

TRAINING PACKAGE ON BIOPHYSICAL GULLY CONTROL AND REHABILITATION MEASURES

PART TWO: TECHNICAL MANUAL ON BIOLOGICAL GULLY REHABILITATION MEASURES



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MODULE 12: NURSERY ESTABLISHMENT FOR BIOLOGICAL REHABILITATION MEASURES



12.1 Concept on tree nursery

A tree seedling nursery is a safe area where young plants are grown under controlled conditions in order to produce strong, healthy and hard seedlings for planting out them in the field. The young plants or seedlings are carefully looked after in the nursery until they are ready for transplanting. It is important that seedlings have a well-developed root system and are well hardened of to maximize survival chances after planting in the field.

12.2 Types of nurseries

Nurseries can be permanent or temporary and centralized or decentralized. In order to choose which type of nursery to establish we have to know the following points:

- 1) How many seedling are required,
- 2) For how long do we need the supply, and
- 3) Accessibility.

a) Temporary nurseries

Advantages of Temporary nurseries

- Low cost of establishment: Needs only land clearing and doesn't require permanent structures which are expensive, and
- Low transport cost because it is established near the area of plantation.

Disadvantages of Temporary nurseries

- The cost of land clearing is repeated every 2-3 years due to changing location of nurseries;
- Difficult to get permanent supply of water to every plantation site;
- Difficult to make close follow up; and
- Difficult to guarantee a permanent skilled labour.

b) Permanent nurseries

A permanent nursery is a centralized place for seedling production that is planned to continue over a number of years. In a permanent nursery, seedling production is continuously under control. As a rule of thumb, establishing a permanent nursery should be done with the following in mind:

- The planting program should continue at least for 5 years; and
- The annual need for seedlings should exceed 0.5million.

When a permanent nursery is built to supply a large plantation, the distance for transporting seedlings grow from year to year since nearby areas gradually are planted. In this connection, the establishment of infrastructures in such type of nursery, especially roads and vehicles, are very critical.

Advantages of permanent nursery

- Possible to employ qualified personnel;
- Production of scale (low cost per seedling when the number of seedlings is large); and
- Easy to follow up soil mix, watering and shade construction which leads to production of quality seedlings.

Disadvantages of permanent nursery

- Expensive to establish because of the need for permanent buildings, water supply and fencing; and
- High cost of transport due to long distance to plantation sites.

12.3 How to start a new tree nursery

Nursery site selection

Nursery site to be selected should be an area where there has not been any nursery or an area where the existing one(s) are not able to satisfy the demands. Hence, before establishing a new nursery, one has to know whether the existing nursery able to satisfy the demand for seedlings in the locality or not.

In selecting suitable nursery site the main criteria's to consider are:-

Accessibility to the plantation site: Seedling transportation is usually done during the rainy season. So, the nursery site should have an access road to transport seedlings. It is good to establish nurseries near the plantation sites. Whenever the nursery is nearer to the plantation site, transport costs are low.

Good drainage systems: Vertisols (black cotton soils) should be avoided because of poor water infiltrations during the rainy seasons. Watering makes the area muddy and this affects routine activities including transporting seedlings by vehicle and wheel barrow. Moreover, Vertisols crack during the dry seasons. This characteristic of the soil damages roots of seedlings.

Proximity to sources of different soils: If only potted seedlings are raised, and the soil-mix ingredients can be brought from other places, the local soil type is not of that important. However, if bare-root seedlings are to be produced, it is essential that the nursery site has a suitable physical soil texture to produce seedlings with vigorous root growth.

Suitable altitude: Altitude (due to its associated rainfall and temperature changes) has the greatest effect on the growth of trees. Similarly, altitude affects the growth of seedlings in the nursery. The lower the altitude and the warmer the nursery site, the quicker the seedlings grow and the sooner they are ready for planting. It is not advisable to grow seedlings that will be used in a highland plantation at a low land nursery site. Seedlings should adapt to the prevailing climate in the future plantation site and this happens best if the nursery is at approximately the same altitude as the plantation site. A good compromise is to establish the nursery in the nearest corner of the project site.

Sheltered location: A nursery site should not be exposed to desiccating winds. Such winds often blow along the bottoms of narrow, deep valleys. Desiccating dry season winds that blow steadily from the east can easily affect the unsheltered seedlings at the pricking out stage. In such places there is also a danger of flooding. On the other hand seedlings can be protected from strong winds by adjacent mountain slopes and/or by natural vegetation or by planting of shelterbelts and wind breaks. Since the most desiccating high land wind blows from the east, sheltered nursery sites are often found on the western sides of the mountains.

Sufficient water supply: Growing seedlings must have enough water at all times. The water supply must be especially sufficient during the driest season when seedlings need water most. If the supply is limited during the dry season, the minimum capacity of the water flow must be calculated. This determines the maximum level of nursery production.

Slope/topography: Relatively flat land, ideally with a 2—5% slope, is most suitable for a nursery site. This permits water to run off so that water logging does not create a problem. The lower or mid slopes of an area with undulating topography usually provide suitable sites. If flat land is not available, terraces must be constructed, but this is expensive and also makes movement and transport within the nursery more difficult. The site should receive full sunlight on all areas used for pot beds so that proper hardening-off is possible at the end.

Infrastructure: A nursery should have an all-weather road that provides access right to the site. If possible, there should be truck access into the nursery itself so that materials can be efficiently delivered and seedlings easily loaded on trucks with minimal labour inputs. It is most desirable to have a good road system that leads from the nursery to the plantation sites so that at planting time it is possible to quickly and efficiently transport seedlings from the nursery.

Enough labour: Another important aspect in selecting the nursery site is the possibility to get enough labour—especially during peak working periods. Most nurseries use very labour-intensive production methods with little reliance on chemicals or mechanical equipment. It is, therefore, essential that a nursery be sited only where sufficient labour can be recruited. There are significant seasonal variations in labor requirements of nursery sites and there may be a conflict with peak season farming activities.

Layout and design of nurseries

When a suitable site to establish a new nursery is found, the next step is to plan the layout for the nursery. The targets in the design should be easy nursery *management* and optimal *land use*. There is no standard layout for the nursery since differences between sites (land

availability, sloppiness, access to water etc.) must be taken into account. An ideal form for a nursery is from square (by which the expensive boundary fencing is kept at a minimum) to slightly rectangular shape (by which longer working lines are provided). Only seldom an ideal, level site can be found to meet these conditions: enough space for ideal nursery form, good road connections from any direction, water available in any corner. In practice the form of the nursery must be tailored into road access, water points, and sloppiness of the site.

The nursery size is determined by:

- maximum annual need for seedlings,
- pot size, and
- area need for infrastructure (buildings, water tanks, compost making sites, roads, fencing, windbreaks).

Points to be considered in nursery design are:

a) Annual need for seedlings

Annual need for seedlings can be calculated based on the area to be planted and the planting density. If the spacing is 2x2m, a minimum of 2500 seedlings per ha are needed. If the annual planting area is, say 400 ha, a minimum of one million seedlings are needed. Additional points must be taken into consideration are number/quantity of seedlings to be culled (rogue out).

The area of the nursery can be calculated, based on the maximum number of seedlings to be produced. When making calculations of area required, allow for the fact that not all pots contain a live seedling, and furthermore that not all living seedlings are of plantable quality. Culling should frequently reject at least 10-15% of seedlings and, therefore, calculations should be made on the basis of about 20% production above the actual number of plant able seedlings required.

b) Effect of pot size

The area needed for a nursery depends not only on the number of seedlings to be raised, but also on the proportion of the nursery stock that is raised as potted plants and bare-root seedlings and as cuttings. The diameter of the pot or the spacing between bare-root seedlings will also have a major effect on the area needed. For example, if the pot diameter is 5 cm, then 400 pots per square meter can be accommodated in pot beds. If the pot diameter is increased to 8 cm, then only 149 per square meter can be accommodated. The area required per pot increases proportional to the square of the radius of each pot. Therefore pot-bed area needed increases rapidly with increasing pot diameter. The number of tightly packed filled tubes (N) accommodated in 1 square meter can be calculated using the following formula: $N = (100/d)^2$ (where d = diameter of pot in centimetres)

A simple calculation gives the pot-bed area required for any number of seedlings grown in a specific size of pot. (Total pot-bed area needed = total seedlings produced divided by number of tubes per square meter.)

Table 1: Doubling the diameter of the pot results an increase in nursery size by a factor of 4

Pot diameter cm	Pots Per square meter	Net area needed for 1 mill. pots ha
4	625	0.16
5	400	0.25
6	278	0.36
7	204	0.49
8	156	0.64

For open-root seedlings calculations can be based on a spacing of 20 cm between rows and 5-10 cm along rows between adjacent plants.

The number of tightly packed filling pots (N) accommodated in one square meter is calculated with the following formula: $N = (100 \times 1/d)^2$ (where d= pot diameter in cm)

c) Effect of infrastructure

Besides effective bed area, additional nursery space is needed for infrastructure that includes areas for working paths between beds, for other pathways, roads, channels for irrigation, water tank, soil dump, stores, fences and windbreaks. If seed is collected by the project, an additional corner is needed for threshing and cleaning the seed.

