above, growers favour a medium loam texture. Incorporation of peat, loose sifted soil, soil/sand mixes or any of the imported specially prepared soil mixes may be necessary to achieve the desired structure.

2.5.2.3. Growing media for transplant beds

For the production of bare root stock, the available nursery soil can be used if its quality measures up to the following points:

- ✓ Good texture with limited clay content to avoid compacting and drainage problems.
- ✓ Organic matter present to ensure optimum physical soil conditions.
- ✓ Adequate nutritional level so that additional fertiliser application will not be necessary or minimal.
- ✓ Absence of weeds and harmful pests and diseases.

In cases where the soil in the nursery is considered to be inappropriate, soils found in the forest or carefully selected top soil from some land use development projects should be made available. Care should be taken to avoid sub-soil which is often available in large quantities at construction sites. Before use, the soil should be screened through a coarse sieve with a 1 cm mesh. Figure 15, illustrates two simple methods of screening soil. After screening, the soil is mixed, if necessary with sand and/or organic matter and appropriate fertilizer if required, prior to bed formation. Rest the growing media for at least two weeks after preparation to allow unwanted weeds to germinate and be removed.

2.5.2.4. Growing media for container seedlings

- ✓ The soil for containers is similar to that for bare root beds as described above.
- ✓ It should be well drained and a mix of soil and sand with organic material is common practice to prevent the root ball from disintegrating when the container is removed at time of planting.
- ✓ Heavy clays are undesirable because of poor drainage and compaction on drying out, and if avoided, the practice of adding sand would no longer be necessary.
- ✓ Presently nurseries use a 3:2:1 mixture of top soil, organic matter and sand. When the supply of top soil is variable and organic matter often unavailable, the quality of seedlings produced leaves much to be desired. The goal should be a 50:50 mixture of

top soil and organic matter, avoiding the use of sand. For example, Pines grow reasonably well on bauxite soils with the addition of organic matter and mycorrhiza.

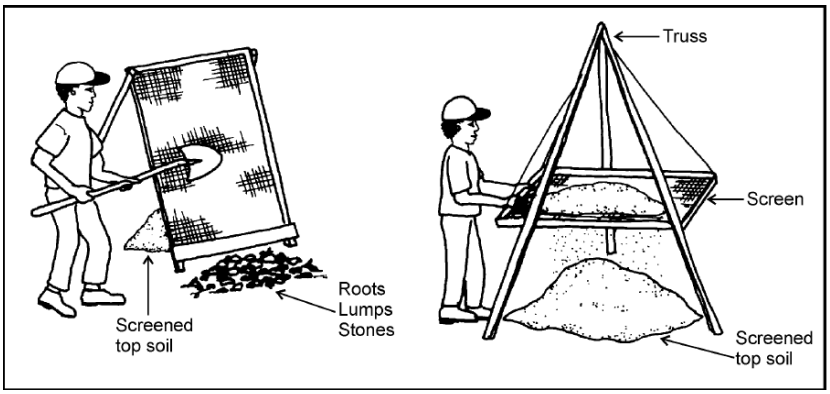

Figure 2. Two simple methods of screening soil.

2.5.2.5. Organic material

The following range of organic material has been used occasionally in mixture with soil to produce the growing media for containers in forest nurseries: animal manures, bagasse, chicken litter, coffee waste, coir dust, saw dust, sludge mostly in the form of compost or partially composted material, and commercial organic matter ('Bioganic'). The use of one or more of the above has been influenced by cost and availability and over the years, results have been variable. Since future supplies of any of the above materials are likely to continue to be erratic, every effort should be made to develop self-reliance for this component in seedling production. In the absence of research data to confirm the most suitable organic material, below are some points that should be borne in mind in developing Departmental capability:

- Material should have a high fibre content to provide internal water holding capacity (small pores) and yet allow for drainage between particles (large pores). Peat and sphagnum moss and sifted compost are good examples.
- If the material appears oily when wet or is slick rather than fibrous when rubbed between fingers, it is unsuitable for container grown plants.
- Sufficient pore space within which air can be trapped as roots need oxygen for development and growth.

- Ability to mix intimately with soil.
- Ability to bind or hold applied substances such as fertilizers.
- Should not be a source of fungi, insect pests or weed seeds.
- Should be sufficiently decomposed as otherwise there may be ammonia
- Damage to roots and foliage or an initially high demand for nitrogen by microorganisms which will induce a nitrogen deficiency in plants growing in comparatively fresh material.

2.5.2.6. Mixing the growing media

With the availability and common usage of such a wide range of organic substances and soil types it is difficult to prescribe an ideal mixing formula. The proportion of soil to compost on a volume to volume basis can range from 1:1 to 3:1. The addition of sand should be unnecessary except with particularly heavy soil. Assuming that the soil and organic material are on the site free of weeds, weed seed, fungi and insects and is sieved into a uniform and acceptable particle size distribution, the nursery operator must take steps to ensure that quality is maintained.

Some hints for maintaining quality media are:

- Proper mixing and handling procedures must be followed.
- The aim is to have a homogeneous mixture with the same measured inputs for each batch. Variability between growing medium batches can result in undesirable differences in plant growth and quality.
- Mixing is best done on a clean hard surface or concrete slab to avoid contamination and water damage from rain.
- Once prepared, the mix should be kept under cover if it is to be stored for periods in excess of two or three days.
- The length of storage determines whether bagged components are stored outdoors or under cover. Most bags begin to deteriorate after a month if left in the open.
- Media should be available when needed, hence the need to make plans well in advance of the production cycle.

To mix soil and compost:

- Pile components on top of one another, broadcasting any additives over the pile.
- Take one shovel full at a time and turn it over on top of the pile, working around the edge of the pile.
- As the material tumbles down the side it gets mixed. Make sure the centre of the pile is moved by gradually moving the location of the pile to one side during the mixture procedure. Mist the pile occasionally to keep the dust down and to make the pile less resistant to water absorption.
- Continue the process until samples from the pile appear to be well mixed.

2.5.2.7. Media compaction in pots

Filling the container with the growing media is an important process because poorly distributed media can negate the beneficial cultural practices of even the best growing media. Under compaction can cause problems but is often ignored. It results in seedlings growing in half or partially filled bags which are small enough as it is and with roots forced to exit containers or become deformed at an early stage. Over compaction can have several effects on the physical, chemical and biological properties of a growing medium. Although total porosity is naturally less in compacted media, the more important effect is the reduction or elimination of the large pores that control aeration and drainage. Media compaction is difficult to assess because of the small container sizes used and there is no precise technique available for measuring it. Containers that are unusually heavy should be suspect. The medium in properly filled containers should still feel springy to the touch. The symptoms of over compaction on tree seedling growth are often subtle and difficult to diagnose. They include foliar chlorosis, leaf drop, root browning and eventual death. Because it affects root function, the initial symptoms of root compaction can mimic drought stress, over watering or even mineral nutrient deficiency since roots may malfunction.

2.5.2.8. Mulching

Mulching means covering the soil surface in bare root beds or individual seedlings with a 5 to 10 mm layer of organic matter. Mulching can provide protection from heavy rain and water splash and it reduces evaporation of soil moisture. In dry localities, the presence of mulch on the surface of transplanted seedlings is a great help in reducing the amount of water required and reduces the tendency for the surface to become muddy or compacted. Like a sponge, a mulch can quickly

absorb plenty of water which then passes slowly into the soil. In very wet situations, it can be harmful by reducing aeration and increasing the risk of damping off, insect damage and over watering.

2.5.2.9. Mycorrhiza

The potted media needs to be inoculated with symbiotic fungi to provide mycorrhiza, which is essential in the production of healthy *Pinus* spp. seedlings and for their subsequent growth in the field. In the absence of mycorrhiza, pine seedlings exhibit slow, irregular growth and obvious signs of chlorosis. The easiest method is to obtain soil and humus containing the inoculant from under stands of pine in plantation forests. If large annual amounts are required, the nearby forest soon takes on the appearance of a mini mined out area. One alternative is to establish what has been described as a mycorrhiza bank or bed at a convenient location at the nursery site. The process involves:

- Removing the soil to a depth of about 20 cm (6 inches) and replacing it with the standard growing media.
- Mature pine seedlings known to have mycorrhiza infected roots are planted 30 to 40 cm apart in rows and the beds mulched with decayed pine needles and humus from pine stands
- Inoculation of the bed should be ready within 6 months after which it can be used as the need arises for one, two or more production seasons.
- The seedlings can be pruned or thinned as necessary and used as Christmas trees or otherwise disposed and the beds replanted, repeating the cycle in the same area or in an adjoining bed every two or three years.
- The seedlings should not be allowed to grow on into a tree to avoid harbouring pests that might be harmful to the young pine nursery stock.
- The size of the bed or beds will vary with demand and can be based on a ratio of one tablespoon of infected soil to three standard size bags of potting soil and added to the growing medium when it is being mixed with the organic matter.

2.5.3. Seed and transplanting beds preparation

2.5.3.1. Germination Section

This area which is set aside for the germination of seeds is best located near the office, to enable the supervisor to maintain a close watch on the activity. It is customary to sow the seeds in elevated metal or plastic trays erected waist high above the ground level. Round wood is commonly used but a more permanent foundation is recommended to avoid frequent replacement. One alternative is to build permanent seedbeds of concrete blocks with an internal measurement of 1 metre wide (see Figure 5 on page 23). Ten metres is the standard length but this varies with location and production targets. The beds may be subdivided into 1 metre quadrants to facilitate sowing smaller quantities of seeds. Since dogs, birds, rodents and insects have been known to damage seedlings during this stage, the germination section may need to be fenced and a 'roll on' cover provided for use when required.

2.5.3.2. Transplanting Area

The nursery beds for growing bare rooted plants or for standing containers occupies the greater part of the nursery area and it is here that the transplanted or direct sown seedlings are grown until they are ready for planting in the field. Normal bed width is 1 to 1.2 metres to facilitate hand tending. Length is also important and beds should not be longer than 20 metres in order to facilitate moving from one bed to the next. Bare root production beds should be located where the soil has the best chemical and physical properties.

The only fixture in the transplant area is the watering system if one has been installed. However, in very hot and dry locations, and with certain species, better results may be obtained by transplanting and raising seedlings under a roof used to control the light intensity. The building need not be elaborate but it should be high enough for workers to stand underneath. Pickets of wood or bamboo slats are commonly used and preservative treatment will extend their useful life. Imported polypropylene shade cloth is available in different light intensities offering a longer lasting, tidy and more efficient material. Polypropylene shade cloth comes in standard widths of approximately 2, 3 and 4 metres (6, 10 and 12 feet) that provide different intensities of shade, e.g., 47, 55, 63, 73 or 80 percent.

2.5.4. Construction of foot paths, production areas, working quarters, and administrative buildings and fences

In general, the average permanent nursery should be designed to accommodate the administration, operations and the agreed production areas. Layout need to be modified to meet the needs of small-scale nurseries but most of the principle need to apply. There should be no waste ground where weeds can accumulate and grow although unused land has to be included if expansion is planned.

2.5.4.1. Administration area

The inclusion of an office and storage facilities depends on the size and useful life of the nursery and the availability of funds. Generally the office and the storage area occupy the same building with the exception of fuels and other inflammable or toxic materials for which separate storage facilities should be arranged. The office should be located close to the main entrance to avoid routine movement of personnel, visitors and vehicles from disrupting nursery activities. It would be an advantage if the location overlooked the production areas to facilitate management and supervision.

