**Chapter****3. Forest nursery establishment and management**

**3.1. Definition**

A tree nursery is a place where plants are grown with special care and protection to the point where the young material is able to establish and flourish under field condition.

* It provides seedlings both for planting program and commercial purpose.

Tree nursery is established:

* Inapplicability of direct sowing of seeds for all of tree species.
* The need of seedlings in large no. to replace the rapid loss of forests
* Enable foresters to produce healthy and vigorous plants.

**3.2. Types of nursery**

Nursery can be categorized base on:

* Time duration the nursery is supposed to serve (Permanent, Extension and Temporary),
* Scale of production (Small scale and large scale),

**1. Permanent nurseries**

Permanent nurseries are usually large centrally located nurseries that are established:

* Where there is a demand for large number of seedlings for long period of time (>5yrs)
* Annual production > 0.5 million
* Usually have permanent workers
* Use sophisticated methods of raising seedling
* Require high establishment cost/capital
* Located far from plantation site in most cases

e.g. most government nurseries

**2. Temporary nurseries**

Temporary nurseries are small to medium in size, in which small numbers of plants are raised during a few years only (usually < 5yrs). It provides only a limited numbers of seedlings for local need and uses. It is the simplest methods of raising seedlings. e.g. many Ethiopian farmers’ nurseries. The disadvantage of this nursery is high cost/ plant

**3.3. Site selection for a forest nursery**

Choosing the best possible site based preliminary survey of potential areas precedes established on a new nursery. The selection of a site for a nursery should be done with considerable care and thought.

Major factors to be considered in nursery site selection are:

**3.3.1. Ecological factors**

a. Climate

* Include climatic factors (RF, temperature and wind)
* Climate condition should be similar to the majority of planting site
* Avoid areas with extremes of temperature, subjected to high wind velocity, hail or ice storms.
* Choose areas with longer growing season

b. Topography

* Avoid areas with large stones and stocks
* Choose almost level area (2 – 3% slope)
* Avoid exposed windy hill topes
* Avoid valley bottoms
* Avoid area where flooding occurs at any time of the year

c. Soil

* Use native soils for producing bare rooted seedlings
* The site should have appropriate soil texture, depth and soil pH
* Avoid clay soil with high shrink-well capacity
* Use fine sand or sandy loam for bare root seedlings
* Select site with soil pH value between 5-7 for broad leaved and 4-6 for conifer species

d. Water

* Is one of the best criteria for choosing nursery sites
* Select site where there is permanent water supply (quantity and quality)

**3.3.2. Economic factors**

a. Land availability

* It should be large enough to produce the number of trees required and allow for future expansion

b. Labor and material support

c. Accessibility and facilities

* It should be easily accessible to facilitate efficient transportation of inputs and plants

**3.3.3. Social factors**

Consider growth of population, wealth, mode of life of the people as they influenced the acceptance of establishing nursery and their products.

**3.3.4. Biological factors**

Select site free of serious insects, disease, weed, pests, as these can affect the growing seedling in the nursery**.**

If condition allow for establishing nursery, it is necessary to set objectives:

* The required production output per year
* Permanent or temporary
* Bare rooted or potted seedling
* Mechanical or manual production



Figure1. Diagram depicting viable and non-viable locations for nursery site

**3.4. Layout and design of forest nurseries**

**3.4.1. Components of nursery area**

A nursery should have:

* Administrative area
* Building area including tools and equipments store, seed processing store, seed drying, seed store, guesthouse, shading and shelter for plants
* Production area (seedbed, transplanting bed and reserve beds)
* Access road and inspection paths
* Windbreaks, fence and hedge
* Compost site
* Irrigation system

**3.4.2. Size and shape of nursery**

The shape should be as compact as possible. Approximately square shape is recommended; if not a square shape rectangular shape is convenient. The size of nursery area depends on:

* Level of annual production (related to area to be planted annually) e.g. a common nursery size has an annual plant production of 0.5- 2 million seedling
* Method of rising seedlings. Containerized seedlings occupy more bed space than bare-rooted seedlings. Hence increase the size of nursery
* Areas required for different buildings, roads, paths, and irrigation system
* Nursery life of plants. Seedlings demanding long period of time to attain the suitable size need more space and hence increase the size of nursery

**Nursery area calculation**

To calculate the most appropriate nursery size, we need to know the

1. Required productive area (pot beds, seed beds, and reserved beds)
2. Non-productive areas (areas needed for road, paths, buildings, fences, windbreaks etc.) and is mostly twice that of productive area
3. Areas for possible future extension (may account 20-25% of the total nursery area)

Example: a forest project planned to raise 400,000 seedlings annually including replacement of last year’s failures. A polyethylene tube having 10cm lay flat will be employed to raise the seedling. Expected nursery failure is 10%. Thus, calculate the total nursery area?