The ratio of total area required for the nursery (including roads, windbreaks, etc.) to the area for pot beds is likely to be approximately 3:1. Unless a very large nursery is to be established, this ratio figure can be used for planning purposes. This means that for one million potted seedlings in 5-cm-diameter tubes a total nursery area of about 7,500 m² (or 0.75 ha) would be required. Thus 1 ha should be quite adequate for production of 1 million seedlings. Based upon an annual production of one million seedlings, the gross nursery size is calculated according to Table 2.

Table 2 Gross area needed for a model nursery with a production capacity of 1 million seedlings

Pot diameter (cm)	Net seedling beds area (ha)	Gross production area (ha)	Total infrastructure area (ha)
4	0.16	0.29	0.48
5	0.25	0.45	0.75
6	0.36	0.65	1.08
7	0.49	0.88	1.47
8	0.64	1.15	1.92

While laying out a nursery, the following activities should be done

- Clearing of trees and shrubs of the site including 10 meters from the boundary of the nursery;
- Removing termite mounds and associated soils;
- Ploughing the whole area and removing roots and big stones; and
- Putting pillars showing blocks and roads.

Nursery production units

For management purposes, a large nursery must be divided in to suitable production units. The basic units are bed, compartment and block. Production should be arranged in such a way that one bed is sown at a certain time, one compartment is sown with a certain provenance and one block is sown with certain species. While laying out the land, care should be taken not to bury the top soil (which is important for seedling growth) and bring up the subsoil. This is especially important while raising bare rooted seedlings.

Production units

The major production units in the nursery are beds, compartments and blocks.

Seed beds/ nursery bed: the basic management unit in the nursery is the seedling bed. The bed is the smallest working unit and is selected to hold a convenient number of seedlings. It is a place where seeds are sown or in which the transplants of cuttings are raised. It is usually about 1.2 m wide because of the difficulty of reaching into the centre. When beds are narrower than 1m, paths between them take up too much space. Beds having 1m wide is

also acceptable with two practical advantages. First, the calculation of bed area and inventory of seedlings is simple. Second, the manual work over the bed-seed sowing, transplanting, weeding and watering are easy. For this reason the bed width should not exceed 1.2m. The longer the bed, the more optimal the use of nursery space will be. On the other hand, the longer the bed the more cumbersome the watering becomes. The standard length of a nursery bed is 20m. It is a compromise between two factors. Path should be 50 to 60 cm wide, which provides adequate space to squat and work.

One square meter of seedling bed can accommodate 400 pots of a diameter of 5cm. Thus, a bed of 1x20m can accommodate a maximum of 8000 seedlings. The working path between the seedling beds varies from a minimum of 0.50m to about 1.0. In flat or gently sloping areas, a bed width of 0.5m can be used, but if the soil must be terraced for the seedling beds, more space between the beds must be reserved, up to 1m or even more. The seedling bed is prepared by first digging a shallow excavation.

Types of seed bed:

- Raised seed bed,
- Sunken seed bed, and
- Level seed bed.

Raised nursery beds: are made in high rain fall areas. Raised beds are made 10 -15cm above ground level with support of bricks, stones or bamboo or bellies which prevent edges of the beds from crumbling during rains or while giving irrigation to the beds. These beds tend to prevent water logging. Even during heavy rains, the root zone is not flooded due to raised beds. Drainage in growing areas is also easy. Raised beds are good for those seeds which do not require more moisture for germination. Such beds are good for raising seedlings of teak.

Sunken seed beds: are made in dry areas. The objective of making sunken beds in dry areas is to avoid flow of water outside the bed. Sunken beds are made by excavating the soil in the bed area. These beds are usually 10cm to 30cm dipper than the normal ground level. It is better to connect such sunken beds to a common drainage line so that water does not stand during rains. Sunken beds are made for raising the seedlings in the bed or for keeping the polythen bags in the bed. Generally, if the seeds are to be sown in the bed, the depth is 10-15cm. However, if the polythane bags are to be kept in the bed the depth is kept about 20 to 30cm depending upon the length of the polythene bags used. Generally, the depth of bed should be 5cm less than the length of the polythene bag. When polythene pots are used for raising the plants, it is advisable to put a polythene sheet equal to length, breadth and height of the bed. This prevents water to go down in the soil. It also prevents the roots of the plant from penetrating the ground.

Level beds: are made in normal rainfall areas. These beds are easily irrigated by cans. The surface of the nursery bed should be perfectly flat or should have a slight camber. In order to enable good drainage in the beds, surface dressing is very important. If the soil is heavy, such dressings are more necessary.

Compartments

The second management unit in the nursery is the compartment. A suitable number of seedling beds are grouped into one compartment. Compartments are located at approximately 1m from surrounding unproductive land such as roads, hedges and windbreaks as well as from neighbouring compartments. A suitable number of seedling beds in one compartment are 20; the productive area is then 400m² and the maximum number of

5-cm pots is 160,000. However, the number of seedling beds in one compartment can vary according to the degree of the slope.

Blocks

The third management unit is the block. Several compartments (for instance, 4 to 6) are grouped together, framed by hedges and separated from each other with nursery roads or irrigation canals.

Whenever designing blocks and beds, consider geometric shapes because it helps:

- Fast and easy management (follow up and seedling inventory)
- Avoids unnecessary space wastage.

Beds can be divided into two:

- For potted seedlings; and
- For bare rooted seedlings.

Design of infrastructure

Area required: The area or land required would depend largely upon the number of seedlings to be produced, the time they are kept in the nursery and density at which they will stand in beds. Before starting calculation of the area required for infrastructure, it is necessary to list down the various components of the nursery. These are:

- Seedbeds,
- Main seeding production area,
- Paths, roads, irrigation channels,
- Working area and potting mixture storage,
- Area for mist chamber and shade house,
- Compost making area and compost bins, and
- Area for buildings and for future expansion

The lists of infrastructure important for nursery development are:

a) Buildings: It is essential to have an office where records of seeds, sowing, etc., can be conveniently and accurately maintained and filed. If there is no office with a table and chair it will be difficult to record the basic information which is essential for future planning as well as documentation of past seedling production (figure 1). The nursery office also serves as:

- Protection from wind and rain
- Temporary store
- Meeting and training place for nursery workers

b) Roads: there are two types of roads in a nursery. A primary, all-weather road that is wide and suitable enough for trucks and tractors that shuttle to the nursery. This road also should traverse the entire nursery at least once to allow for efficient transport of seedlings. If the space and terrain allow, another all-weather road should be constructed as a perimeter and a third cross-road against the main traverse. The width requirement for the primary nursery roads is 5m.

Secondary access roads, 3m wide, are needed to provide access to all blocks (and to separate them), buildings, the soil dump and germination compartments. These secondary roads do not need to be all-weather (figure 1).

c) **Windbreaks:** tender seedlings must be sheltered efficiently against the dry season winds. During the first years of nursery operation, temporary windbreaks around the compartments may be sufficient; however, the best windbreak in the long run is a living one. Hedges between blocks serve partly as windbreaks. The best windbreak is the one that does not stop the wind entirely, but slows speed by letting part of the air penetrate the obstacle. A solid windbreak (wall) creates air turbulence behind the wall, and the sheltering effect does not reach far (figure 1).

Fencing and shelterbelts: How to plant trees for live fence?

A very effective tree for making live fence is *Cupressus lusitanica*. A good quality tree for effective live fence is that which can be pruned the side branch and the tip and 3 meters high and 2 meters wide at the bottom, which by frequent pruning, will be attractive and effective against animals. To form an effective live fence *Cupressus lusitanica* takes 3-4 years. To establish a live fence there should be a well prepared 2.5 - 3m wide land.

Steps for live fence establishment:

1. Digging one meter wide place in the 2.5-3m area
2. Marking two lines 50cm apart i.e. from the 1m dug place 25cm from each side
3. In the marked line planting of strong and about 30cm high seedlings at an interval of 50 cm. The trees planted on one line should be in zigzag with the other line
4. Proper watering and weeding
5. When the seedling reaches a height of 1.5m, prune the tip and side branches so that it will be wider at the bottom and narrow at the top. Sunlight can also easily reach the bottom parts.
6. In order to ensure that the branches are interwoven and maintain proper shape frequent pruning is necessary.