Very often washing and toilet facilities and a lunch room are overlooked when nurseries are being planned. These are essential to ensure high standards of personal hygiene as most workers are in daily contact with soil and chemicals and sometimes have to work at very close quarters with each other in large numbers.

2.5.4.2. Operation areas

Adequate space should be provided to accommodate the following operations:

- Extracting, drying and processing of seed

The surface of this area should

- have a concrete floor close to covered facilities and could have multiple
- functions as it is usually suitable for other operations
- preparing germination trays and potting mixtures
- screening compost and soil

- filling pots
- soil shed with compartments for screened soil, sand and compost: the soil shed should allow for soil mixing and the filling of containers to be carried out under shelter throughout the year
- composting area: compost production should be considered mandatory in all nurseries, and a place provided for this purpose.

2.5.5. Development of water collection chambers

Water collection chambers need to be excavated at some corners of the nursery for workers to take water from the chambers with watering cans and regularly water the seed and transplanting beds. The size or volume of the water collection chambers depends on the size of the nursery and the amount of seedlings being produced.

2.5.6. Compost preparation

If sufficient organic raw material is available, compost with the above characteristics can be produced at the nursery site or at a central location. For this reason and in view of its important role in container seedling production, it is mandatory for each nursery to produce at least some of its own compost needs on a continuing basis. A central shredder close to a source of fibre from which sustained amounts could be transported to nurseries would facilitate this activity. In addition to the organic materials already mentioned, the following raw materials are also suitable for making compost and should be more easily available on a sustained, self-reliant basis:

- Weed growth and culled plants at the nursery
- Thinning and coppice regrowth from woodlots
- Foliage and branches from trees felled in urban centres
- Grass and other road side shrubs and vines
- Bark residue and sawdust

2.5.7. Erosion control and protection from wind

The nursery and the seedlings to be raised need to protect from damages that can be posed by flooding, erosion, and wind. Diversion channels or cut-off drains need to be excavated at the upper side of the catchment of the nursery to divert erosive floods from coming into the nursery

and damage the nursery compound and the growing seedlings. Shelterbelts/windbreaks need to be established against the wind direction to avoid damage that can be caused by wind erosion. Hedge rows can also be established along blocks to maximize protection of growing seedlings.

CHAPTER 3: SEEDLING PRODUCTION

3.1. Production of tree seedlings from seed

The responsible office should control which tree species /provenance to be used or take the responsibility for collecting or purchasing local seed requirements.

3.1.1. Seed pre-sowing treatment

3.1.1.1. Storing seed for short period time

- In arrival, divide the seed lot into manageable size and remove from storage only the amount required to be sown on the appointed day
- Use pest proof containers which should be airtight if possible
- Avoid extreme temperature and humidity
- Keep the seed in a refrigerator if it is available and use uniform temperature in the refrigerator, above $5\ ^{o}C$
- Do not store seed in a freezing compartment
- Apply seed fungicide and insecticide on arrival of seed at the nursery if this was not previously done.
- Some seeds cannot be stored for long periods, for example, neem. When such seeds arrive at the nursery they should be given priority for immediate sowing.

3.1.1.2. Seed Dormancy

Seed dormancy is a state of viable seeds fails to germinate when provided with favorable conditions to germination, these are, adequate moisture, appropriate temperature and light.

- Some tree or shrub seeds are ready for sowing as soon as they are collected
- Others pass through a dormant stage, during this time the embryo completes its development

Often, a pre-treatment is used to hasten germination or to obtain a more even germination. The methods of pre-treatment vary with the different types of tree or shrub dormancy. The main types of seed dormancy are:

- Exogenous dormancy – it is associated with the properties of the pericarp or the seed coat (mechanical, physical, or chemical)
- Endogenous dormancy – it is determined by the properties of the embryo or the endosperm (morphological or physiological)
- Combined exogenous and endogenous dormancy.

The advantage of dormancy is that it prevents seeds from germinating during storage and normal handling. On the other hand, where dormancy is complex and seeds need a specific pre-treatment, failure to overcome these problems may result in poor germination.

Some pretreatments are not directly related to seed dormancy but are carried out in order to speed up the germination process. For example, **Separation of empty seed,** this usually applied to small seed and may be achieved by soaking the seed in water overnight and discarding those that float as this often indicates emptiness.

3.1.1.3. Seed pre-treatment

- ✓ Weaken seed coat or break dormancy

Many type of seeds exhibit dormant characteristics:

- the hard seed coat of many legume species prevent the uptake of moisture
- some seeds contain chemical germination inhibitors which must first be removed
- others have partially developed embryos which need some more time to mature

The techniques used to overcome this problem are varying with the particular species and include the following methods:

Stratification

Many woody plant species require a cool temperature and moist media treatment for seed germination to occur. Cool-moist treatment of seed to promote germination is called a stratification treatment.

In most cases seeds with stratification require a minimum of 6 to 12 weeks treatment in a moist, aerated environment followed by a warm, moist environment for seed germination to occur. Seed must be maintained cool and moist since either warm temperature alone or dry media during the stratification process will inhibit germination. Burying the seed between layers of wet, sifted sand is a form of stratification that facilitates germination of some seed.

Scarification

This method facilitates germination by physically removing enough of the seed coat by nicking, piercing, chipping, filing, or drilling with the aid of a knife or needle or by burning. This method is time taking and rarely used and impractical where large seed quantities are sown.

Pre-treatment with hot water

Dormancy of Leguminoseae seeds can be overcome using hot water, which causes cracking or weakening of the seed coat.

- This method is most effective when seeds are submerged into the hot water and not heated together with the water.
- A quick dip is also better to avoid heat damage to the embryo. For most hard-coated *Acacia* species, it is enough the water to boil and put the seeds in the hot water after removing the flame. The seed can be sowed as soon as the water cools or kept in storage for short periods.

Pre-treatment with Sulphuric acid

Soaking hard-coated seeds in Sulphuric acid for 5 to 60 minutes, depending on the concentration of the acid and a kind of seed coats, can improve germination but care and experience is necessary as results vary considerably between species and seed lots. The duration of acid treatment should aim at reaching a balance in which the seed coat is sufficiently ruptured to

permit the seed to imbibe water. The acid may be re-used several times although its strength will gradually decline. After soaking, the seed is removed from the acid and rinsed under running water for at least 10 minutes.

Pre-treatment with fungicides or insect repellent

This method is useful if there is a risk of insect or damping-off sign in the nursery site. Dust the seed with appropriate fungicide/insecticide prior to sowing.

3.1.2. Pot filling

Nursery potting soil should have the following characteristics:

- it must be light;
- it must be cohesive;
- it must have good water retention capacity;
- it must have high organic matter;
- it must be fairly fertile or made so by the addition of 2 kg NPK/M3 of soil.

A good soil mix for tree nurseries can be different in different places; one example mixture is 3:2:1 ratio of forest soil, clay soil and sand respectively.

To test whether the soil mixture is a right mix it is possible to roll a damp of soil mix sample in the hand (see Figure 2)

- A good soil mixture should roll and hold its shape but break if the roll is bent
- If it does not break, then it has too much clay.
- If it crumbles before you can roll it, then it has too much sand.
- To ensure adequate fertility of the soil, add one mixing basin container of sieved manure or compost to every three or four basins of the standard mixture.

Figure 3. Nursery soil mix treatment

- Potting soil must be acidic (i.e. pH6). If it happens to be alkaline, it can be acidified by a solution of 2% sulphuric acid.
- Sometimes nursery soil has to be sterilized against pathogens by use of a 40% solution of formaldehyde applied as 80 cc per 5 liters of water and applied to the soil, 7 to 10 days before sowing the seeds.
- Soil fumigation is also a treatment against fungi by methyl bromide gas.

Polythene pots of different sizes are now used for raising nursery plants. It is very important to determine the pot size because large pots require more soil, take a lot of labour to fill and transport, they occupy a large nursery space and require more water in contrast to small pots. But they produce large plants in a short time. As a general rule "the harsher the planting site, the larger the pot should be".

When the pots are filled with mixed soil, care must be taken to have no voids by shaking and knocking regularly. After the pots are filled, leaving a small space at the top, they stacked side by side on nursery beds.

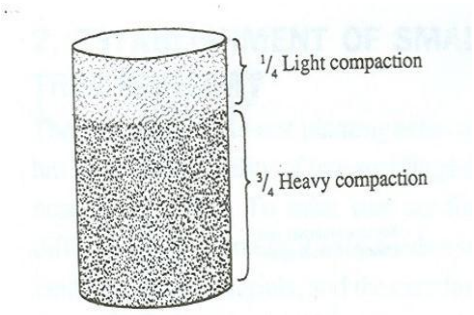

Figure 4. Pot compaction standard

The quantity of soil needed is directly related to the size of the containers used. The relationships between the diameter of the containers (ranging from 5 to 15 centimers) and their heights (15, 20 and 25 centimeters) and the soil volume (in square meters) is shown in the Figure 3 below

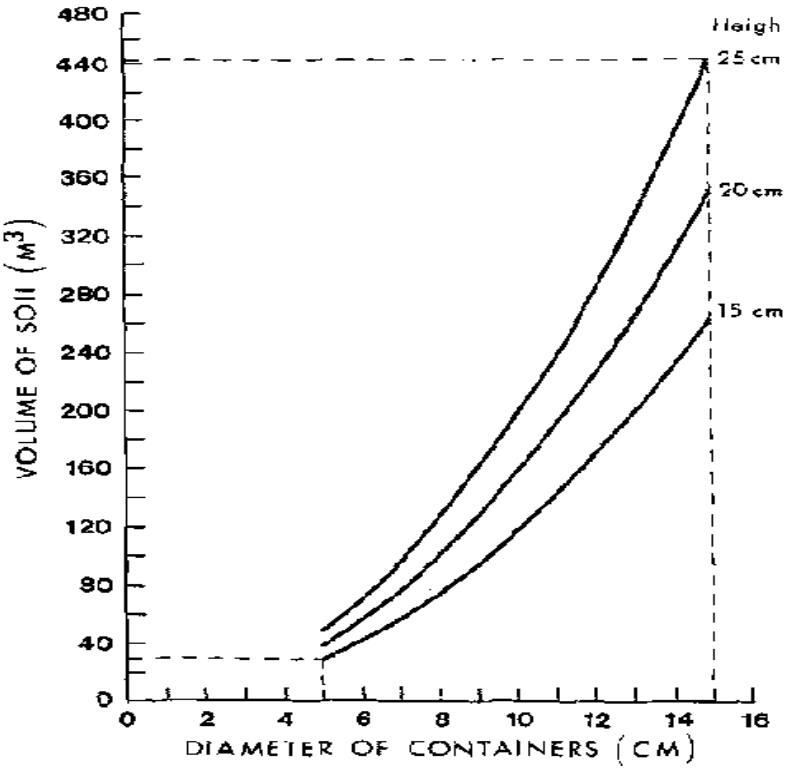

Figure 5. Relationship between the diameter of the containers and their heights and the soil volume

3.1.3. Seed sowing

3.1.3.1. Tree seedlings

Seedlings for planting are mostly produced from seeds. Purchased or collected seeds should have the following main information:

- Sources of seed
- Seed quality in % [(weight of cleaned seeds/weight of the sample seeds)*100]
- Germination power in % [(number of germinated seeds/the amount of sown seeds)*100]

- Number of seeds in one kg of seeds

3.1.3.2. Required seeds

The size of land and number of seedling to produce from various species must be known in advance to estimate the amount of seed required.

- Seedling may damage in the nursery due to number factors and then additional 20-25% seedlings are required to compensate the loss.
- Seedlings may damage in the planting field due to number factors and then additional 20% seedlings are required for biting up.