Procedure for calculating the total area

Step1: calculate the productive area

1. Seedling production

Annual seedling production = 400,000

Expected nursery failure (10%) 400,000\* 0.1 = 40,000

(Replanted included) \_\_\_\_\_\_\_\_\_\_

Total seedling production = 440,000

2. Calculate area needed for transplant/pot beds

Depending on the size of polyethylene tube size 10cm lay flat we can calculate the diameter of the pot, use the following formula

C= $π$\*D → D= C/$ π$ where: D= diameter of polythene tube, C= circumference of polythene tube and$ π$ = 3.14

C of 10cm lay flat polythene tube is double of 10 diameter

. Accordingly the corresponding D will be 20/3.14= 6.4cm

 6.4cm= 1pot

 100cm= ?

15 pots can be stacked in a straight line on one meter. Therefore, the total number of seedlings/m2 is 15\*15= 225 potted seedlings/ m2

To calculate the total area for pot/ transplant beds

1 m2 = 225

X = 440,000

**= 1955 m2**

3. Calculate seed bed area, which are usually 20% of the transplant beds

1955 m2\* 0.2= **391 m2**

4. Reserved beds area, which is 20% of transplant beds and seed bed

1955 m2 + 391m2= 2346 m2

2346 m2\*0.2= **469m2**

* **Total productive area becomes= 1955** **m2+ 391m2+ 469m2= 2815** m2

Step2. Calculate the non-productive area

As it can be seen practically more non-productive area (area for access road, paths between beds, tool store seed processing room, soil dump, compost, fences and windbreaks, buildings and others) are needed and should be calculated.

*As a rule of thumb*, the non-productive area will be *twice the production area* i.e. seed/pot beds area. Therefore, the non-productive area of the above will be= 2815 m2\* 2= **5630 m2**

Total nursery area = productive + non- productive

= **2815** m2+**5630 m2= 8445m2**

If 20% reserve for future expansion is needed the total nursery area become

 (**8445 m2\*0.2) + 8445 m2= 10,134m2 i.e. 1.0134ha**



Figure1: Examples of effective nursery layouts

**3.5. Nursery fence, hedge and windbreak**

Nursery fence or hedge is needed to demarcate the area and protect them against animal and to some extent winds.

**3.5.1. Common fence type**

Fencing may be done in three ways

* Barbed or pain galvanized wire (or partly of each)
* Wire mesh (chicken net fence)
* Electric fencing

All fencing type requires- fencing post should be sound, straight, suited size to the purpose and properly treated against insect attack.

**3.5.2. Hedges**

A hedge is a one or two rows of seedlings that are planted in a straight line. It can serve as shelterbelt in protecting seedling against strong winds. It is considered as live fences.

Disadvantages:

* It may take 2-3 years to grow it to full size
* Needs continuous and regular tending (hoeing, weeding, watering…)
* Needs clipping at least twice a year

Advantage: cheap to establish, has long life, gives more protection against animals and wind.

**3.5.3. Characteristics of a good hedge species**

Growing fast, able to grow in a very restricted space, withstand repeated clipping, ever green looking and long lived.

E.g. *Cupressus lussitanica, Casuarina, Dodonea, Viscosa*, etc

**3.5.4. Wind break**

Wind break are three or four rows of suitable that are planted on wind wide sides of production areas and germination beds or around the nursery. It helps to reduce drying eroding and abusive effects of winds on growing seedling. Sometimes they protect from animals. *Avoid selecting* those species *whose root systems compete with bare-root seedlings for water and nutrients*.

**3.6. Seedling production techniques**

Seedling production involves all techniques dealing from preparation of beds for seedling to sowing, watering to adequate size and transpiration of seedlings for planting.

**3.6.1. Bed preparation**

*Seedbeds*: are elongated strip of prepared soil in which seeds are sown and seedling are raised.

*Transplant beds*: are elongated strip of prepared soil or leveled ground in which seedlings are moved from one bed (seed bed) to another to promote additional growth.

Seedbed should be 1 m wide to reach the center of the bed from either side of the bed.