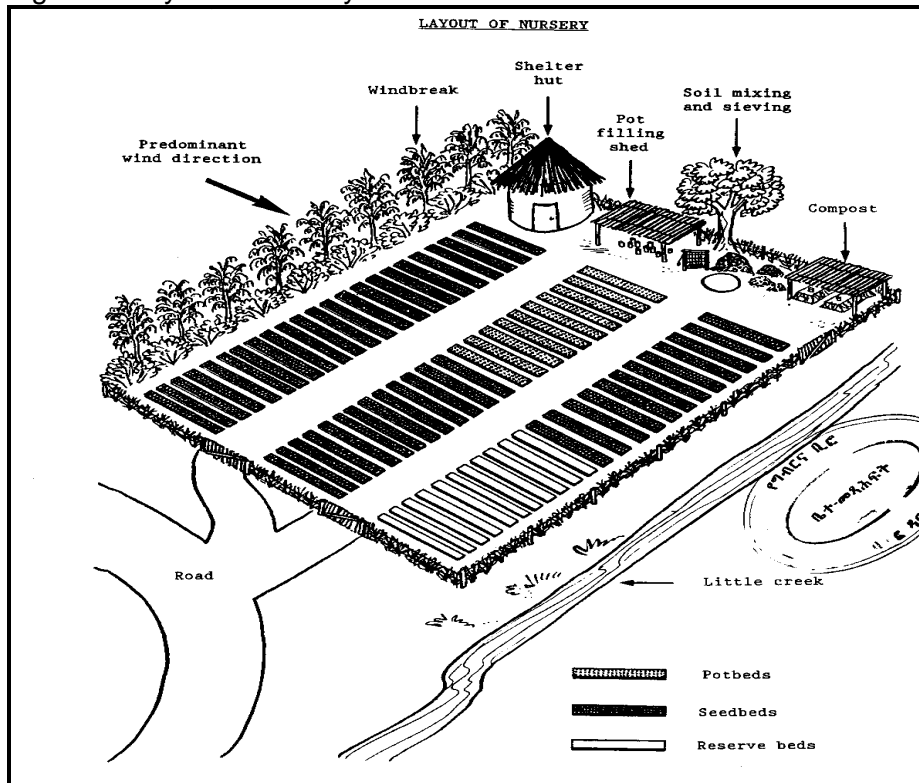
The outer side of the live fence should be planted with shrubs (serving as barriers against livestock) while the inner one with trees. Tree/shrubs recommended for the outer and inner part are as follows: *Acacia holosericea*, *Eucalyptus Camaldunensis*, *Acacia. Senegal*, *Euc. Globulus*, *Ziziphus spina – Christi*, *Euc. Citriodora*, *Parkinsonia acculata*, *Casuarina cunninghamiana*, *Prosopis Juliflora*, *Casuarina equistifolia* *Leucaena leucocephala* *Euphorbia tirucalli*, *Cupressus lusitanica*, *Grevillea robusta*

d) **Soil dump:** for a nursery with a capacity of 100,000 seedlings, a shed with 5 m x 3 m in area and 2 m height should be sufficient. The delivery truck should have road access to the storage dump so that double handling and moving by wheelbarrow are not required (figure 1).

e) **Seed-extraction area:** most nurseries collect and extract at least some of their own seed requirements. An area exposed to plenty of sunshine is needed for efficient seed extraction in some species (figure 1).

f) **Compost area:** in dry climates it is usual to prepare compost in pits. A convenient size is 1-1.5 m deep, 1 m wide and 2 m long. The compost pit should have a roof to provide shed and protection from rain (figure 1).

Figure 1: Layout of nursery



Source: GIZ-SLM (Dagnachew Gebeyehu)

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MODULE 13: PLANNING AND RECORDING OF NURSERY ACTIVITIES

13.1 Planning activities

Careful planning, organization, implementation and control are required to avoid mismanagement with resulting poor quality of planting stock. In order to simplify activities, a plan of activities, covering at least one productive season in the nursery should be made. This will help to plan and implement activities that require more labour or special equipment. Some labour intensive activities like sowing, transplanting, root-pruning and lifting must be done in a limited time, and these periods are usually of critical importance. Other labour intensive activities like pot filling, weeding and shading must be carried out more or less continuously during the production season. These continuous seven-days-a-week activities should be well supervised as they are essential if quality target seedlings are to be produced.

Nursery management can be simplified if a detailed plan is prepared before the start of the nursery season. The nursery management plan includes all important nursery activities. It should cover one full cycle of the nursery year, starting with an empty nursery at the end of the main rains and extending until the next rains when the seedlings are transported to the planting site.

Following the nursery management plan it is possible to smoothly implement those nursery activities that require most labour or special equipment. Certain labour - work such as transplanting and lifting must be done during a limited period of time, and these phases are usually critical; success of the whole planting year depends upon them. Another type of labour-intensive activities is the phase during which pots are filled. This activity can be done over a longer period, and should be planned to start well in advance to avoid bottlenecks (the soil coming late, a shortage in the plastic tube supply, etc).

Some activities, like the watering of the seedbeds, must be done continuously, regularly and over a certain period of time. For such work, the management plan must reserve a reliable team of permanent or semi-permanent nursery workers who can be employed seven days a week for the period in question. The annual nursery management plan is based on the following factors:

- number and type of seedlings to be raised;
- applicable work norms; and
- timing of activities

The number and type of seedlings to be raised is decided when the nursery was set up. However, the annual amount of seedlings, species by species, is decided every year. *Juniperus procera*, for example – needs a full year in the nursery before reaching transplanting stage. Nursery work norms, together with the seedling production level, help to establish the need for casual labour. The applicable work standards are based on experience from the nursery itself, or from similar nurseries elsewhere in the country.

In calculating the need for casual labour a provision must be made for weekends as well as for official and church holidays. The people who live in the Ethiopian highland can be counted to work only for 20 to 25 days per month. Therefore, an average need for 600 man-days for sowing would translate into a requirement of 30 people for a sowing period of one month (20 working days).

13.2 Recording in nursery operations

Records are important elements in nursery operations. They are critical especially for newly appointed staff member who likes to learn about the local nursery management and practices. In contrast, inadequate record keeping can result in loss of valuable information, information which could improve methods of production. Nursery records can be conveniently divided into three categories as: seedling production, costs, and daily diary.

In the interest of standardization, and to ensure that all relevant information is recorded, nursery registers should be produced and used by anyone running or starting a nursery. The register provides an adequate annual record of production procedures and, with time, a history of each particular bed. This means that each bed in the nursery, whether it is a seedbed or a pot bed, must be allocated a particular number which it retains permanently thereafter. There should be a label indicating the unique number of each and every seedbed and pot bed in the nursery.

The nursery register is divided into five major sections, as follows:

1. Seed source
2. Sowing
3. Pricking-out (or transplanting)
4. General remarks
5. Dispatch location.

Section 1: Seed source

This section deals with details of seed-collection and should include a unique batch number which is applicable to only one specific collection. From this batch number alone it should always be possible to retrieve the other collection details. If local seed collections are made, then a local seed register should also be started, and particulars of each collection recorded. If seed is received from external sources, it should already have its own unique batch number. However, if for some reason it does not, it should immediately be given a number from the local register, and all relevant collection details recorded.

Section 2: Sowing

This section deals with recording basic information about sowing and should include dates, rates, pre-sowing treatment, date germination started, date germination was completed, actual germination rate (percent) and actual number of germinants. This section provides valuable information of particular use in organizing future sowings, and is well worth the little extra effort required to acquire it. The total labour expended on sowing should be recorded in man-days.

Section 3: Pricking-out

This section is to record the essential details of pricking-out, including dates when the work was done, the seedbed number of the transplanted seedlings, size of pots used, and potting mix used. The survival rate of the seedlings should be recorded when no further mortality is likely to occur. The total labour expended on pricking-out should be recorded in man-days.

Section 4: General remarks

This section is included to encourage nursery foremen to closely monitor the quality of the plants they are growing. The specific dates of root-pruning(s) should be recorded here without fail. Notes on watering, shading, pests and diseases, weeding, fertilizers, etc., should also be included here.

Section 5: Dispatch

This section provides information about when, and how many seedlings are sent to be planted in various locations. It is very important to enable a specific plantation to be traced right back to the nursery and seed collection from which it originated. This facility is an essential prerequisite for effective forest management.

The data recorded in this section of the nursery register allow for examination of nursery- and seed-origin factors which may have contributed to poor survival or growth after planting. Alternatively, Section 5 may also hold the key reasons as to why a plantation in a certain site was particularly successful.

Such success may in fact be traceable to either good-quality nursery stock or seed of superior genetic quality. A sufficiently detailed Section 5 might be the only available way to identify that desirable superior genetic source or nursery. After it is identified, this of course creates the opportunity to disseminate more widely the methods of the identified superior nursery or genetic source.

13.3 Keeping records

Good record keeping in the nursery helps to run the nursery well. References to documented records are important for the current nursery management staff and especially important for any newly appointed staff that can learn about nursery needs and practices by studying the records. Inadequate record keeping, results in the loss of valuable information about new methods, sources of seed, suitable planting times and different problems in the nursery.

The main purpose of recording nursery data, activities and experiences is to make planning and management for the coming years easier. With proper record, upcoming activities can be better planned. Potential bottlenecks that are apt to occur every year can be better met; deadlines and production targets for seedling production can be more easily attained. There are 3 types of technical records that should be kept for the nursery:

- a daily journal,
- registers , and
- inventories.