Example to calculate the amount of seed:

- Planed planting site= 10 ha
- Seedling needed=3334/ha
- Number of seedlings 10*3334=33340
- The estimated damage seedlings in the nursery and planting field are together 40%*33340=13336
- Then generally 33340+13336=46676 seedlings are needed
- So to produce this much seedlings we need to know to estimate the amount of seed in kg:
    - The number of seeds/kg=2000
    - Germination %=50
    - Seed quality %=50

The amount of seed in kg= $\frac{\text{Number of seedlings generally required}}{\text{Germination rate X seed quality X seed/kg}}$

=9.33kg

The germination process begins with the absorption of water and ends with the elongation of the root. The following steps are involving:

- Seed coat absorbs water and it moves into the inner membrane
- Stored food reserves are activated
- Cells multiply and elongation process begins

- Seed coat cracks and
- Roots emerges and seed germinate

3.1.3.3. Time of Sowing/nursery calendar

Time of sowing is important since seedling to be of the right size and quality by the planting season. For example, if the seedling takes 3 months to be ready for planting size and quality, then seed should be sown this amount of time in advance (see Table 3).

3.1.3.4. Method of Sowing

Two basic methods are known, for container or bare root seedling production, as direct sowing and broadcasting.

The choice of method may depend on the following motives:

- Development of transplants are sometimes slow compared with undisturbed direct sown seedlings
- There is a risk of root distortion during transplanting with broadcast sowing
- Direct sowing is easier if the seed is large enough in size to be handled individually and the risk of root distortion is reduced with this method.

✓ *Broadcast Sowing*

This is usually done in seed beds containing sandy loam *sowing medium* (see Figure 6 below).

- It is essential to have free drainage in the beds
- Make the surface of beds smooth, level and firm but not compact
- The seed should not be too thickly over the bed surface to avoid overcrowding
- A cover may be necessary to protect the seed from birds and to provide shade.

Broadcast Methods

- Used for tiny seeds such as Eucalyptus species, the practice is to mix the seed intimately with an equal part of fine, dry sand of a similar size and spread the mixture evenly with the fingers.

- An alternative method is to make a 20 by 20 cm tray using strong mosquito or similar wire netting. The tray is then covered with fine sand particles just large enough that they will not penetrate the netting. On top of this the seed is added, usually sufficient to sow 1 square metre of the germinating seed bed. After shaking the tray, the small seed will find the openings and be deposited on the bed evenly and in the quantity desired. If the seed is mixed with sand of a similar size, it will be sown more evenly and uniformly.

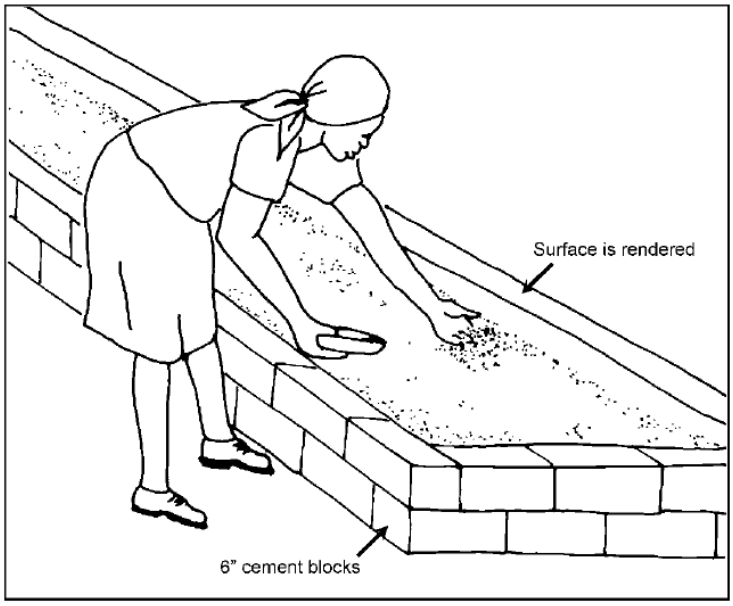

Figure 6. Pre-mixed sterile sowing medium in concrete block frame for broadcast sowing

✓ *Direct Sowing*

- The advantages of direct sowing are lower cost and the avoidance of damage to seedlings through careless transplanting. Only one seed is necessary for one pot if the germination rate is high, if not the aim is to sow an average of two or three seeds per container.
- With small seed, special methods need to be used to regulate the amount to be sown. In some nurseries, a shaker is used. It is made from a small bottle with graduated holes in the lid set to allow a given number of seeds to drop per shake.

Depth of Sowing

A general rule is to cover the seed to a depth equals to twice the seed diameter and not deeper than 1 cm *with bigger seeds*

The recommended practice is:

- To apply the lightest cover of soil, which is capable of withstanding routine watering?
- Do not press the seed into the seedbed or container
- The tendency in some nurseries has been to sow the seed much deeper than necessary to avoid the washing out or uncovering after heavy watering. In such cases it is the water that should be regulated, using nozzles and pressure that will reduce the force of the water.

3.1.3.5. Methods of raising tree seedlings from seeds

Common methods of raising seedlings:

- Container production - growing in pots
- Bare-root production – growing in beds in the soil
- Raising seedlings using wildlings
- Root trainer

It is important to decide which method (or mixture of methods) suits individual situations (site, business objectives, and time and investment level).

Advantages and disadvantages:

Container production

- Enables growers to have greater control of the growing environment and extend the growing season
- Requires more capital investment in infrastructure (irrigation, etc.) and has higher production costs (composts, containers, etc.)
- Watering and ventilation requirements are more labour/capital intensive in summer

Bare-rooted seedling production

- It is subjected to more environmental limitations (weather/soils, etc.) to the growing/working season
- Require less capital investment in infrastructure and has lower production costs
- Has a larger land requirement, (e.g. when lining out trees from nursery beds).
- Has higher production costs for weeding, needing to employ labour and/or chemicals.
- Watering is somewhat required less labour/capital intensive.
- To produce saleable plants, it is usually, at least a 2-year growing/sales cycle.

Initially, seedlings are rising in bare rooted and planting them in the field, the survival rate is often low due to several reasons. Some are unpredictable weather, dry conditions and seedling stress due to high temperatures in the field. However, survival of seedling may increase considerably when they are grown by polyethylene tubes.

It is noticeable that many different types of containers are now available with obvious advantages; but the following disadvantages are prevailing:

- The need for high quality seeds
- Expensive to get and prepare suitable growing media (soil mix) and pot filling process
- Individual seedlings are heavy when compared with bare root seedlings and therefore costly to handle and transport

With improved seedling conditioning, and to effect cost savings, consideration should be given to reverting to bare root production particularly for sites with adequate rainfall.

The sequence of operations for the bare root method and that for containers are shown in below Figures 7 and 8:

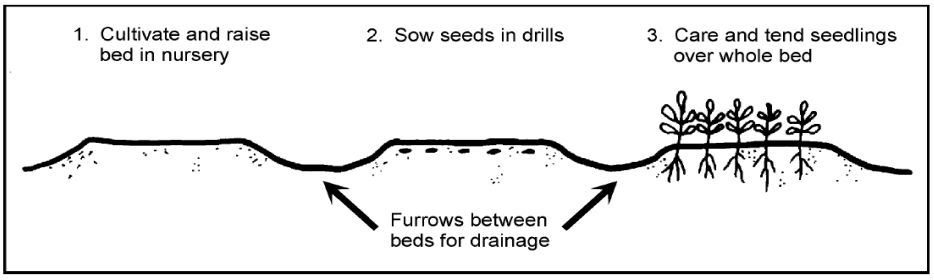

Figure 7. Bare root cultivation

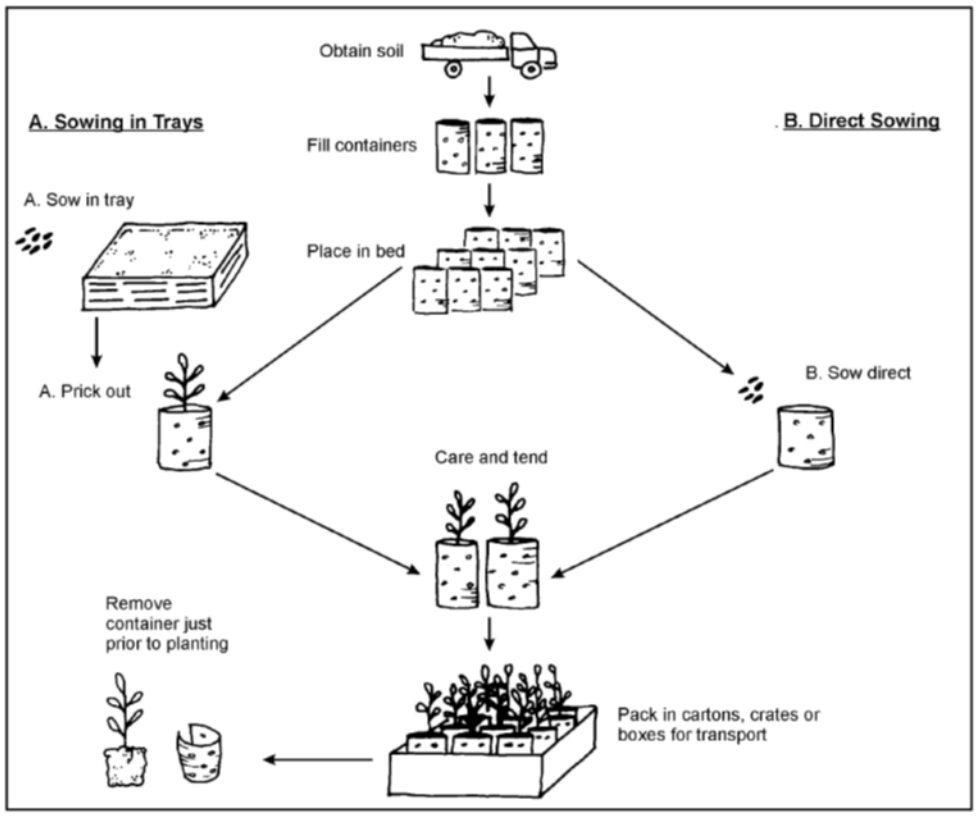

Figure 8. Sequence of operations for container growing

Raising of seedling using wildings

In addition to the conventional methods of seedling production, it is also possible to prepare seedlings using wildlings from natural forests. Natural regeneration (wildlings), refers to seedlings that have germinated under parent trees. In recent years, there has been an increased demand and use of seedlings from this source because of:

- Shortage of planting stock in many places
- Inadequate seed supply
- Seed germination is low
- Higher demand of seedlings at short notice

Points to be remembered:

- Select younger seedlings before tap roots have developed

- Arrive on the site with the necessary tools and equipment
    - ✓ pick-axe to loosen the earth
    - ✓ plastic for packaging
    - ✓ compost material to reduce moisture loss from roots and stem
    - ✓ sharp knife for root pruning
    - ✓ container with supply of water to keep package damp and reduce shock
- Do not pull seedlings which are firmly rooted in the soil.
- Put seedlings in water; root prune if necessary.
- Package seedlings in bundles of 20 or less packing damp compost around the roots.
- Transplant seedlings as soon as possible in to containers.
- Place seedlings under shade until roots recover and start absorbing moisture.

3.1.3.6. Root trainers (Seedling trays)

Root trainers are the perfect start for nearly all plants, and especially those that are sensitive to disturbance and require deep root runs. Ideal for growing on seeds, seed-lings, plugs and cuttings. The root trainer system is made up of deep seed trays, divided into separate segments known as 'books'. They are unique because they open up like a book, for easy inspection and easy transplanting.