They can be any length, but usually not longer than 20 m. soil used in seedbeds should be coarse in texture for good root penetration of the germination seed and easy lifting. The seedbed should be prepared about one month before sowing to allow the soil settles naturally over that period and weed germinate and weed out. The surface just leveled again just before sowing.

Two types of bed can be constructed for transplanting bare-rooted seedlings:

* Traditional bed: is prepared like a bed for vegetable using the soil in the nursery.
* Swaziland bed: is an improved way of producing seedlings in beds. The bed is filled with transplant soil mixture to the level of reverting boards and then firmed and leveled.

**3.6.2. Potting soil mixtures**

For the production of bare root seedlings native (available) soil is used while for seedlings raised in pots, soil ingredients used for filling of pots are brought from outside the nursery. The proportion (ratio) of soil used for filling of pots varies from place to place, the species to be raised and availability of different soil ingredients. The qualities, which make up good nursery soil, are:

* Good drainage
* Satisfactory content of essential nutrients
* Good organic matter contents to retain moisture
* Sufficient adhesion to form a soil cylinder
* Correct acidity

A mixture will containing local soil (forest soil), sand, and compost in the ratio of 1:2:2 for clay soil, 1:1:1 for clay loam soil and 1:0:1 for sandy soils is recommended for the healthy growth of the majority of species. The potting-mix components should all be sieved before being mixed together so that no large clods, stones, or roots are present in the final mix. A mesh size of about 1 cm is usually adequate, but a 5- mm mesh is preferable.

**3.6.3. Type of seedlings**

There are two types of seedlings depending on the media of growth for seedlings.

1. **Bare-rooted seedlings**

Bare-rooted seedlings are seedlings directly sown on the nursery beds without the need for the container such as polythene tubes. They are easy and cheap to rise in the nurseries. The main advantage of bare-rooted seedlings is that they are easy to transport and handle in the field as they are not accompanied by a heavy ball of soil. Bare-rooted seedlings can be stored in the field for very short period of time, because their root surfaces are not bound to soil with moisture to protect seedlings from desiccation (drying). The disadvantage of bare rooted seedlings in their unreliability.

1. **Potted seedlings**

Potted seedlings are seedling grown in containers such as polythene (plastic) tube. They are more expensive to raise in the nursery as potting material of right amount and size tube type has to be bought from further distance. The main disadvantage of potted seedling is the weight and volume of the pots, which makes it very difficult to handle. Transportation of potted seedling to remote areas is one of the bottlenecks in tree planting programs. Potted seedlings can be stored for longer period of time in the field before planting without damage to seedlings, provided that seedling are watered.

The main advantage is reliably on all kinds of sites, especially on the difficult soils and in dry area. The size of the tube varies according to species and the size to which the seedlings should be grown in the nursery.

Seedling should not be grown to sizes larger than 45 cm in small pots, because the root may be badly constricted. Large 10 cm lay flat tubes are preferable for raising tall and strong plants of more tender species such as *olea* and *podocarpus (zigba*). Large pots are mainly best for indigenous hardwoods destined for planting in natural forests. The use of 10 cm lay flat tubes is also recommended for planting in dry areas.

**3.6.4. Sowing methods**

There are two main methods of propagating plants/ seedlings

1. Using tree seeds

2. Using vegetative parts

**Direct sowing into pots versus seed bed sowing**

Nowadays, there is a propensity towards more and more direct sowing into pots, to eliminate the labour consuming operation. However for, expensive seeds that are small in size, direct sowing is not advisable. *Seedbed sowing* should be done when:

* Seed is expensive or scares
* Germination percent or germination period is not known
* Seeds takes a long time to germinate

It is always better to sow the seeds of a new or little known species into the seedbed. Direct sowing onto pots can be done when:

* Germination percent is known to be fairly high
* Germination period is short
* Transplanting would cause damage or death to seedlings
* The species develops a long sensitive taproot
* There is a shortage skilled worker to do the transplanting.

**Time of sowing**

Sowing should be timed properly so that seedlings can attain the right size (short length) which is generally agreed as 25 to 40 cm at the time of planting. Recommended sowing dates are given to most important plantation species considering that planting is done in June.