In addition to these, a financial record is compulsory. All relevant information in line with daily operations should be recorded in a journal. The time of sowing of the different species in individual compartments should be indicated, as well as the time of transplanting and any other treatments given to the seedlings. The time and the labour used for different nursery operations should also be recorded daily. Notes about nursery efficiency, the final number of seedlings produced per square meter, etc., are useful. A record of water consumption and irrigation practices should also be made. All this information is essential for a continued successful nursery operation, and together with financial records, gives the basic data for calculating seedling production costs.

Labels are important for nursery records, to avoiding mix-ups with species, provenance's, sowing dates and other data. The labels should be used from the moment the seeds have been collected until the seedlings are released to the field. Labels should, at the least, show the seed batch number and the botanical name of the seedlings. Aall countries in the world use Latin botanical names for trees. The use of a Latin name is safe vis a vis use of a local name, which likely creates confusion.

Regular inventories

A thorough nursery inventory should be taken annually to record the seed stock, consumable materials like plastic tube and fertilizer, tools and expendable equipments. The

annual inventory is best done between the dispatch of plants from the previous nursery season and the beginning of the new nursery season. Local materials like watering cans and hoses, wheel barrows, etc., can be procured before the high nursery season. Purchase orders for imported materials such as plastic tube should also be prepared at this time since the arrival of such items normally takes up to one year from the date of ordering.

Seedling production is monitored with monthly inventories. The nursery manager must know at every moment how many healthy seedlings he has in his nursery to compare against the annual production target and against the safety margin of seedlings needed to reach this target. It is a normal biological fact that some seedlings will die before the planting season and another amount may be too weak for transporting.

The greatest problem occurs with a sudden dieback of seedlings. If the dieback is not recorded in time, the achievement of the annual production target may be at risk. By taking regular seedling inventories, the problem of sudden diebacks can be overcome. If the number of losses is closely monitored and those pots removed from beds, there remains a possibility to produce additional, fast-growing seedlings for the coming planting season. Fast growing and simple to raise *Sesbania bispinosa* seedlings can be substituted for dead acacias or eucalyptus. If the latter half of the nursery season is already at hand, it may be feasible, in case of sudden losses of seedlings, to make enquiries at neighbouring nurseries where it might be possible to obtain the missing seedlings.

The first seedling inventory is done immediately after sowing by counting and measuring:

- The number of beds,
- The dimensions of the beds (length x width), and
- the number of pots per square meter

The next inventory should be taken a week or two after the pricking out. A simple way to do this is to take a random sample of 100 pots from every bed. In each sample the number of empty pots and pots with viable seedlings is recorded, and the survival percent calculated;

$$\text{Survival \%} = \frac{100 \times \text{no. of viable seedlings}}{\text{Total number of pots}}$$

Such a survival count should be carried out once a month up to the time of lifting.

Quality control

Besides quantity, the quality of seedlings should be continuously monitored. Empty pots and sick as well as weak seedlings should be recorded and removed from production beds. Seedlings with diseases must be taken away from the nursery or destroyed by burning or burying with notes taken. Weak but healthy seedlings can be grown further for possible use in the beating up.

At the time of lifting, seedlings should meet the following requirements:

- the root – to – shoot ratio should be in balance;
- the size should be correct;
- the seedlings should have no damage; and
- the seedlings should have a healthy colour.

All seedlings that do not fulfill these requirements, even one of them, must be discarded from the transport. The optimum seedling size for planting is between 15 and 40cm, depending on pot size and species. The larger the pot, the bigger the seedling can be at planting. If the seedling happens to be over-sized before the planting, the stem of the seedling has become

slender and its ability to endure transport is low. The root-to-shoot ratio is too small, and such seedlings should not be accepted for standard planting.

The use of large seedlings favours survival since these can withstand weed competition better than smaller seedlings. The planting shock, however, is greater for big seedlings, and there will not necessarily be any advantage in their growth pattern after the first growing season. It is evident that height alone does not suffice for grading plants. An additional characteristic is the root collar diameter which correlates highly with seedling survival. The thicker the root collar, the better the survival.

13.4 Transporting of seedlings for field planting

Organization of the work chain

The organization of seedling transport is the last link in the seedling production chain and recording for the batch. It is the final step between the proper nursery season and the planting season. The success of plantation establishment is greatly dependent on the efficient lifting, loading and unloading of seedlings. The handling and transport of seedlings is the easiest if wooden or plastic crates designed for that purpose are used. Seedling crates are built to standardized dimensions: length 33 cm, width 17cm and height 25 cm. The weight of one create with seedlings should not be more than about 15kg. The crate capacity depends on the pot size.

An adequately trained and equipped labor force must be available in advance at both ends of the transport chain. This is especially important in the field. A truckload of 5,000 to 6,000 plants should be planted out within 2 hours of their offloading. If a tractor and trailer is used for seedling transportations, the transport efficiency is greatly improved if 2 or 3 trailers can alternate with the tractor.

If transport from the main nursery to the planting site exceeds one hour, strategically located temporary nurseries, less than 2 to 3km from the planting sites, should be available to facilitate the chain of transport and planting. Proper attention, however, must be given to the decision to use temporary nurseries since they always involve a risk of losing some seedlings due to double transport and often unavoidable water supply problems.

Transport capacity

Seedlings are usually transported from the nursery with trucks and tractors. If the seedling crates are well designed and well constructed, they can be loaded in piles one on top of the other. In addition, plastic bags can be used for short distances. The method of using crates or plastic bags requires a special device on the truck or tractor platform. Two or more, often 3 loading decks must be constructed above each other. A truck with three loading decks has a platform area of about 24m². The maximum transport capacity of such a truck can be calculated by loading the seedlings without crates or plastic bags, vertically in the three decks. The pot size will determine the number of seedlings per truck load.

A common way of loading seedlings is the so-called "sardine-method". The seedlings are loaded horizontally on the truck or tractor-trailer deck above each other, like sardines. This method users the deck volume most efficiently, but it is detrimental to the seedlings. The other possibility of transporting seedlings – over short distance – is to use pack animals or porters. Generally, however, manual transport and handling of seedlings should be limited to carrying pots from the beds to the truck and from the truck to the planting site. Normal seedling crates can be used; on steep slopes the seedlings may be carried in back packs.

It is preferable to move seedlings on cloudy or rainy days to prevent desiccation during transport. When moving seedlings to temporary nurseries before the planting season, transport should be done early in the morning or late in the afternoon.

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MODULE 14: NURSERY SOIL PREPARATION FOR BIOLOGICAL REHABILITATION



Nursery soil preparation

14.1 Soil components

The growing media or "soils" that are used in nursery (particularly in pots or tubes) are possibly the most important factor in growing high-quality, healthy seedlings. Careful selection, mixing, treatment and handling of the components of the potting soil should provide the best possible growing conditions for plants, resulting in healthy seedlings that have a high chance of survival in the field.

The mix must provide water, nutrients, oxygen and physical support for the seedlings as long as they are in the nursery. A single source of soil is not usually able to provide all these requirements, so it is necessary to mix several components together to produce the potting mix. For the production of bare root seedlings/nursery stocks, the available soil in the nursery is used. But we usually mix additional additives such as sand and organic matter.

We must rely on mixing soil, sand and manure/compost in such proportions that the basic requirements for healthy plant growth are fulfilled. The soil in the pots has to facilitate germination and root development and to supply the seedling with water and nutrients. It should therefore be light and rich in nutrients. On the other hand, the soil should not fall out of the pot during handling and transport or crumble too easily when planted. Soil with a lot of

weed seed in it should be avoided. Soil from underneath leguminous trees such as Acacia is particularly rich in nutrients. Suitable soil has to be brought with a cart or truck, or possibly a wheelbarrow if it is not available at the nursery site. Usually different types of soils have to be mixed to obtain potting soil. Having quality nursery soil will have the following characteristics:

- Good drainage
- Satisfactory contents of essential nutrients
- Good organic matter content to retain moisture
- Sufficient adhesion to form soil cylinder (keeps the soil in pots without falling through the bottom)

Many soil types do not fulfil all these qualities. But humus rich soils & compost have more of these desirable characteristics than other soils. The local soil which is easily available in large amount is called basic soil. According to the need, adding some ingredients can modify the basic soil.

The basic soil component for pots is sandy loam or loamy sand. It should be found in sufficient quantities either in the nursery or in the vicinity of the nursery. Availability of soil is one of the criteria for choosing the nursery site. The soil particles in sandy loams and loamy sands are ideal to provide good soil aeration, root penetration and easy watering.

Often the ideal mineral soil is not found. The available topsoil inside the nursery or in the vicinity, is either too heavy (clay) or too light (sandy). Neither of these options is good, but both of them are usable if their basic properties are understood.

Clay soils have a tendency to become hard and compact. They absorb water too slowly and the irrigation of pots becomes difficult. However, clay soils can be improved by adding sand or some humus rich soil. The presence of clay soil helps the soil bound the roots & form soil cylinder (improves adhesion). Sand or nursery residues are added to mixture, they must be chopped into small pieces. As such they decompose quicker, and this later facilitates mixing the compost into other nursery soil.