A root pruning container is an aid to the cultivation of young plants and trees in nurseries. Many pot designs train the roots. One example is a truncated plastic cone in which a seedling is planted. There is a drainage hole at the bottom and the main tap root tends to grow towards this. What this achieves is to encourage the roots grow a denser system of root hairs. How it does this is to have the pots designed so as to air prune the roots. The advantage is when the plant is planted into its home environment it has a stronger root base to start with.

Figure 9. Some example of root trainers

3.1.4. Preparation of Shade

3.1.4.1. Care of Seedbed and Direct Sown container

- Shading is required immediately after sowing the seedbed and direct sown pots. It gives protection from sunlight and wind and to maintain humidity and even damp moisture condition that favors germination.
- During the first sign of germination, the shed must be lifted to about 30 cm or higher.
- Watering must be done gently with a fine spray where piped water is available. Mist nozzles are recommended for watering seedlings.

Light and Shade

Light affects all the different stages of growth of container tree/shrub seedlings. The grower should manage to increase photosynthesis which takes place in the leaves.

- By photosynthesis, the seedlings are able to produce carbohydrates, amino acids and fats and also generate oxygen which is essential for the respiration of all organisms.
- Water is absorbed in the roots and transported to the leaves where it is combined with carbon dioxide in the presence of light to produce glucose.
- This product of photosynthesis is transported throughout the plant and used in respiration to release energy that required for a wide variety of growth and maintenance functions.

- Seedlings will do best under high light intensities and the goal should be to grow seedlings in the open wherever possible.

Note:

- It is a mistake to use shade once the seedlings are survives the shock of transplanting, but nursery staffs interested to keep them under shade to reduce the amount of watering needed and also to hide the effect of bad transplanting.
- Plants that have been transplanted will require shade averagely for only up to 3 days.

Figure 10. Shading of young seedlings

3.1.4.2. Shade nets

Shade nets provide shade in greenhouses and nurseries to seedlings. They protects seedlings against adverse climatic conditions (frost, cool temperature, etc.). They also act as windbreaks and are suitable to spread above greenhouse tops, flexible, light, strong and easy to spread. Moreover, they are designed to protect seedlings from pests and birds. They can be placed on simple support structures. These nets regulate both quality as well quantity of light and temperature which is essential to control the growth conditions and also manipulates growth pattern plants from excess sun rays and wind.

Figure 11. Samples of shade nets

Raising seedlings in frost prone areas

Seedling are injured by frost causing ice crystals to form in plant cells. This makes water unavailable to plant tissues and disrupts the movement of fluids. Frost-damaged leaves appear water-soaked, shrivel and turn dark brown or black.

Protective measures

- Water the soil thoroughly (except around succulents). Wet soil holds heat better than dry soil, protecting roots and warming air near the soil.
- Use shade net as referred in the preceding section.
- Remove the coverings when temperatures rise.

3.1.5. Transplanting the Young Seedlings

Depending on the species, seedlings are normally ready for transplanting from 3 to 5 weeks after germination when 2 or 3 pairs of leaves have formed. For example:

- For Pine *spp.*, transplanting is best done at the 'match-stick' stage of the seedling while the seed coat is still attached to the young stem and when lateral roots have not yet started to show.
- For *Acacia* spp, transplanting is best when the first pair of leaves show. Some selection may be necessary at this stage since all the seeds do not germinate at the same time.
- For Casuarina spp., and Cypress seedlings, transplanting is best when the heights attain 3-4 cm.

3.1.5.1. Transplanting Seedlings

- We need to reduce the frequency and the amount of water in the last 10 days before transplanting seedlings in order to harden them, particularly if they are more than 4 to 5 weeks old.

- Seedlings to be fresh and firm. This is achieved by watering them well the day before they are transplanted. At the time of lifting the soil should be only moist, not wet.

- In lifting the seedlings we need take care not to damage the roots or the stem. Do not pull them individually. Lift the seedlings by raising a whole block of soil using a thin piece of wood.
- Hold the seedlings only by the leaves or by the needles in the case of pine spp. If the stem or root is held, the plant is more susceptible to damping off fungi from bruising, crushing or infection by the fingers.
- As soon as the seedlings are taken from seedbed, place the roots in water in a shallow container to avoid drying out before transplanting.
- Plant the seedlings at the same depth as they were in the seedbed or perhaps a little lower but never higher.
- Prepare the transplanting slot using a broad flat stick or your fingers.
- Prune the tip of the root if it is too long using a sharp knife, making a clean cut, leaving about 5 cm of root.
- After transplanting, firm the soil gently around the root. Do this carefully to avoid air pockets at the bottom or side of the slot. Do not use force as this could bruise the seedling and reduce the porosity of the soil medium by compaction.

- Plant the seedling in a straight, upright position in the center of the container. The roots should not be allowed to bend or curl in the planting space (see the below Figure 12).
- After transplanting, seedlings must be watered immediately and place them under shade if the days are particularly hot. This should not be necessary if the transplants were sufficiently 'hardened off' or grown in full sunlight.

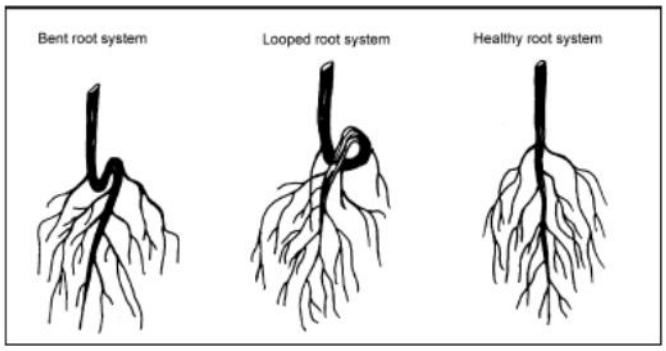

Figure 12. Examples of bent and looped seedling root systems due to bad potting/ transplanting practices.

3.1.6. Tending the Seedlings

3.1.6.1. Watering

The most important factor in seedling production is water but too much water can be harmful.

- For tiny seedlings, a heavy dose of water is unsafe and may leaches out the soil nutrients.
- Several light applications of water is far better than one or two heavy applications.
- Keep the soil moist but never sodden, watering preferably in the mornings and avoiding the mid-day period when the sun will cause excessive evaporation.

Over Watering

- Excess water is nearly always damaging since the water tends to replace the air in the soil and cause compaction.
- Excess water also promotes development of fungal diseases like damping off.
- The visible symptoms of over watering are slight to severe yellowing and stunted growth.
- Over watering tends to occur in nurseries with heavy soils.

Under Watering

- Wilting is one of the early signs of under watering.
- Any signs of wilting should be immediately supplied by the addition of water so as to prevent permanent damage.

Watering Methods

Watering may be either by hand or by irrigation

- Hand watering with cans fitted with spray
- Hand watering with a plastic or rubber hose fitted with a spray is also popular
- The ideal system for large nurseries is overhead sprinkler irrigation as it is easily controlled and provides the most uniform method for the application of water.

3.1.6.2. Weed Control

Weeds are competing with the seedlings for nutrients, water and light. If they are not eradicated on time, the competition may suppress the growth of young seedlings.

Eradication of weeds is more difficult after they have invaded the seedlings growing in transplant beds, both the potting soil and the pre-filled containers may be watered in advance so that to germinate weeds and remove them in advance of transplanting. For this purpose, the plastic pots should be filled 4 weeks in advance of transplanting or direct sowing if weed free potting soil is not available.

Important points to be remembered:

- The most problematic weeds are dicotyledonous plants (e.g., grasses) that grow from a root sacker. If such a weed is cut off at the ground level, it will sprout again and continue to grow and hence the need to remove the whole plant.
- Most weeds produce large quantities of seeds, which are easily transported by water, wind and also bring by top soil and farm yard manure.
- No weeds should therefore be allowed to flower and fruit in the nursery site.
- Grassy areas should be regularly cut and trimmed.

3.1.6.3. Fungi and Insect Control

✓ *Control of Fungi /Damping Off*

Damping off is the most likely fungal disease. The symptom is the development of a zone of weakness where the stem and the root meet. The seedling rapidly loses turgidity, bends over and soon dies.

Important points to be remembered:

- Heavy watering, particularly in the afternoon and evening hours encourages the disease, watering should be in the mornings.
- If possible, to prevent seedlings from damping off, the seedbed should be sprayed once a week with a solution of a copper based fungicide.
- To control the attacks of the fungus, the fungicide should be applied every three days until they are to be controlled.

✓ *Control of Insect Pests*

- Temporary control of pests can be achieved by isolating the plant until spraying is done.
- Protection against leaf eating insects is sometimes necessary. A number of formulations are available on the market, and distributors should be consulted on the most suitable chemical for the particular problem.

3.1.6.4. Root Pruning

- The roots of tree/shrub seedlings required to be straight and dense with healthy root hairs.
- The corresponding stems should also be straight and vigorous.
- After transplanting, the roots of seedlings tend to exit through the drainage of the pot at the bottom into the soil. If they fail to penetrate due to ground barriers, the root will develop abnormalities by having to run circles inside the pot.
- In situations where the root exits the pot, root pruning is necessary. Then pruning stimulates root growth and causes the roots to become compact and fibrous rather than long and thin.

- Otherwise seedlings look healthy in the nursery bed but may develop to unbalanced root to shoot ratio and they will be the first victim in the planting field. This is because the vigorous shoot loses water through its leaves and soon wilts as the weakened root is unable to perform its normal function of replacing the loss of water by absorbing from the soil.
- As a general rule, the first root pruning is carrying out as soon as the roots appear through the bag and enter the ground.
- Repeat the pruning every two weeks or as necessary; it is best to practice in a cloudy day when transpiration is low. If there are signs of wilting, then the plants should be watered.

Methods of root pruning

This can be done by either lifting each container or by cutting the tap root of bare rooted stock.

✓ *Root Pruning by Lifting*

- In this method (see Figure 13), the first row of plants are carefully removed from the bed to provide operational space and each plant in the second row is lifted and placed in the vacant row after root pruning is done with pruning scissors or a sharp knife.
- Do not shock the seedlings by lifting them forcibly as this damages the roots

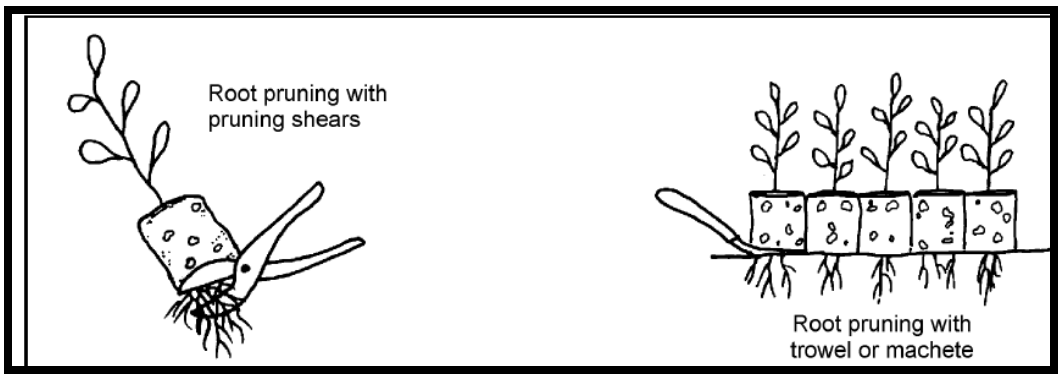

Figure 13. Pruning container grown plants.