**Density of sowing**

If seedlings are transplanted soon after germination when they are still small (e.g. eucalyptus, pines, and cypresses), it will be possible to get approximately 2000 seedlings from each square meter seedbed.Large seeds should be sown at a lower density of 800 to 1500/sq m. Too low density of sowing means that the seedbed is not fully utilized. This is not economically acceptable. Too dense sowing increases risk of fungus disease in the nursery. For optimal sowing density calculation, we need to know the Weight of the seed (number/kg), germination percent and purity percentage. These are needed to determine the number of viable seeds/kg.

*Example 1*

 *Pinus patula has 135,000 seeds/kg and a germination rate of 85%. How much should be sown to each square meter to obtain a density of 2000 seedlings/sq m?*

*Solution: each kg of seed produces(85/100)x135,000 seeds = 114,750 seedlings 114,750 = 1000 grams*

*2000 = x gramsx = 17.4 g*

*Cupressus lusitanica has 220,000 seeds/kg and germination rate of 15%. How much should be sown to each square meter to get 2000 seedlings*

*Solution: each kg produces 15/100x220,000 = 33,000 seedlings*

*2000 seedlings x 1000 = 60.6 grams*

*33000 seedlings/kg*

*Exercise casuarina equisetifolia has 700,000/kg and a germination of 50%. How much seed is needed to raise 2000 seedlings/sq.m?*

**3.7. Care and conditions of seedlings**

**3.7.1. Nursery bed shades**

Germination seeds need no light but only warmth and moisture. Of course, seedlings need protection from drought, cold wind, heavy rain and burning sunshine. Shade benefites in reducing soil temperature and minimizes evapo-transpiration rate and damage of seedlings and direct sunshine. For these reason, shade must be provided especially when the seedlings are young. After transplanting, taller seedlings need protection mainly against sun and heavy rains. Full and dense shade on the seedbeds gives best results with most species.

The need of shading/shading intensity differs according to Species, stage of seedling development, weather condition and location of the nursery. Full and dense shade on seedbeds gives best results with most species. Full shade for seedlings should be given during the most delicate growth stages, i.e. during and shortly after transplanting. When seedlings are resistant, reduce shading gradually to none, as light is essential for photosynthesis. For the last months in the nursery seedlings should be exposed to full sunlight.

**Orientation of shades**

In order to obtain the maximum effect of the shade, the beds should be oriented east to west. During the period from April to September, when the sun is in north of the equator, the shade should be sloping down to the north. During the rest of the year, which is the main nursery period with most species in Ethiopia, the shades should slope down towards the south. If the sun is very strong in the morning and later afternoon, one extra section of the shades can be erected vertically to protect the plants from against the rays of the sun. Sloping shades have an advantage over horizontal shades in case that sowing and transplanting take place during the time of the year when there are rain showers. Elephant grass mat, bamboo split shade, grass or broken leaves can be applied for making shads.

**3.7.2. Watering**

**Seedbeds**

It is important that a seedbed is kept constantly moist down to minimum of 5 to 6cm depth. Watering should be done frequently, at least twice a day, in small quantities. The amount and frequency of watering depends on the soil mixture in the bed, species, age of plant and weather condition. A very approximate recommendation for total amount of watering per day is equivalent 8 mm of rainfall. This means 8 liters of waters/sq. m of seedbed. Too heavy watering must be avoided. It causes pudding of soil and poor aeration, which creates favorable conditions for damping off fungi. Watering should be done early the morning (before 10am) and late in the afternoon (after 4pm) for efficient utilization of water sprayed on to them without being lost. If the seedbed is covered with mulch grass, the moisture of the soil surface should be frequently checked. Some of the water is absorbed and evaporated by the grass, which, on the other hand, slows down evaporation from the bed surface. Fire-hose watering cans must be used in watering of seedbeds without grass mulch. If fire-hose cans are not available, it is necessary grass mulch.

**3.7.3. Transplanting (prinking out)**

Any plant that is growing in seedbed is called seedling s. If a seedling is lifted from its bed and planted to another bed or pot in the nursery it is thereafter called “transplant”. It is a crucial stage in the life of the plant as it always causes a shock to the seedlings even when done carefully. Bad transplanting easily kills the seedling.

**Size of seedlings:** Conifers can be transplanted immediately after the seed coat appears above the soil surface at the “match stick’ stage. Broad-leaved seedlings should be transplanted soon after germination. Acacia and other legumes are transplanted when the first leaves appears after the complete unfolding of cotyledons.

**Preparation of transplanting:** for a couple of weeks before the intended transplanting day, the empty pots or bed should be watered lightly for some days. This encourages germination of weeds. As soon as the weeds have emerged they should be removed. The pots/beds should be moist but not too wet at the time of transplanting. Seedlings should be handled by the leaves but never by the stem or root, which are easily burned.