14.2 Organic matter

It is widely accepted that organic matter has several important benefits for producing a high quality potting mixture, and thus helping to produce high-quality seedlings. The main benefits of organic matter are the following:

- It binds together the mineral particles of soils into aggregates. This improves soil structure and therefore the supply of oxygen and water to the plants;
- It is a source of nutrients for plants. These nutrients are released slowly as the organic matter gradually decomposes;
- It regulates the supply of nutrients by holding them in readily available forms and reducing losses into drainage water through leaching;
- It helps to control root diseases through a general reduction in the level of pathogens by antagonistic micro-organisms that decompose the organic matter; and
- It may stimulate seed germination, root development and general plant growth through the plant-hormone-like activity of some of its components.

14.3 Soil mixtures

A common problem of nursery soil is that soils are too "heavy" in texture; that is, they contain too much clay and silt. These results in poor aeration and little pore space, both of which

reduce root growth. The final mixture should have a texture classified as "sandy loam" or "loamy sand".

The proportions of soils, sand and compost/manure to be used will depend on the individual nursery because the texture of the soil component used in each one varies. There can be substantial changes even at one nursery, if the origin of the mix components changes from year to year.

A mix containing soil, sand and compost in the ratio of 2:1:1 is recommended as adequate for the healthy growth of the majority of species. Some nurseries had adopted ratios such as 3:1:1 and found seedling quality improved due to the improved root growth in these lighter-textured mixes. If the high cost precludes using sand in such a high proportion, then try to include as much compost as possible, up to a maximum of 40%.

If possible, forest topsoils, which often already contains a high proportion of sand, should be used to produce the final potting mix. Such topsoil often also contains useful organic matter and has a lower pH than dam silt, but it may also contain a lot of weed seeds. Now, the different nursery soil components are ready: local nursery soil as a basic soil, forest soil, some compost, some cattle manure. All the components have also been sieved to a uniform size that is easy to mix, pour and press into seedling pots. How should the different components be mixed?

The determining factor in mixing is the structure of the basic mineral soil. If a good sandy loam or loamy sand has been found, only some compost, cattle manure or forest soil is needed to improve the basic material. The missing proportion of basic soil to humus soil is 80 – 20. If the basic soil is clay, some sand must be added to make the mixture lighter. The mixing proportion of clay to sand to humus is 50-40-10. In some areas only sandy topsoil is available for use as the basic material. In such cases it is better to transport humus-rich soils-if available- than poorer clay materials. Preferable mixing proportion of sand to humus soil is 67-33 (3 to 2). Suitable mixing proportions are found by test and experience. All soil particles must be sieved and thoroughly mixed before pot filling.

14.4 Quantities of soil required

Once the ration (proportion) of different soil components is determined, the required quantities of soil mix can be calculated in relation to the container size (dimensions) and the number of seedlings to be produced. The quantity of soil required depends on the level of production and kind of seedling to be raised (either by bare rooted seedling or potted seedlings). The volume of soil mix required can be calculated as follow:

$$V = (\pi \times r^2 \times L \times N)$$

Where $\pi = 3.14$

R = radius of container = D/2

L = length of container

N = no of seedling to be produced

Example

If we are planning to produce 500,000 seedlings in pot of size (5cm diameter and 15 cm height), and 500,000 bare rooted seedlings, how much soil do we need?

For potted seedlings the amount of soil required is

$$= \frac{\text{No of seedlings} \times d^2 \times \pi \times h}{4}$$

Where d = is diameter
H = height

$$\begin{aligned} & \Pi = \text{Pi (3.141927)} \\ = & \frac{500,000 \times 0.05 \text{m}^2 \times 3.141927 \times 0.15 \text{m}}{4} \\ & \mathbf{147.278 \text{m}^3} \end{aligned}$$

For bare rooted seedlings the amount of soil required is

$$\begin{aligned} & = \frac{\text{No of seedlings} \times 0.1}{1000} \\ & = \frac{500,000 \times 0.1}{1000} \\ & \mathbf{50 \text{m}^3} \end{aligned}$$

Total soil required is $\mathbf{147.278 + 50 = 197.278 \text{m}^3}$

In order to produce seedlings on bare root (seed beds) 1m^3 of soil is enough for 10m^2 of bed size ($10 \text{m} \times 1 \text{m}$). For potted seedlings the volume of soil per pot varies with diameter and height of the pot. For example, for a 5cm diameter, 15 cm height pot and 1m^3 volume of soil is enough for 3400 pots. In most cases the size of polythene tube is given in lay flat. So the diameter can be calculated using:-

$$C = \Pi D$$

$$D = C / \Pi$$

Where C = is circumference of the poly then tube

D = Diameter of the poly then tube

$$\Pi = 3.14$$

Exercise 1: If seedlings are raised in pots or containers, each with a diameter of 5cm and pot length of 15cm, calculate the required quantity of soil mixture to raise 1million seedling?

$$\mathbf{V = (3.14 \times (0.05 \text{m})^2 \times 0.15 \text{m} \times 106) = 295 \text{m}^3}$$

Based on these figures the required number of truckloads can be calculated.

Exercise 2: If seedlings are raised without container (bare roots per 1 cubic meter is required to renew the substrate in a $10 \text{m} \times 1 \text{m}$ bed. Seedlings are planted $10 \text{cm} \times 10 \text{cm}$, i.e. 1,000 bare root seedlings in a $10 \text{m} \times 1 \text{m}$ bed.)

14.5 Preparation of polythene pots

Size of container

The size of seedling that can be grown depends primarily on the size of container available. A general guide is that seedling height should be no more than twice the length of the tube. This is dictated by the fact that, for good survival, seedlings must have a good root/shoot ratio. If large seedlings are grown in small tubes they will invariably have a low root/shoot ratio and subsequently poor survival.

To decide on container size, it is, therefore, essential to have information on the size of seedlings that constitutes the most suitable target seedling for planting. From experience in other countries it is recommended to have a seedling at least 20 cm tall for planting in relatively dry climates. Experience suggests that tubes at least 15 cm long would be required. A 15-cm long tube is suitable for growing seedlings with a height of 15- 30 cm. If larger seedlings are to be grown, then longer tubes are required. If grass competition is likely, then larger pots, in which larger seedlings can be grown, should be used. This is particularly relevant to eucalypts which are not tolerant of grass competition during the first few years after planting.

It is a general rule that the dryer the climate, the larger the container required. The reliability of rainfall in the post-planting seedling establishment period of about a month is also very important in determining container size. The less reliable the rainfall, the larger the container required. From experiences in Ethiopia, containers with 6-8 cm in diameter and 15-20 cm length for areas with rainfall of 400-800 mm per year are suitable.

It is clear that larger tubes result in better survival because they allow for development of larger root systems and greater moisture storage, but of course larger tubes are more costly. Larger tubes incur greater cost for tubing, potting mix, watering, weeding, transporting to the planting site, etc. A balance must be achieved between greater production and planting costs and increased survival when using larger pots. It is suggested that the other, cheaper, nursery-management improvements suggested in this manual be implemented first. Remember that if the tube diameter is doubled while maintaining a constant length, the volume and weight of the tube increases four-fold.

A suitable pot size also depends on the species grown. Larger pots, and also larger seedlings, are needed for beating-up (replanting to replace dead seedlings in plantations) to enable them to catch up to the seedlings that were planted earlier.

A 5-cm diameter tube can be from 10 to 20 cm long. A practicable length is 15 cm, as is commonly used in highland nurseries. Problems with air pockets can easily develop with longer tubes unless filling with the potting mix is done very carefully, providing just sufficient compacting to prevent air pockets. There are also difficulties with stability of long pots when standing them in pot beds, and this can result in non-vertical tubes with uneven root development within the pot. For 8-cm diameter tubes a length of 20-25 cm is appropriate. In general terms, the ratio of tube length to diameter should be about 3:1.

Tubing for containers must be ordered in adequate time so that it is in stock at the nursery in required quantities before pot filling begins. Using tubing of 0.05-mm gauge, 1 kg of plastic (polyethylene) will produce about 1,000 tubes of 8-cm lay-flat diameter and 15 cm length. One reel of tubing should produce 4,500 pots, so that one carton which contains two reels should produce 9,000 pots. For 1 million seedlings, 1,000 kg of plastic rolls would be required. For pots of 8-cm diameter and 20-cm length, about 500 pots can be obtained from each kilo of plastic. Therefore, for these larger pots that are usually used in lowland nurseries, you will need 2,000 kg of plastic roll for 1 million seedlings. When ordering plastic it is usual to specify the width of the tubing when it is laid flat. Thus if you order 8-cm diameter lay-flat tubing it will produce filled pots with a diameter of 5 cm.