✓ *Root Pruning in Bare Root Transplant Beds*

- Root pruning of the seedlings in the bare rooted transplant beds can be carried out in underground with a sharpened spade; vertical cuts are made between the seedlings to shorten long lateral roots (see Figure 14).
- The pruning level should not be neither too deep nor too shallow ranging from 10 to 30 cm below the soil surface depending on the species and the size of the seedling.

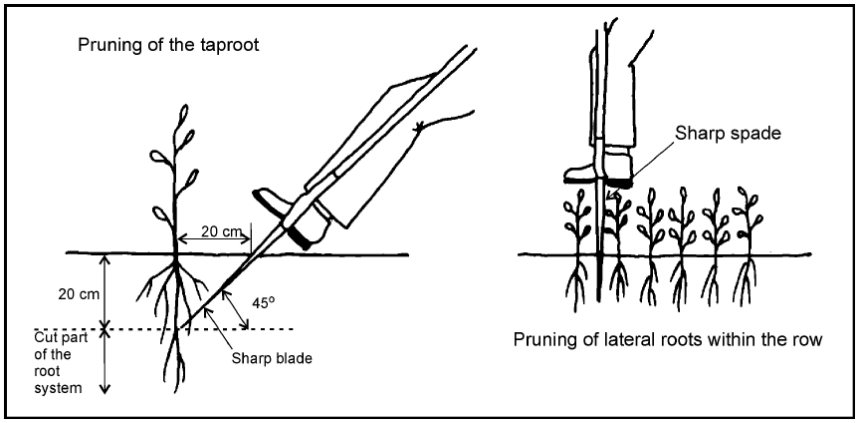

Figure 14. Root pruning bare root seedlings in a transplant bed.

Cutting Back Oversized Seedlings

- Oversized seedlings may cut back to a convenient height of up to15 cm and allowed to recover in the nursery before planting in the field.
- A second pruning of unwanted shoots also done as soon as they appear, to facilitate the growth of the main stem.
- This method is particularly useful if seedlings reach the desired sizes sooner than the required time and the need exists to hold them back for two to three months.

Important points to be remembered:

- Remember that when keeping the seedlings for the next planting season, by then the seedlings would have been consumed all the fertility in the small plastic bags.
- Seedlings may develop abnormal roots and could reduce the chances of survival in the field.

3.1.7. Hardening Off

- Hardening off is the gradual withdrawal of normal growing conditions to the seedlings in the nursery to facilitate the survival of seedlings in the harsher environment in the planting field.
- This treatment should begin in the halfway through the life of the seedling in the nursery.
- Reduce the amount and frequency of watering gradually to two or three times per week depending on the species, the potting medium and the local climatic conditions.

Characteristics hardened seedlings:

- Seedlings have firm, lignified stems, often brown in colour
- They are robust, well developed crowns with leaves extending over three quarters the length of the stem.
- Seedlings have vigorous, healthy, leathery leaves and compact rather than oversized and weak

Procedure to facilitate the hardening off process:

- Reduce the frequency of watering
- Reduce the quantity of water
- Cut off fertiliser applications early
- Expose plants to full sunlight as soon as possible
- Prune roots
- Cut back shoots if oversized
- Ensure that each plant has adequate space

3.1.8. Setting standards and grading seedlings for out planting

3.1.8.1. Setting tree seedling standards

Seedling standards vary across ecologies and among species. For example, in temperate ecologies where there is adequate rainfall, it is possible to use tall seedlings to plant and increase their survival. In dry areas, this practice may be difficult as there is a problem of water balance to

sustain the seedlings. In conventional tree planting practices, it becomes a normal procedure to plant sturdy and vigorous seedlings which have passed through hardening-off procedures. However, with the current trend of global warming and its consequences, conventional ways of tree planting have become less effective in survival and growth in Ethiopia. As a result, tree growers especially in urban areas tend to plant tall seedlings grown on large pots and such practices have been observed to be effective in some cases and are gaining societal acceptance through time. However, it is very important to carry out a research on the effectiveness of these options to advise the wider tree growers accordingly. Therefore, for the case of this manual, the following seedling standard is proposed based on some observations and experiences:-

Table 1. Seedling standards for field establishment

Rainfall/Moisture regime	**Pot size (lay flat)**	**Seedling height**	**Remarks**
Adequate rainfall (moist) areas	18-25cm	>50 cm	In wet and moist areas with deep soils, experiences show that, planting well grown and tall seedlings have been found to be effective in field establishment.
Medium rainfall (moderately moist) areas	25-30Cm	40-50cm	In moderately moist areas, planting medium size seedlings with medium size pots is effective in field establishment.
Low rainfall (moisture stress/dry) areas	>30cm	30-40cm	In arid and moisture stress areas, observations show that, planting sturdy and vigorous seedlings that passed through hardening-off procedures in the nursery are found to be effective in field establishment. Such seedlings have the ability to withstand shock and harsh conditions.

3.1.8.2. Grading seedlings

Some of the main causes of low field plant survival are low quality and poor condition of seedlings and these should not be taken to the field for planting. The few survivors may grow slowly and must be tended for longer periods than good quality and faster growing seedlings. Losses have to be replaced incurring additional cost and also represent a waste of time, effort and money.

The following points should be considered in judging whether a seedling is a good quality planting material or not.

✓ *Health*

- Seedlings should be free of disease and insect attack. Discoloration of leaves and weak crowns indicate improper nursery treatment or abnormal roots.

✓ *Injuries*

- The seedling should be free from mechanical injuries although some damages can be repaired by pruning.

✓ *Stems*

- Stems should be straight and stand firm without support. Curved stems usually signal abnormal rooting.

✓ *Sizes*

- Each planting unit should receive seedlings of the same size and therefore plants of different sizes should not be mixed.
- For most species, 25 to 35 cm height including the pot size is considered to be the best height for mature planting seedlings and should be ideal in terms of vigour
- Some growers favour taller seedlings but they tend to lose the lower leaves and are inclined to bend over when planted. They have more difficulty in maintaining their water balance and tend to wilt much sooner under dry conditions.

3.1.9. Dispatching and transporting seedlings

- This is the final responsibility of the nursery management; the seedlings should properly prepare to transport to the planting site.
- During this process, usually seen bad lifting (holding their stem), damage of seedlings at the root collar, vibration on the way from the nursery, wind damage, drying out and sun burning, and bad storage.

- To minimise the physical damage, the seedlings should not be lifted by
- Care must be taken with handling of seedlings at every step of the transporting process from the transplant beds to the planting hole.

Important to be remembered

- Although good quality seedling are produced in the nursery, survival of them in the field may be less than 40 percent if good handling of them during transportation is missing.
- The container grown seedlings should be packed and moved at each stage in open top boxes until they arrive at the planting hole. It is important to pack the boxes tightly so they cannot move about in the truck.

Figure 15. Transporting graded/ quality seedling

3.2. Production of seedlings through vegetative means

The concept of vegetative propagation is that an exact copy of the genome of a mother plant is made and continued in new individuals. This is possible because plants have meristematic, undifferentiated cells that can differentiate to the various organs necessary to form a whole new plant (Teotônio, et. al., 2004). A piece of plant shoot, root, or leaf, can therefore grow to form a new plant that contains the exact genetic information of its source plant. There are different types of vegetative propagation-Macro and micro-propagation methods (Figure 16)**.**

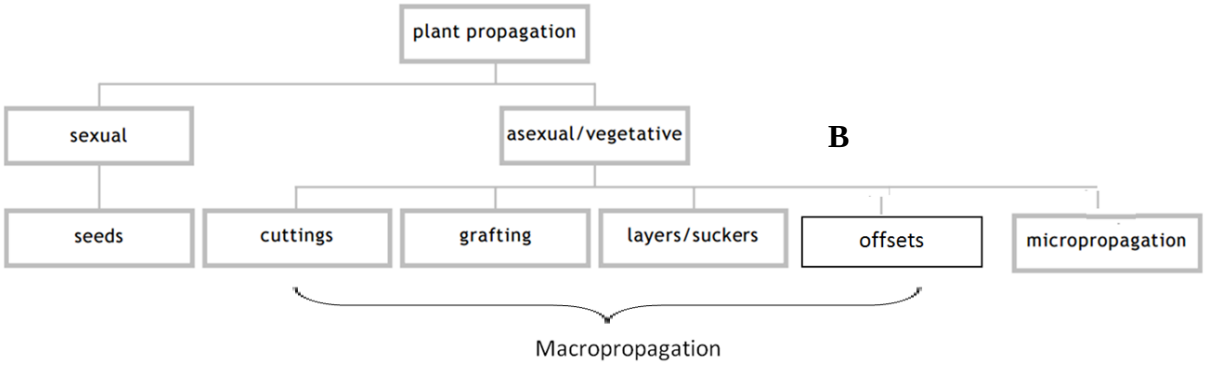

Figure 16. The different types of plant propagation

3.2.1. Propagation of seedlings using macro-propagation techniques

3.2.1.1. Cuttings

A cutting is a vegetative plant part, with at least one node, which is severed from the parent plant in order to regenerate itself, thereby forming a whole new plant. Various plant organs can be used for cuttings: stem, root, rhizome fragments or leaf cuttings. Multiplication through the rooting of cuttings is probably the most common technique by which trees can be propagated vegetatively. Now a days, by employing improved rooting and shooting environment, mini-cuttings of 3-4 cm (Figure 13) are become easier means of vegetative propagation especially in mass production of Eucalyptus seedlings for commercial purposes. Plant propagation by cuttings can yield a high multiplication rate and produces plants with their own root system.

A **B**

Figure 17. (A) Stem cuttings of Populs sp. ready for planting on the propagation bed and (B) mini-cuttings of Eucalyptus ready to be planted in a root trainer

Facilities required for producing seedlings from cuttings

Stock plant source

Stock plants or tree selected from genetically superior mother trees, either from seed or vegetative means, from which cuttings will be taken for mass production of seedlings, need to be established near the propagation area. Cuttings then will be collected, inserted into the root trainer or growing media and proceed to the sequential processes of seedling production.

Rooting chamber (controlled room for rooting of cuttings)

Mini-cuttings require high humidity and consistent temperatures to prevent excessive drying of young meristematic buds and at the same time enhancing root development during propagation. Hence they should be placed in appropriate growing media, with a root trainer with in a mist propagation chamber (Figure 18) for few days, depending on the species till roots are developed. The mist propagation chamber is an area with controlled environmental conditions mainly temperature, moisture and air movement or wind.

Figure 18. Mist propagation chamber (rooting house) for cuttings

The propagation chamber can be constructed the same way modern tissue culture laboratory growth rooms are built and equipped with modern temperature and humidity control units (Figure 18). It can also be constructed using locally available materials, like what is produced for

Juniperus procera.

Construction of the propagators (growing media) using locally available materials.

External parts of the three dimensional propagator can be constructed using wooden frames. The procedures are as follow:

- Cover the wooden frames with clear, colorless pieces of plastic sheets.
- Partition it internally in to six equal but self-contained compartments
- Overlay each compartment with double – layered plastic sheet such that the entire unit compartment will be watertight,
- Layer the bases of each compartment successively with stones (6-10cm), small stones (3-6cm) and gravel.