**Additional points:** transplanting must be done quickly and carefully under shade at all times. It should be done only during the cool hours of the morning (before 10:00 AM) and the evening (after 4:00 PM). The workers must be skilled. Women are often very skillful in this work.

**3.7.4. Root pruning**

Root pruning involves cutting of the taproot, in some cases also of lateral roots, to encourage the development of fibrous root systems. This kind of root system gives the seedling the best possible starts in plantation. Root pruning also controls depth of root penetration and makes lifting of seedlings easier and less harmful.

**Frequency of root pruning**

The frequency of root pruning depends on the growth rate of the seedling. Weekly punning is recommended with fast growing Eucalyptus.

**Care of seedling during root pruning**

Root pruning should be done on a dull cloudy day, or during the cool hours of the day. A clean cut with a sharp blade will fav or proper healing of the pruned roots. Seedlings should be watered immediately after pruning. The soil should be reasonably moist also before pruning.

**3.7.5. Control of Birds, Rodents and Pests**

**Birds and Mice:** birds can be kept at a distance by spreading thorny branches onto the seedbeds. A better way of controlling both birds and mice is to construct frames with close mesh wire (less than 6-mm mesh) and set these protect the seedbed.

**Red ants:** if red ants attack germinating seeds or seedlings, dieldrin can be sprayed. For this directionson insecticide packages should be followed.

**Grasshoppers:** Spraying the seedlings with a suspension of dieldrin or aldrin wettable powders somesticker can control leaf-eating insects

**3.7.6. Cultivation and weeding**

**Cultivation**

Satisfactory growth of seedlings may be expected when the soil is good physical conditions. Cultivation (working of soil surface) is the technique of preserving good physical conditions of soil in pots and beds during the growing season. Cultivation should be timed to improve soil tilt and eliminate weeds. The interval between cultivation should not more than one month. Cultivation must not be done too deep, as this would damage seedling roots.

**Weeding**

A weed is plant growing where it is not wanted. Weeds compete with plants for water, and soil nutrients. They may also harbor insects and diseases. The principal methods of weed control are manual, mechanical and chemical. Weeds grown in Swaziland bed in pots can be removed with hand only. Weeds grown between pots in bed should be uprooted during root pruning. Herbicides can be also used in small scale and trying first in small tests.

**Weed prevention techniques:**

* Establishing hedge around the nursery or compartment will prevent weed infestation by wind,
* Filtering irrigation water passing through weed infested areas in open canals using a fine wire screen before distribution
* Potting soil and compost may be sterilized to kill all weeds
* Rhizome infested compartment must be repeatedly worked to remove all rhizomes before nursery beds are laid out.
* Water beds and containers for some days before sowing of the tree seeds soas to facilitate the germination of a weed seeds and to eradicate them

**3.8. Preparation for planting out**

Before the seedling can be delivered for planting in the field, some steps are still required such as hardening-off, grading, packing and transport.

**3.8.1. Hardening-off**

Hardening-off is a common nursery practices to gradually impose harsher conditions to the stock starting a few weeks before planting. Some 4 to 6 weeks before planting, watering is reduced progressively down to about three-quarter to one half of the normal quantity. Watering applied less frequently. Depending on planting conditions and if planting areas are dry, it is sometimes advisable to reduce watering to the point where seedlings are almost wilting.

**3.8.2. Lifting and culling**

Culling is rejecting of all poor quality seedlings that are not satisfied the requirement. Culling is done in connection with lifting of seedlings for transport to the planting site.

**3.8.3. Quality control and transport of seedlings**

Grate care should be taken when seedlings are sent from the nursery to the plantation site. The main dangers during transport are scorch from the sun and wind, broken stems, damaged roots, and wilting due to transpiration. Potted seedlings should be water the day before transport. It is important that pots are standing upright to prevent the soil and seedlings falling off the pots during the transport. After lifting from the bed, bare-rooted seedlings may be laid down nearly on wet banana leaves, sacks or other materials. Never carry seedling in the open tuck or lorry. The foliage will be damaged by wind and excessive transpiration will occur in a very short time.

**Quality Criteria**

At the time of preparing the plants for transport to the afforestation sites, the seedlings should fulfill the following requirements:

* Balanced shoot/root ratio
* Right size, not straggly
* Growing well.
* Not physically damaged
* Good, healthy color.