Currently the tubing is cut to the required length of individual pots by laboriously cutting single lengths by placing the endless tubing on a wooden board marked at regular intervals. In this way 20 pieces can be cut at a time thus greatly improving productivity. The diameter of the round-wood determines the length of the pots obtained. If the diameter is 4.8 cm, tube length will be 15 cm, while a diameter of 6.4 cm will provide 20-cm long tubes. The round wood is best turned in a lathe, but it is also possible to use a debarked piece of branch of the required diameter. The efficiency and convenience of the pot-cutting roll can be further improved by fitting a winding handle to the round-wood.

Pot size can be selected from diameters between 4 and 10cm. Also the length can vary. The smallest pots are usually 10cm long; the widest pots can be up to 25cm long. The general rule holds: the bigger the pot and the earth ball, the better the success in planting. However, the pot soil that can be obtained and transported becomes unbearable if the pot size is

increased. If the diameter is doubled and the length of the pot remains the same, the volume of soil needed becomes fourfold (Table 1). Therefore, the pot size must always be a compromise between secured planting and practical limits in soil transport.

Table 1: Pot size and the soil needed for one pot

Diameter (cm)	Length (cm)	Volume (cm ³)
4	10	126
4	15	188
5	15	295
6	15	424
6	20	565
7	15	577
7	20	770
8	15	754
8	20	1005
9	20	1272
9	25	1590
10	25	1963

The pot size also depends on the tree species. Broad-leafed trees or fruit trees required larger pots than eucalyptus.

The need for plastic tubes

Plastic tubing is usually the most important piece of imported material in the nursery. Plastic tubes are needed early in the nursery production preparations: at the start of pot filling. The amount to be procured should be calculated carefully.

The corresponding plastic tube order should also be placed well in advance, at least 6 months prior to the time needed.

<i>According to work plans the following amounts of seedlings need to be produced:</i>		
- Project A	3.5 mill	54%
- Project B	1.4 mill	21%
- Project C	1.6 mill	25%
<u>Total</u>	<u>5.6 mill</u>	<u>100%</u>
<i>One reel of plastic tubing is enough for 4500 pots and one cartoon contains two reels, therefore.</i>		
- Project A needs	778 reels or 389 cartoons	
- Project B needs	311 reels or 156 cartoons	
- Project C needs	356 reels or 178 cartoons	
<u>Total</u>	<u>1445 reels or 723 cartoons</u>	
<i>Or, based on plastic tube weight – one kg of plastic tubing is enough for 950 pots.</i>		
- Project A needs	3684 kg or 36.84 quintals	
- Project B needs	1474 kg or 14.74 quintals	
- Project C needs	1684 kg or 16.84 quintals	
<u>Total</u>	<u>6854 kg or 67.42 quintals</u>	

14.6 Potting methods

The plastic pots are filled with soil mixture either by hand or by using a funnel. The pots are filled first from the bottom to a height of about 5cm. This bottom soil is compacted. The remainder of the pot is filled loosely. Packing pots in stages is important to avoid air pockets inside the soil. After filling, the pots are transferred to beds where they are packed tightly in an upright position to await seed sowing or seedling transplanting.

Seedbeds

The soil used for seedbeds in nurseries is often the locally occurring topsoil. It is better; however, if a separate mix can be used for seedbeds to cater for the special demands of germinating seeds. Seedbed mix should be sieved through a 2-mm mesh sieve to ensure larger particles do not interfere with germination. It is even more important than for potting mixes that seedbed mixes should be well drained as disease is especially prevalent in germinating seeds.

Light-textured mixes also allow the roots to be removed more easily without damage at pricking-out (transplanting) time. The soil in seedbeds should be neutral or slightly acidic as this leads to better nutrition and lessens the chance of severe disease outbreaks. The proportions of soil and sand to use for a good seedbed mix depend on the specific particle-size distribution at a given nursery. A mix of one part river sand and one part sandy loam soil should usually be suitable. There is no need to add compost to seedbeds as the seedlings will not grow there for a sufficiently long time to require large amounts of nutrients. Indeed, compost often increases the severity of disease in non-pasteurized mixes.

Sieving and mixing

The potting-mix components should all be sieved before mixing together so that no large clods, stones, roots, etc., are present in the final mix. A mesh size of about 1-cm is usually adequate, but 5-mm mesh is preferred and often recommended. The sieves in most nurseries are made with the same wire mesh used to make beds, and they have proven quite satisfactory. For seedbed soil, a 2-mm mesh sieve is better. For covering seed and for refilling holes during pricking-out, it is best to use fine sand which is below 1 mm in diameter. If such fine sand is not available, then at least the sand should be sieved through a 2-mm mesh.

After sieving, the dry components are thoroughly mixed to provide a uniform distribution of soil, sand and compost. The different components should be measured by volume, for which a wheelbarrow is convenient as a unit of measurement. To facilitate easier mixing, it is good to dump single barrow loads of the various mix components in alternating sequence into a heap. This heap is then turned over to make another adjacent heap. This process of repeated turning is continued three or four times, backwards and forwards, to obtain a uniform mixture.

Filling pots

After the preparation of a suitable potting mix, and having cut polythene tubes to the required length, you can begin pot filling. The soil mix should be moist but not saturated to facilitate rapid filling of pots to the required density. The labor and time spent on filling tubes is a major component in the cost of running nurseries and so this task should be carried out efficiently.

If open-ended tubes must be used, it is only necessary to compact 3-5 cm of soil in the bottom of the tube. This can be conveniently done with a flat-ended round stick of about 4-

cm diameter. Alternatively, a tube is compacted by hand pressure at the top end only after filling and the tube is then inverted when it is placed in the pot beds.

The rest of the tube should be filled with quality soil mix to the top of the polyethylene, with only slight compacting so that air pockets do not develop in the tube. The development of air pockets is especially likely with longer tubes and this is the main reason why tubes with a diameter of 5 cm should be no longer than 20 cm.

The filled tubes can conveniently be stacked and carried to pot beds in robust planting trays. The tubes must remain in a vertical position all the time, in contrast to the compacted soil tubes which are stacked horizontally for convenience of nursery workers. Pots should be placed into pot beds exactly vertically to prevent roots growing unevenly within the pot. Pots should be packed tightly, but without deformation. This will leave spaces for drainage of any excess water between pots.

14.7 Basic nursery equipments and tools

Even if seedling production can begin with a minimum of infrastructure and tools, and the nursery appears to run well producing good seedlings for the first year of planting, a further plan for additional equipment and material must be prepared as soon as possible. The orders for materials must be placed well in advance, and the building of infrastructure (stores, shelters, office, housing, etc) should start at an early stage. By careful planning the nursery will run smoothly later when it is in full production.

Table 2: The minimum equipment needed for a labor intensive model nursery with the production capacity of 0.6 to 1.0 million seedlings per annum

S/N	Type of material	Unit	Quantity
1	Buckets	No	10
2	Watering cans	No	25
3	Measuring tape, 50m	No	1
4	Ropes (local material)	Metered	50
5	String, plastic, 50 m	No	1
6	Sieves for sieving soil	No	3
7	Seed bed labels	No	100
8	Sacks	No	10
9	Bags	No	20
10	Boxes	No	20
11	Rakes	No	10
12	Hoes	No	20
13	Spades	No	15
14	Root pruning knives (Secateurs)	No	15
15	Sharpening stones	No	2
16	Crowbars	No	4
17	Shading mats	No	20

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MODULE 15: SEED PREPARATION FOR BIOLOGICAL CONSERVATION MEASURES



Seed supply, processing and storage

15.1 Seed

A seed is a small embryonic plant enclosed in a covering called the seed coat, usually with some stored food. It is a ripened plant ovule containing an embryo and a propagative part of a plant, as a tuber or spore. Successful raising and growing of trees depends on the right kind of seed, good quality, sufficient amount and availability at the right time. Seed can be obtained from distributors or collected locally.

15.2 Seed supply

In any stand of trees of the same species, whether in natural forest or plantation, the individual trees often appear different in many respects, for example, vigour, health, stem form, branch size, fruit, fodder or resin production. When we wish to produce more trees of the same species, we aim to use plants that have the best characteristics in respect of the product we want. To achieve this, we must collect seeds from trees which show one or more of the desired characteristics. Selecting good trees as a source of the seed (mother trees), however, will not in itself ensure that we reach the goal of growing more trees with the desired characteristics. The ways in which the seeds are collected and subsequently processed, transported, stored and pre-treated also have critical consequences for seed quality and, eventually, the final results of the tree plantings.