- Cover the remaining top most layers of the compartments with clean sand, sieved using 1mm mesh-sieve, and washed in running tap water to remove mud and debris,
- Erect a piece of plastic pipe, diameter 3 cm and length 40cm, in the front right corner of each compartment.
- The level of water in each compartment then will be maintained at a height of 20cm from the bottom of the compartment,
- Cover layer with clear sand with a depth of 5-7cm to serve as rooting medium for the treated cutting
- Keep all the propagators under 1.5m high wooden beds, cover them with leaves of phonex reclinata or other similar cover for obtaining up to 80% interception of direct sunlight

Green house

After mini-cuttings develop roots, they are transferred to greenhouse (Figure 19), that is a less controlled environment as compared the mist propagation chamber, for shoot development and further growth up to reaching plantable size.

Figure 19. Green house for growing rooted cuttings in to a full sized seedling

Hardening bench in the open air

Seedlings produced using root trainer, after reaching plantatble size, are exposed to open air by transferring them from the green house and fixing them in a nursery bench (Figure 21) for hardening purpose.

Figure 20. Hardening of seedlings after transfering from the green house

3.2.1.2. Offsets or apomixes

Trees and shrubs can also be multiplied using offsets or apomixis. Offsets are lateral shoots that develop from the base of the stem of some plants. Offsets are important in propagating monocotyledons, such as bamboo and palms. They are severed from the mother plant with roots attached and can be potted immediately or planted in the field directly. If insufficient roots are present, they can be treated like a mini-stem cutting and placed into a mist propagation chamber.

3.2.2. Selection and preparation of cuttings

The targeted vegetative collection of tree germplasm from identified sources or nature may result in superior trees being made available more quickly to farmers, with earlier expression of desired products and uniformity of growth form and may also lead to narrowing of the genetic base of cultivated material and can be both costly and time consuming. Hence care should be taken while selecting planting stock for collecting cuttings from sources.

The capacity of trees to be propagated vegetatively ought in theory to be similar to that of herbaceous plants; however, their greater size and structural complexity at maturity result in a loss in rooting ability which has to be avoided or overcome by using young plants, coppice or 'rejuvenated' shoots. Thus giving attention on the age of the stock plant from which the propagating material was taken and the condition of the propagating material (vigour and pest and disease damage) are important considerations while selecting cuttings. It is now known that the major influence controlling the successful propagation of woody plants from stem cuttings is the inherent level of regenerative capacity present in the material selected for propagation.

Regenerating capacity is a function of the physiological status of the plant from which propagoule is collected. Older cultivars are usually more difficult to root than more recent ones. This was seen to be a major influence on successful propagation, rather than the treatment of the propagation material after it had been isolated.

A woody plant progresses through juvenility, maturity and senility. The potential asexual regenerative capacity during this cycle declines in a sigmoid curve fashion. The highest level of this regenerative capacity occurs during the juvenile phase, declining only slightly as time progresses. At the onset of sexual maturity the capacity declines markedly and continues to decline steadily, until the senile phase is reached when this potential is virtually lost.

The relative capacity to regenerate between different families, genera and even species varies considerably but is normally constant. Thus, the inherent regenerating capacity varies significantly and is not the same for all woody plants. This implies that there is a spectrum of this capacity which, at the extremes, means that stem cuttings of a taxon may be 'difficult' or 'easy' to root.

Moreover, for propagation of woody plants from stem cuttings, the significant factors for maximum success - especially with plants regarded as difficult to root – are that the basal swelling is incorporated into the cutting, and that only this particular cutting is likely to be successful. This basal swelling, which develops as a result of the initial surge of growth from the dormant bud, represents the fastest growth rate of the new shoot. After woody plants grown from cuttings with basal swellings show the expected characteristics of the mature cultivar by the second season after propagation.

Specific techniques of ample species that reproduce vegetatively

Stock plant establishment and management

- Produce seedlings following the procedure stated under section 3.1.
- Allow the seedling to grow and develop in a glass or lath-houses for 8-12 months with the provision of environmental condition and proper care,
- The relative humidity (RH) need to be maintained from 65-75%.

- The seedling should be able to produce sufficient number of branch that are suitable for cutting production.

Procedure for seedling production from mini-cuttings collected from stock plants

- Collect leaf branch cutting early in the morning 6:00- 7:00 AM, using clear polyethylene bags; spray water into cuttings to avoid water loss;
- Take to laboratory for further trimming to length ranging from 7 to 10 cm
- Subdivide the branches in to cutting that range from ca 7-10 cm long and diameter of ca 2-3mm.
- As cutting preparation progresses, spray the cuttings with water now and then.
- Hold a bunch of 5-7 cutting upside down b/n the fore and the middle fingers, and treat each cutting with just a drop of 0.2-0.4% IBA using a micropipette
- Immediately after applying the hormone ventilate the treated parts of the cutting manually or expose them for ca 60s to a cold stream of air generated by a pump
- Cutting were packed in clean polyethylene bags and were taken to the propagators to be inserted in to the prepared rooting medium (sand) inserted in depth of ca 2-3cm
- Maintain the RH of the propagator to within 75-80% by intermittent tap water sprays and optimal temp (ca 25-30 OC) is critical for the initiation of root peimorida
- It takes 22 weeks, depend on the stock plant age
- The assessment on the survival, callused and rooted cutting need to be made 4 week after inserting cuttings in to the growing media and then every week during the subsequent periods

Established and performances of rooted cutting

Rooted cutting need to be transplanted to plastic pots containing a mixture of local soil, livestock dung and sand in ratio of 2:1:1, respectively.

These need to be maintained in the glass house by watering them once a day till reach plantable size

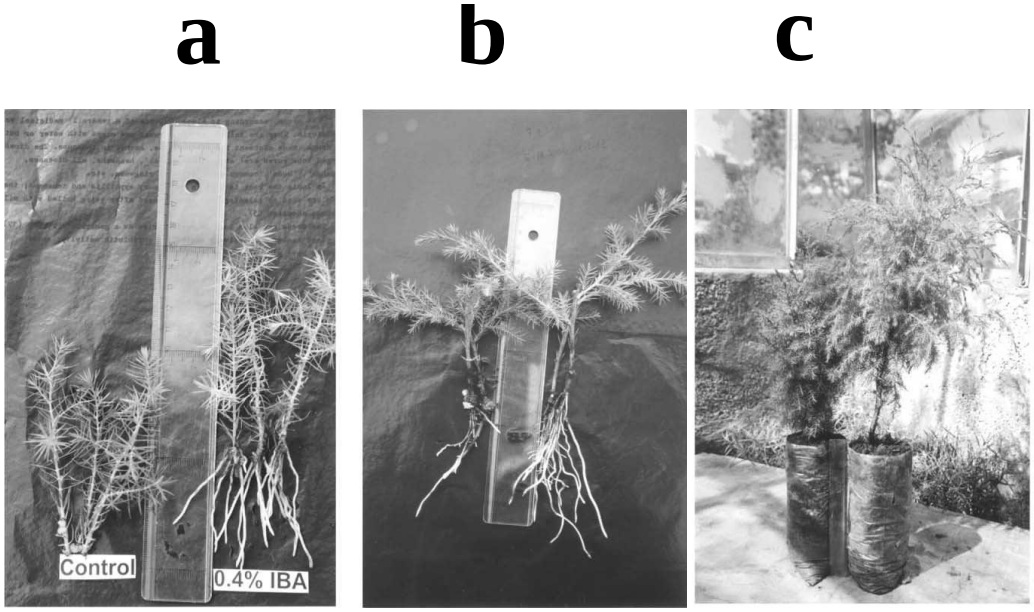

Figure 21. J. procera cuttings in their 8 weeks (a) and 16 weeks of age (b) after planting in the propagator; planting stocks taken from 5 and 15 month old stock plant, respectively. (c) 12 month old stecklings of J. procera obtained from clonal propagation (Legesse Negash, 2002).

Propagation of bamboo using offset (rhizome-based) methods

Propagating bamboo using rhizome-based techniques considers the following main pints:

- The detached rhizome-based propagule carries the required plant parts such as rhizome with all its appendages, portion of the culm and in some cases some branches (except when the planting material is only rhizome) needed for the growth of a new plant.
- A portion of the rhizome-culm system, but including the rhizome, need to be severed or separated from the parent clump (Figure 13), and nurtured to develop into an independent plant.
- The propagule should be separated with care, using sharp and clean cutting instruments to ensure that the rhizome system, on which the plant is dependent for its growth and health, is not damaged.

The methods included under this method are (1) offset, (2) stump or rhizome offset, (3) rhizome and (4) the whole culm technique that takes part of the rhizome mainly for moisture maintenance ***(Figure).***

Propagation of Bamboo using cuttings (culm and branch)

- Propagation using cuttings of bamboo utilizes culm cuttings of one node or two nopde and branch cuttings of five nodes (Figure).

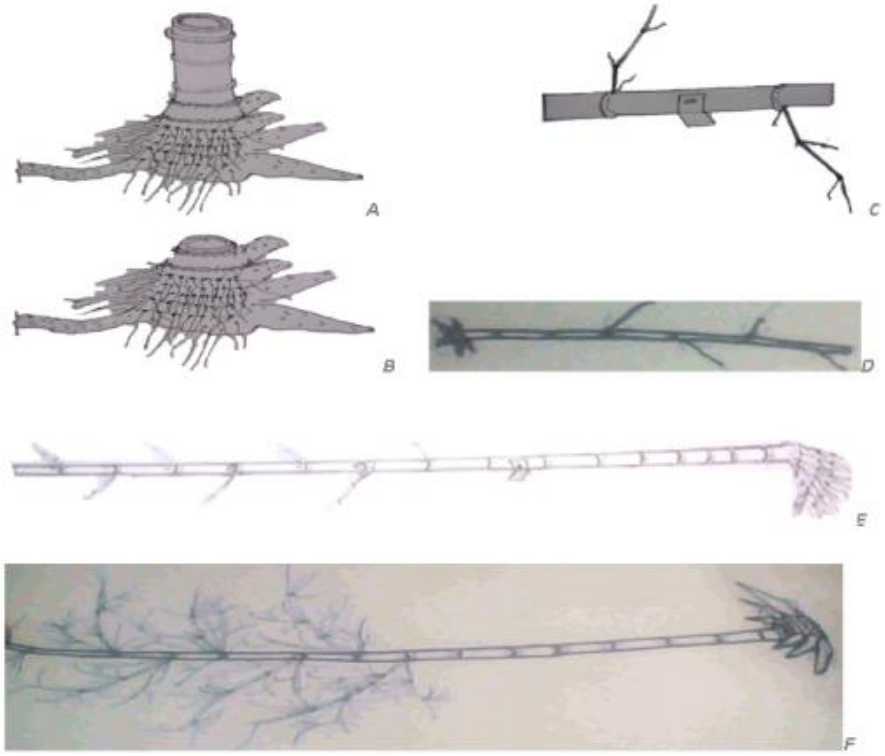

Figure 22. The different types of vegetative propagation techniques; A (stump or rhizome-offset), B (rhizome), E (whole culm) and F (offset-traditional method in Ethiopia, will be planted by erecting the propagule but with slight inclination) are rhizome-base techniques. C (culm cutting) and D (Branch cuttings) are cuttages that are not found promissing propagation techiques for highland bamboo so far.

Offsets propagation step by step

The method of offsetting involves separating the rhizome-culm system or the propagule from mother clump and shortening it to the node above the first branches. Since the branches of highland bamboo typically appear at upper nodes of the culm, the offsets will be very long and heavy, and not practical for transporting to another location. Some preparatory work is therefore advisable before proceeding with actual offsetting.