Seed orchards can easily be established around nurseries and Farmer Training Centres. These sites serve both for demonstration/teaching and as sources of seeds of desired species. The huge gap between demand and supply of seeds can be easily minimized locally if such approach is followed. Moreover, strategies like organizing landless people in seed collection, processing and marketing will enhance supply of local species. There are, in many woredas, forest areas owned by either the state or the community. These sources can be effectively utilized if such organized groups are engaged in seed production Endeavour. It serves two purposes:- the first is creating livelihood opportunities and the second one is reducing the grave shortage of forest tree seeds

Observable characteristics of a good seed source (site and mother tree)

The first step in good seed procurement practice is to obtain your seeds from well-identified locations and to make good records of the sources. The next step is to examine the quality of the seed source. There are a number of basic conditions that must be fulfilled if an area is to be considered as a seed source:

- The conditions of the locality of the seed source must match as closely as possible the conditions of the locality where it is planned to plant the trees you will grow from the seeds;
- The trees must be sufficiently old and big so that the health, vigour, flowering and quality of the product we are looking for can be satisfactorily evaluated;
- The trees must be healthy and vigorous. The appearance of the trees in respect of the end use (i.e. timber, fuel, fodder, fruit, etc.) must not be inferior to trees of the same species found in other areas in the neighbourhood;
- In years of good climatic conditions most of the trees in the area must flower and set fruit;
- If they do not, the genetic and physical quality of the seeds obtained is not likely to be satisfactory. In the case of plantations, there must be confirmatory records of the health and vigour of the trees. If there is no information about the origin of the trees in the plantation from which you plan to collect seed, then only use the source temporarily until a better one can be located;
- In the case of naturally occurring stands, the location must provide at least 30 healthy and vigorous trees, or groups of trees, spaced at approximately 100m. Trees growing close together are assumed to be related, therefore, it is better to collect seeds from trees that are far apart which represent wider genetic variation;
- In plantations there must also be a minimum of 30 healthy and vigorous trees. However, there is no requirement for a minimum spacing other than the spacing required for good crown development, good flower and fruit production. In plantations, neighbouring trees are assumed not to be closely related provided the seed from where the trees originated were collected properly;
- If collecting seeds from 30 trees, or groups of trees, does not provide a sufficient amount of seed, and then do the following:
 - In plantations, simply increase the area you collect from until the demand for seed is met. As an alternative, other areas may be located. In natural stands, collect from trees in between the 30 initially selected trees but make sure you collect from specimens in all directions around the initial 30 trees.
- The source must be reasonably easy to reach with a vehicle. Only if there is no other choice should an inaccessible location be chosen as a seed source; and
- It should be possible to protect the seed source from destruction or damage such as by browsing, cutting and lopping by humans, or fire.

a) Seed collection techniques

There are various methods for collection of tree seed. In each case the choice of method depends on many factors, for example type of fruit, kind of tree, stand and site characteristics, amounts to be collected, available equipment, safety, weather and, of course, the skills of the staff available. Details of techniques and methods will not be discussed here. But only some important points to remember when planning and carrying out seed collections are mentioned below.

Four rules are important when locating seed trees and when collecting seed:

- i) Any tree you collect from must be healthy and show vigorous growth;

- ii) Avoid collecting the earliest maturing fruits or seeds or those that have fallen to the ground. Such seeds are often damaged by insects or are empty. If there is no alternative, then check a representative sample of seeds to see if they are viable;
- iii) In the case of fruits that have a soft moist pulp (pericarp), do not collect those that have become brown or black, or where the pulp has dried out or become fermented; and
- iv) Avoid collecting fruits or seeds that have come into contact with the soil as this will often result in the seed being contaminated with various fungi.

b) Seed processing

The collected seeds need to be dried to the required moisture content prior to storage. Do not store wet or fleshy seeds and fruits since they easily rot and get spoiled. Therefore, the collected seeds must be spread over canvas or mats for drying in the sun and air. During the drying process, turning over of the seeds until they are fairly dried is necessary. To separate some seeds from their fruits, threshing and winnowing may be required. After the seeds are well sorted, they should be packed in sacks or bags and stored in a dry place.

Seed processing may require also extraction from the fruits or pods and drying them before sawing. If seeds are enclosed in a fleshy fruit, remove the flesh with knife, wash off the rest under water and sow the seeds immediately. For seeds in a seed pod, such as *Luceana leucocephala*, let the pods split open naturally by laying them in a semi-shade place. Similarly for other fruits with hard coat, drying them in semi-shade or gentle cracking could be applied.

c) Storage of seed

The seed storage needs to be free from moisture, a well ventilated and raised bed and free from pests. In order to keep the seed cool, storage along a wall facing a south westerly direction should be avoided since this wall tends to be warmer than the other walls during the afternoon. Also seed should not be stored too high in the building because hot air will concentrate under the roof. The sack, jars, or boxes with the seed must be placed in such way that air can circulate around each container. For this purpose shelves can be placed in the store. Some seeds can be dried to low moisture content of about 5% and be stored successfully at low temperatures. Others cannot survive drying below 20-50% moisture content. Therefore, seed storage requires the knowledge of the nature of the species. Several species of leguminous and other plants have high longevity (surviving for long years), For example, seeds of Acacia, Albizia, Cassia, Leucaena, Prosopis, Hibiscus etc, can be successfully stored for more than 20 years

15.3 Preparing seed for sowing

Amount of seed for raising seedlings

The amount of seed we need to purchase depends on the purity of seeds and germination percent. For example if we want to produce 60,000 seedlings of a given species the amount of seed we want to avail is calculated as follows:

Purity percent

In order to calculate the purity percent of a certain seed lot, take a sample of 10 gram and count the number of good seeds (assume 284 seeds), then convert to number of seeds per kg which is 28,400seeds. Then to arrive at the purity percent weight of the pure seeds, which can be only 8.6gm of the 10 gm sample, then the purity percentage is = $(8.6/10) = 86\%$

Germination percent

Information on germination rates for each seed lot is essential to

- determine appropriate sowing rates and
- calculate the exact total amount of seed required for the planned production levels.

In order to determine the germination percent, count 200 seeds from the pure seeds (record provenance, sowing date). Then count the number of seeds germinated (every week) by removing of counted ones

For example if 32 seeds after one week, 104 seeds after two weeks and 122 seeds after three weeks germinated, then the germination percent of the seed is:

$$=122/200*100=61\%$$

Once we know the purity and the germination percent, how much seed we need to produce 60,000 seedlings is calculated as follows?

Since the germination percent is 61% we need

$$60,000/0.61 = 98,361 \text{ seeds and the weight of these seeds is } = 98,361/28,400 = 3.463\text{kg}$$

Since the purity is only 86%, the total seed we need is

$$3.463/0.86 = 4.027 \text{ kg}$$

Since all germinated seeds does not reach planting site, consider 20% loss which gives us a total of 4.83244 kg. This is the amount of seed we have to order for purchase or collection

Seed pre-sowing treatment

After collection, seeds from many forest trees are completely or partially dormant; they are not ready for immediate germination. These seeds need pre-treatment before sowing. Dormancy has evolved in trees to help their survival and spreading into new areas. A good example is *Balanites aegyptica*, a scattered pioneer species occurring in semi-arid and arid low lands throughout the Sudano-Sahelian belt. If the seeds drop under the mother tree, they will hardly germinate. The fruit of Banalities must first be eaten by animals such as goats before the seeds inside the fruits are ready to germinate. Seeds that have passed through the intestinal tract of ruminants (especially goats) particularly germinate well.

There are 5 different categories of seed dormancy (Maydell 1986):

- Seed coat dormancy,
- Embryo dormancy,
- Immature embryo,
- Induced or secondary dormancy, and
- Double dormancy, combining two or more of the above strategies.

Seed coat dormancy is the most common in dry land species, and it occurs in many legumes (like acacias). The hard seed coat prevents the uptake of moisture, and it must be softened or broken down by pre-treatment.

Dormancy caused by hard seed coat can be overcome by several methods. In a large nursery the most practical way is to immerse seeds in boiling water that is 4 to 6 times the volume of the seed lot. The water and seeds are then allowed to cool for 24 hours. After this, they are ready for sowing. This is the usual practice with *Acacia decurrens*. There are various treatments which can be applied to seed to reduce seed dormancy so that germination becomes more rapid and uniform. This naturally helps to simplify nursery management, and also makes it more efficient and, therefore, cheaper to raise seedlings. The types of seed pre-treatment can include the following.

Scarification

The objective of the scarification method is to reduce the thickness of the seed coat so that it becomes more permeable to water. This can be achieved by nicking, filing, rubbing with sandpaper or rough stones. This method is time consuming and so is usually only used with larger seeds and when the seed source is scarce or valuable. If a cement mixer is available it is possible to scarify large quantities of seed by tumbling the seed with gravel or sand. The nick in the seed coat should be made opposite the point where the seed was attached to the pod; this point is often a tiny light-colored spot at one end of the seed. The nick should be no more than 1mm square to ensure that the embryo is not damaged. Soaking the seed in cold water for 24 hours before sowing, but after scarification, should further hasten germination.

An extreme type of scarification is practiced by removal of the whole seed shell; this is usual with the seed of *Olea europaea* subsp. *africana*, and should also be tried with *Zizyphus* species. Cracking of the seed shell must be done with great care so that the seed itself is not damaged in the process.

Soaking in water

Hot water

Seed-coat dormancy of many leguminous species can be successfully overcome by treating with hot water. This is a quick and easy method and allows the treatment of a large number of seeds economically. A typical treatment might be carried out as follows:

- Boil some water—about 10 times the volume of the seed to be treated;
- Remove water from heat and immediately place the seed in the water; and
- Allow the water to cool gradually with the seeds in it.