- 6 to 12 months before obtaining offsets, make a selection of 1 to 2 years old culms that will be used. Culms of this age can be identified by their green color and their culm sheaths have fallen off.
- The culms should be selected from a healthy and vigorous bamboo clump in the forest or homestead farm.
- Cut down or coppice the culms just above the 4th or 5th node from the ground.
- Remove all foliage and small branches and use them to mulch the clump. This returns nutrients to the soil and is a practical means of clump management.
- The coppiced culms will generate branches in the lower nodes. These shortened culms can be effectively offsetted after they have developed some branches and foliage which enable photosynthesis and growth obtained from bamboo stands as outlined below:
- If the above mentioned preparatory activities are carried out, the selected coppiced culms which have developed some branches and foliage at the lower nodes can be used as offsets.
- Dig out about 60 cm below the ground for a rhizome of a one to two years old culm.
- Once a rhizome is exposed cut back the aerial culm just above the first branches with leaves but not less than 3rd node above the ground level.
- Cut the rhizome off from the parent clump. Avoid injuring the junction of the culm and rhizome, and the underground dormant buds at the base of the culm.
- Cut the roots and soil at least 10 cm away from the rhizome so that the offset includes rhizomes with roots and soil.
- Replant the offset immediately and flood it with water, and mulch it.
- If planted directly on the ground, make sure that the planting hole insufficiently deep and large to facilitate the easy development of new shoots.
- If planted in a container, make sure that the container is sufficiently large and deep to allow the plant to grow as it would on the ground. Make sure that the container has holes so that there is good drainage.
- Water the plant frequently so that the soil is always moist.

Propagation of bamboo using culm cuttings (Step by Step pictorial procedure)

Figure 23. Select a 1 to 2 year old culms with healthy buds (a)

Figure 24. Cut the Culm down above the first node from the ground and remove its top part (b)

Figure 25. Prune all branches under the first node (c)

Figure 26. Cut the Culm into segments that include one or two nodes with healthy buds. More nodes increases success rates, but make handling more difficult. Keep at least 5 cm on either side of the node (d)

Figure 27. Wrap the segments in organic material and wet it for transport to the planting site (e).

Figure 28. Water the propagation bed (f).

Figure 29. Dig planting holes 3 to 6 centimeters deep and 30 centimeters apart. In one-node segments lay the branch and bud upward. Lay two-node segments with their branches sideward (g).

Figure 30. Bury the segments in horizontal position with branches sticking out and cover with soil (h).

Figure 31. Cover the soil with a layer of mulch and keep it wet. Also shading can be provided with bamboo sticks and leaves (i)

Figure 32. Provide appropriate shading and water it twice a day (j)

Figure 33. Transplant it in to the pot for further growth or directly plant the seedling on prepared land (k.)

Table 2. Propagation methods for indigenous and selected introduced bamboo species in Ethiopia

Name of species	Culm cutting	Offset	Branch cutting	Stump (Rhizome– offset)	Rhizome cuttings	Whole culm	Seed	Macro proliferation
Dendrocalamus hamiltonii	√	√	√	√		√	√	√
Dendrocalamus asper	√	√						√
Dendrocalamus giganteus	√	√	√	√	√	√		√
Bambusa vulgars	√	√		-	-	-		√
Other introduced sp.	√	√	-	-	-	-	√	√
Oxytenathera. abyssinica	-	√	-	-	-	√	√	√
A. alpina	NG	√	-	√	NG	√		√

Note: "√ "indicates that the species propagates using the selected method of propagation.

3.2.3. Tending the planted cuttings (propagules)

Planted cuttings are sensitive to environmental stresses and fluctuations. Thus, controlling their growing environment such as protecting from water deficit, excessive heat and wind should be done with due attention and regularly.

3.2.4. Grading of seedlings for planting

See seed section 3.1.8, same information can be used

3.2.5. Dispatching and transporting seedlings

See seed section 3.1.9, same information can be used

3.3. Micro-propagation

Propagating trees using micro-propagation technique initially requires high investment, in terms of equipment and training. Therefore micropropagation is usually only used for high value tree crops, which are deemed to be of commercial importance.

Micropropagation covers a wide range of methods and techniques to vegetatively propagate relatively small parts of plant material in extremely controlled environments. In this method, all forms of tissue culture and micropropagation are combined. The characteristic of these techniques is that plants are developed from single cells or tissue, which are grown in aseptic culture media. Micropropagation allows a very high multiplication rate; from a single plant thousands of new 'daughter' plants can be produced. Tissue culture offers enormous potential in producing large quantities of genetically uniform proliferates of the desired material in a short time frame. Very small pieces of a tree are washed free of all bacteria or fungi, grown on a special nutrient medium in sterile culture, and encouraged to produce many plantlets. These are then potted, grown on, weaned and hardened. However, it is essential that enough care is taken in selection of the initial material, production of the plants, nursery development and field plantation

Even though this is not a common vegetative propagation technique, it is important to be familiar with the overall concepts and principles, as to understand why this method can be considered in the broader context of plant propagation and tree domestication.

3.3.1. Selection of plant material to be propagated

Newly growing shoots have meristematic regions that, under favorable environmental conditions, can grow in to plantlets. The age of the cultivar determines its potential and relative regenerative capacity. Secondly, the ability to recover regenerative capacity can be improved by manipulation of the parent plant, for instance by harvesting old parts and using propagules from new coppices.

3.3.2. Collection and preparation of ex-plants

Taking the 'micro-cuttings

Small pieces of tissue are taken from the selected tree with a sharp blade, and thoroughly washed in a disinfectant such as hydrogen peroxide (H_2O_2) or a solution of hypochlorite. Success has usually been achieved with strongly juvenile material, such as parts of newly germinated seedlings, but small, active buds and even flowering parts have also been used.

Setting the 'micro-cuttings'**:** Using the sterile-air bench and sterilised tools, a tube is opened and a single piece of tree tissue planted on the middle of the slope. A little sterile water is added, the tube closed again and placed under the lights.

3.3.3. Preparation of growth media

The capacity for propagation by in vitro culture is limited by the establishment and maintenance of the tissue in an appropriate condition to induce the rapid division and subsequent differentiation of cells. The ex-plant must be kept in sterile conditions, and provided with (a) macro- and micronutrients, (b) a source of energy, usually sucrose, (c) vitamins, amino-acids, etc, and (d) the correct balance and sequence of plant growth regulators, co-factors, etc, to regulate the subcellular and cellular processes of cell division and differentiation of shoot, root, or embryo. Success will also depend on the osmotic pressure and pH of the medium, which can be a solid or liquid, and the physical environment.

*Preparing the media**:***

There are several different media which have given good results, and the basic chemicals can be obtained ready mixed. Distilled water and agar are added, together with specific quantities of the plant growth regulators (hormones) that determine whether shoots or roots are formed. (Note: Cytokinins tend to stimulate shoots, while auxins promote roots; but both are often needed). After autoclaving - to kill spores of micro-organisms - the medium is poured into sterile tubes on the sterile-air bench, closed with cotton-wool, and allowed to set at an angle, producing a sloping surface. [Note: some heat-sensitive hormones must be added after heating, using a sterile syringe].

3.3.4. Multiplication and transplanting

*Shoot multiplication**.***

The aim of the first stage is to encourage the culture to form many small shoots (Figure 14). This may take a few weeks, or longer.

Figure 34. Small shoots under multiplication using tissue culture

Sub-culturing

Once the shoots on the 'micro-stockplant' can be handled, they should be transferred to a fresh tube containing a medium that will promote rooting. The ability of plant tissues to form adventitious roots depends on the interaction of many different endogenous and exogenous factors. Skoog and Miller (1957) reported that the shoot/root formation is generally dependent on the cytokinin/auxin ratio in the nutrient medium. Jones (1978) demonstrated that the cytokinin inhibit rooting and also prevent the root growth. Therefore, it is better to culture the shoots on a PGR free medium before they are transferred to a rooting medium. If shoot multiplication is slow, the whole culture will need transferring to a new tube each month.

*Rooting***.** In the second stage, each shoot forms a root system.

Transfer of plantlets to soil.

The new plantlets need to be placed carefully into a sterilised potting soil in small pots, covered with a polythene bag and allowed to grow larger under the same conditions as the cultures. *(Note: At this stage they are still very delicate, and need 'intensive care)*

Weaning

The established plantlets need to be *gradually* accustomed to less humid conditions and somewhat brighter lighting (A 54). It is easy to lose them if this stage is done too rapidly,

particularly when they are taken to a shaded nursery bed. However, if weaning is too slow the shoot may become drawn and weak.

Re-potting

During the nursery part of weaning, transfer the plants carefully to larger pots, using un-sterilised soil. The inoculum for mycorrhizas or nodules can be added to the potting mixture.

Hardening

For light-demanding species, the shading can be gradually reduced after the plants have been fully weaned.

3.3.5. Grading of seedlings for planting

See seed section 3.1.8, same information can be used

3.3.6. Dispatching and transporting seedlings

See seed section 3.1.9, same information can be used

CHAPTER 4: NURSERY RECORDS

Nursery record is a valuable document compiled for the purpose of providing particular information for the nursery workers as a whole. The details may vary based on size of the nursery, but whether the nursery is small or large, good records are necessary for task allocation and for monitoring the efficiency of the day to day work. The long-term records provide for reviewing the success of the nursery.

The efficiency of a forest nursery may be evaluated by its productivity and costs of production. The nursery is required to produce healthy, vigorous seedlings on time and at reasonable cost. These can be achieved through proper planning and using the past records of nursery operations.

4.1. Nursery calendar

A nursery calendar is a useful tool in scheduling of nursery activities such as sowing dates (Table 3). In addition, some nurseries prepare a second type of calendar to show activities, on a monthly basis (Table 4), including dates for bed construction, preparation of potting soil, start of compost production, sowing, weeding, repairs to nursery and the timing of annual staff leave.

Table 3. Example of nursery register used to determine best date for sowing different species

Events	**Species**		
	Eucalyptus globules	*Pinus patula*	*Juniperus procera*
Days needed from transplanting to planting out			
Days needed from germination to transplanting			
Days needed from sowing to germination			
Total days needed			
Sowing date	Determined by counting back from anticipated date of planting in the field		

Table 4. Example of Nursery Calendar Activities on monthly basis

Activities	**Time of the year**											
Site Selection	**July**	**August**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**
Site preparation and fencing												
Compost preparation												
Design and Layout of nursery site												
Seed pretreatment												
Preparation of nursery soil												
Pot filling												
Seed sowing												
Preparation of Shade												
Preparation of Transplanting bed												
Transplanting Seedlings												
Tending Seedlings												
Hardening Off												
Grading of seedlings for planting												
	Peak period applicable for most species											
	Period for sporadic events											

Source: Tree seed, nursery and planting calendar/unpublished

4.2. Seed and seedling register

The register of seed and seedlings encompass the entire period from seed arrival in the nursery store until the seedlings are dispatched to the planting site. For each seed lots, identity number should be given on arrival in conjunction with the species name. It is recommended to use serially consecutive numbers on the bases of arrival year (e.g., No. date/year). In addition to the identity number and species name, it is customary to register the date of sowing and transplanting. Further details can be also included on additional lines showing, for example, the type of fertiliser and fungicide used and the dates of application.

It is important to monitor the species and number of seedlings in different stages of survival, development and distribution. Careful and up-to-date production record helps to assess whether the nursery is operating as planned or not.

Table 5. Example of a Seed and seedling register

Nursery:					
Officer I/C:					
Position:					
Seed and Seedling Record					
Data	Eucalyptus grandis	Pinus patula	Juniperus procera	Acacia saligna	Remarks
Identification number (Month/year)	2/2016				
Date sown (Date/Month/Year)	20//1/2016				
Quantity sown (kg)	0.2kg				

Method of sowing (Broadcast/Direct)	Broadcast				
Date of first germination (Date/Month/Year)	2/2/2016				
Date of last germination (Date/Month/Year)	10/2//2016				
Number germinated (%)	80				
Date transplanted (Date/Month/Year)	10-16/5/2016				
Number transplanted	4,000				
% dead after 2 months	8				
Culls/rejects	160				
Number distributed	1,800				

4.3. Nursery Production Record

This record is important to keep track of the species and number of seedlings in different stages of survival, development and distribution. A well-kept and up-to-date production record helps to assess whether the nursery is operated as planned or not. If seedlings are under or over produced so that remedial action can be taken promptly. It should therefore be prepared in a tabular form, suitable for collection and analysis.

Table 6. An example of production record.

Species	No. of plants for potting	No. of weeks before ready to plant out

	Not ready	Ready	16	14	12	10	8	6	4	Not ready	Ready		

4.4. Nursery labels

In each bed it is useful to make labels for each potted or bare root seedlings. In local nurseries, it is commonly practiced by painting detailed information on small rectangular metal which is fixed with a piece of wood.

Table 7. Example of tree seeds and their characteristics in Ethiopian conditions

Name of species	**Agroecology**	**Number of seeds/kg in 1000**	**Seed pre-treatment**	**Method of raising**	**Germin-ation percentage**	**Germi-nating power in days**	**Seedling nursery life in months**
Acacia Abyssinica	1500-2800 asl, Dega and Woinadega	10-12	Immersing in hot water and cooling them for 24 hrs.	Plastic pots	25-60	7-21	8
Acacia albida	ħ1500-2600 asl, Woinadega	10-13	Immersing in Sulpheric acid for 30min and rinse by water or immersing them with hot water and cooling them for 48 hrs	Plastic pot	40-90	7-21	8-9
Acacia Seyal		16-17	Immersing in Sulpheric acid for 30min and rinse by water or Immersing in hot water and	“	40-70	14-21	8-9

			cooling them for 24 hrs				
Acacia Cynophila		50-75	Immersing in hot water and cooling them for 24 hrs	"	20-60	14-21	4-5
Acacia decurrens	ћ1000-2500 asl, Dega and Woinadega	50-80	Immersing in hot water and cooling then for 24 hrs	Pot	80-95	14-21	8-9
Acacia gumifera		7-10	Immersing in hot water and cooling them for 24 hrs	"	70-80	14-18	7-8
Acacia melanoxlin	ћ700-2500 asl, wet kola and all Dega and Woinadega	30-40	Immersing in hot water and cooling them for 24hrs	Pot and seed bed	40-70	7-14	9-10
Acacia nilotica	ћ600-1700 asl, all kola and Dega and Woinadega	5-6	Immersing in Sulpheric acid for 1 hr and rinse by water and Immersing in hot water and cooling them for 24 hrs	"	40-70	7-14	7-8
Acacia senegal	ћ500-1700 asl, all kola and Woinadega	8-10	-	Pot	80-90	7-14	8-9
Acacia tortilis	ћ300-1900 asl, all kola areas	8-9	Immersing in Sulpheric acid for 45 min and rinse by water	Pot	60-90	7-14	8-9
Albizia lebek	ћ500-1500 asl, all kola areas	8-10	Immersing in Sulpheric acid for 30min and rinse by water or Immersing in hot water and cooling them for 24 hrs	Pot	60-90	14-18	7-8
Albizia		7-10	Immersing in hot water and	pot	70-80	14-18	7-8

gumifera			cooling them for 24 hrs				
Aningeria adolfifrederic		0.8-0.9	Sow immediately after collection	Pot	30-50	4-5	8-9
Azadirecta indica	ħ400-1500 asl, all kola and wet Woinadega	6-7	-	"	30-50	10-12	11-14
Casuarina equistifolia	ħ0-2200 asl kola and Woinadega	1000-1500	-	Pot	50-70	15-21	7-8
Celtis Africana		450-600	-	Seed bed and pot	50-60		
Cordia Africana	ħ900-2500 asl, Dega and Woinadega	2.5-4.5	-	Pot	40-60	20-45	5-7
Croton macrostachus		20-25	-	pot	40-50	18-25	6-8
Cupressus arizonica		60-100	Cooling in 3-5^{o}c temperature for 21 days	pot	20-40	17-21	7-8
Cupressus lusitanica	ħ1500-3200 asl, Dega and Woinadega areas	170-350	Cooling in 3-5^{o}c temperature for 21 days	Pot and seed bed	30-50	21	7-8
Cupressus torolosa		200-225	Cooling in 3-5^{o}c temperature for 21 days	pot	40-50	14-28	12-24
Delonix regia	ħ200-1600 asl, all kola and wet Woinadega	2-3	Immersing in Sulpheric acid for 1 hr and rinse by water or Immersing in hot water and cooling them for 24 hrs	Pot	70-95	7-14	5-6

	areas						
Doviyalis abysinica	ћ1700-3000 asl, Dega and Woinadega areas	24-40	-	Pot	75-95	7-21	7-8
Ekebergia capensis	ћ1600-3000 asl, Dega and Woinadega areas	2.5-3.5	-	Pot	50-75	20-35	9-10
Eucalyptus camaldulensis	ћ1200-2800 asl, all kola and Dega and Woinadega	1000-2000	-	Pot and seed bed	75-100	7-14	4-5
Eucalyptus citrodora	ћ1800-2000 asl, wet Woinadega	150-200	-	Pot	80-95	7-14	4-5
Eucalyptus ficifolia		60-70	-	Pot	80-90	7-14	7-8
Eucalyptus globules	ћ1700-2800 asl, Dega and wet Woinadega	300-400	-	Pot	80-100	7-14	4
Eucalyptus grandis	ћ1700-2800 asl, Dega and wet Woinadega	2300-3000	-	Pot or seed bed	85-100	7-14	4-5
Eucalyptus		150-200	-	Pot or	90-100	7-14	4-6

maculate				seed bed			
Eucalyptus robusta		2500-3000	-	Pot or seed bed	70-90	7-14	4-5
Eucalyptus saligna	ћ1700-2300 asl, Dega and wet Woinadega	2000-3000	-	Pot and bare root	80-100	7-14	4-5
Eucalyptus viminalis	ћ2000-3400 asl, Dega and wet Woinadega	800-900	-	Pot or seed bed	80-90	7-14	4-6
Grevillia robusta	ћ1500-2700 asl, Dega and wet Woinadega	80-110	Immersing in cold water for 48hrs	Pot or seed bed	60-80	10-21	8-12
Hagenia abyssinica	ћ2300-3300 asl, Dega and wet Woinadega	350-500	-	Pot	20-30	14-21	7-8
Jacaranda mimosifolia	ћ1200-2400 asl, Dega and Woinadega	60-90	-	“	80-100	14-21	7-8
Junipuress procera	ћ1500-3300 asl, Dega and wet Woinadega	450-550	-	“	20-30	50-60	12-16
Leucenia leucocephala	ћ0-1600 asl, kola and Woinadega	17-25	Immerse in 80% boiled water for 2min and cool for12hrs	“	40-80	10-21	4-5
Melia	ћ0-2400 asl,	1.4-2.5	Immerse in cold water for a few	“	65-80	60	7-8

azadirachta	kola and Woinadega		days				
Millettia ferruginea	ħ1000-2500 asl dega and Woinadega	1-2.5	-	Pot or seed bed	50-60	7-10	6-7
Mimusops kummel		2.3-3	-	Pot	20-30	50-60	
Olea africana	ħ1400-3300 asl, Dega and wet Woinadega	6.5-7	-	Pot	20-50	60	12
Parkinsonia aculeata	ħ300-1700 asl, all kola and Woinadega	10-12	Immerse in hot water and cool for 24hrs	Pot	70-80	21	4-5
Pegium Africana		3.5-4.3	-	“	Very low	50-60	
Pinus patula	ħ1900-3000 asl, Dega and wet Woinadega	130-200	-	Pot or seed bed	50-70	15-21	12
Podocarpus gracilier	ħ1500-2500 asl, Dega and Woinadega	1.5-2.5	-	Pot	10	60	12-14
Prosopis juliflora		30-40	Immerse in hot water and cool for 24hrs	Pot	40-60	21	3-4
Shinus mole	ħ0-2400 asl, all kola and Woinadega	25-65	-	“	57-90	18-21	7-8

Sesbania aculeate	ħ300-2000 asl, all kola and wet Woinadega	100-150	-	“	20-25	15-21	
Spatodia nilotica	all kola and Woinadega	150-200	-	“	60-90	21	

References

Ashenafi Gebrelibanos, 2012. Protocol optimization for in vitro propagation of the EthiopianLowland bamboo (Oxytenanthera abyssinica (a. Rich) through nodal culture, M.Sc. Thesis. Jimma University

Duryea, Mary L., and Thomas D. Landis (eds.). 1984. Forest Nursery Manual: Production of Bareroot Seedlings. Martinus Nilhoff/Dr W. junk Publishers, The Hague/ Boston/ Lancaster, for Forest Research Laboratory, Oregon State University, Corvallis. 386 p.

Environment and Forest Research Institute (EEFRI). Addis Ababa, Ethiopia.

Forest Research Center. (1987). Tree nursery manual: ministry of natural resources development and environmental protection. Ethiopia, Addis Ababa.

Growing native trees from seed: A Practical Guide to Tree Nursery Production. Retrieved from http://www.nativetrees.org.uk/downloads/growing_native_trees_from_seed_tree_nursery_production_guide.pdf.

Keats C. Hall (2003). MANUAL ON NURSERY PRACTICES. Forestry Department Ministry of Agriculture 173 Constant Spring Road Kingston 8 Jamaica (West Indies).

Legesse Negash, 2002. Successful vegetative propagation techniques for the threatened African pencil cedar (Juniperus procera Hoechst. Ex Endl.). Forest Ecology and Management 161: 53-61.

Munjuga MR, Gachuiri AN, Ofori DA, Mpanda MM, Muriuki JK, Jamnadass RH, Mowo JG. 2013. Nursery management, tree propagation and marketing: A training manual for smallholder farmers and nursery operators. Nairobi: World Agroforestry Centre.

Roshetko, J.M., E.L. Tolentino, Jr., W.M.Carandang, M. Bertomeu, A. Tabbada, G.E.S. Manurung, and C.E. Yao. 2010. Tree Nursery Sourcebook - Options in Support of Sustainable Development. World Agroforestry Center-ICRAF and Winrock International. Bogor, Indonesia. 52 p.

Skoog, F. and Miller, C.O. (1957) Chemical Regulation of Growth and Organ Formation in Plant Tissue Cultured in Vitro. Symposia of the Society for Experimental Biology, 11, 118-131.

Species in Ethiopia Based on Practical Experience and Research, 77 pp. Ethiopian

Teotônio Francisco de Assis, Arthur G. Fett-Neto, and Acelino Couto Alfenas, 2004. Current techniques and prospects for the clonal propagation of hardwoods with emphasis on Eucalyptus. Plantation Forest Biotechnology for the 21st Century, 303-333.

Yigardu Mulatu and Asabeneh Alemayehu (2016). Manual on Propagation of Bamboo

የዋና ዋና ዛፍ ዝርያዎች ምቹ ሥነ-ምህዳር፣ የዘር ባህሪያትና ጥቅሞች. የዛፍ ዘር ቴክኖሎጂ ማስተባበሪያ. ህዳር 2009፤ አዲስ አበባ ፤ ኢትዮጵያ