The seed should be sown immediately and not dried or stored. Sometimes, soaking for further 24 hours will improve germination rates and speed. The precise temperature of the hot water into which seeds should be immersed varies with species, as does the most suitable period for soaking. Do not allow the water to heat to boiling point as this is injurious to most species.

Cold water

Many seeds germinate readily after soaking for 24 hours in water at ambient temperature. Prolonged soaking may benefit some species, but unless the water is changed daily there is risk of injurious effect on the seed. The use of running water to leach out inhibitors from the seed is also an effective pre-treatment for some species. A useful way to separate viable seed from non-viable seed and chaff is to float the seed in cold water. Viable seed are heavy and tend to sink, while non-viable seed are light and tend to float.

Chemical treatments

A wide range of chemicals have been used for seed pre-treatment, including acids, hydrogen peroxide, potassium nitrate, silver nitrate, potassium permanganate and a variety of trace elements. The most widely used of the chemical methods is the use of concentrated commercial sulphuric acid. The seed is soaked in the acid for a period long enough to weaken and soften the seed coat but without damaging the seed. A period of 10 minutes may be sufficient, but up to 1 hour may be necessary for maximum germination in some species. After removal from the acid, the seed must be thoroughly washed to ensure that all the acid is rinsed off the seeds.

The species which respond well to acid treatment are usually those which also respond well to scarification or treatment with boiling water (e.g. hard-coated leguminous seed), and it is

often reported that equally good results can be achieved by any of these methods. Which method you chose, therefore, may depend mainly on which method is most convenient. The danger posed by the use of concentrated acid by unskilled workers is, however, a serious disadvantage. The dangers of acid to safety of workers and equipments suggest it should not be used for routine pre-treatment of seeds.

Time of sowing

If seed can be stored for sometime without undue loss of viability, then you can be flexible in deciding convenient sowing dates. If, on the other hand, seed rapidly loses viability in storage (e.g. *Azadirachta indica*) it should be sown as soon as possible after collection. If seed can be stored, then the sowing date is primarily determined by the anticipated date of planting and the size of the target seedling that is desired at that time. In the Ethiopian highlands the seedlings should be ready for planting any time after the beginning of July, by which time the rainy season is usually established and labour for planting has been organized.

The target seedling at planting time should be about 30 cm tall if 15-cm long tubes are used and about 40 cm tall with 20-cm long tubes. The sowing date can then be decided if we know how long it takes to produce a seedling of such height. The time to grow the required seedling is subtracted from the planting date and this provides the sowing date. In order to decide what will be the correct sowing date you should allow sufficient time for the following:

- Pre-treatment of seed before sowing,
- Sowing,
- Germination,
- Pricking-out,
- Growing seedlings to the required size,
- Hardening-off, and
- Grading.

The time required for several of the above operations is very much dependent on the species grown. This applies especially to the time required for germination and the time required to growing a given species to the required size. Time required for hardening-off should be about a month, but this is an operation which is frequently not allowed for in the calculations used to decide sowing dates. The environmental conditions at a particular nursery also affect the growth rates of seedlings, the most important being temperature, which is highly correlated with elevation. Other environmental factors of some importance are wind, relative air humidity and frosts or minimum temperatures. Frost in particular may dictate that sowing time. Frost sensitive species are delayed until at least February, by which time the probability of frost is reduced. The best guide to sowing dates should be based on the experience obtained at each individual nursery from the results of previous years. The use of a production calendar showing the dates of sowing, pricking-out, etc., is most useful to record current operations and help to plan operations for the following year.

If a large amount of seed needs to be sown, it should not all be sown at the same time because there will be a peak in germination and many seedlings attaining the same size. Unless there is abundant suitable casual labour, it will be difficult to prick-out all the seedlings at the correct time. It is, therefore, advisable to sow large seed lots over a period of several weeks. This will also help to produce more uniform plants at planting time because the seedlings produced from the earlier sowings can be planted before those from later sowings.

If the sowing date is too early, large plants with a poor root/shoot ratio will be produced. This situation can be partly salvaged by shoot pruning of excessively long seedlings. Most broad-leaved species, including *Acacia* and *Eucalyptus*, can be shoot pruned once or even twice and this restores a more favorable root/shoot ratio, which is helpful for obtaining good survival after planting. If sowing is done too early, it will be necessary to root-prune repeatedly and this adds to the cost of raising seedlings. Hardening-off should be started earlier than initially anticipated if it appears that otherwise the seedlings will be too large at planting time. This should result in control of further height growth while allowing some increase in diameter of the seedling stems, and so good quality seedlings can still be produced.

If sowing is done too late, the seedlings will be too small at optimum planting time and it is likely that there will be no time for hardening-off. This combination of small, unhardened seedlings is likely to result in poor survival after planting. From the above considerations it is evident that sowing too late is likely to present worse problems than sowing slightly too early. Early sowing should help to produce well-hardened seedlings, but nursery costs will be higher because of higher labor costs incurred over a longer growing period. If there is insufficient labor to effectively root-prune, great care should be taken with determination of sowing dates so that overgrown plants with poor root systems are not produced as a result of sowing too early.

Sowing methods

When deciding on raising tree seedlings there are two basic options available. One consists of sowing seed directly into the **container** in which the seedling will remain in the nursery. The alternative is to sow seed at a relatively high density into **seedbeds** or seed trays where they germinate and are allowed to grow for only a short time before being pricked-out (transplanted) individually into new tubes. Some species are better suited to grow in pots and others can be conveniently grown as bare-root seedlings, while many species can be raised by either system.

Although direct sowing is usually more convenient, sometimes it is necessary to use seedbeds or seed trays and to prick-out the seedlings. A major advantage is that germination of seed can be concentrated in a small area, rather than spread through the whole nursery. This allows specialized techniques to be used under close supervision. In particular, improvements can be made to the sowing medium and to watering, shade and protection from insects, diseases and rodents. Seedbeds or seed trays are also recommended when:

- Viability is expected to be low (less than 40%);
- Germination is prolonged and erratic;
- Seed is very small, e.g. *Eucalyptus*;
- The seed is scarce or expensive; and
- Several plants germinate from one stone, e.g. *Melia azedarach*.

Sowing directly into pots

For seeds which are large enough to be handled individually, and which usually have a good germination rate, direct sowing of one or more seed into pots is often the best method. A particular advantage of direct sowing is that root damage and root deformation, which can result from pricking-out, are avoided. Genera that are usually sown in this way include *Acacia*, *Lucaena*, *Balanites* and *Azadirachta*. Pots should be thoroughly watered on the evening of the day before and lightly again after sowing. After seed is sown, watering should only be done with a watering can that is fitted with a rose that has small holes and, therefore, delivers a fine water spray which does not cause soil erosion and possible seed

displacement. This is especially important for smaller-seeded species where the seed is close to the surface.

The foremen use coarse water roses because watering is faster, and if it is done with shades or mulches these do help to reduce the erosive impact of coarse water sprays. After shades are removed, however, it is essential to use fine water sprays for germinating seeds and small seedlings. The seed should be sown in the centre of the tube at a depth equal to 2-3 times its smallest dimension, but in any case the top of the seed should be no more than 10 mm below the surface.

It is usually necessary to sow two or more seeds in each pot. The right number depends on the germination rate expected. It is wasteful to sow too many seeds and this also results in greater thinning costs at a later date. As a general rule, sow 1-2 seeds per tube if field germination capacity (FGC) is expected to be over 80%, 2 seeds if germination is 60-80 %, and 3 seeds if germination is 40-60 %. Seed with less than 40% germination should be sown in seedbeds and pricked-out. If germination capacity is over 80% half the pots should be sown with 1 seed, the other half with 2 seeds. The extra seedlings can then be used to prick-out into any empty tubes. Some species, such as *Rhamnus prinoides* (*ghesho*), are difficult to prick-out and should, therefore, be directly sown.

After germination there will be 0, 1, 2, or more seedlings in each pot. When germination is almost finished, prick-out plants from pots that have more than one seedling into pots without any germinant. This may still leave some pots with more than one seedling. If the extra seedlings are not removed, they must share the nutrients, moisture and light that are available for one pot and as a result inferior plants will be produced. During germination, twice daily watering is usually required, but as soon as roots penetrate a little into the soil it can be reduced to once per day.

Direct sowing is frequently also used for species with fine seed such as *eucalyptus* and *Casuarina*. The technique consists of first loosening the surface soil in the tubes, which is hard because it was previously compacted during pot filling. This loosening is done by careful digging to a limited depth with a wooden dibble or similar stick. Next, a "pinch" of seed held between thumb and forefinger is placed in the tube and the top stirred with a dibble or similar item. Sometimes a small amount of soil is also added to the pot after sowing.

If non-compacted tubes are used there is no need to dig up the surface of the potting mix, which creates an irregular surface not conducive to even germination. If the germination rate of the seed is known it can be appropriately diluted with fine sand or, preferably, with sawdust (sieved through a 2-mm mesh sieve). A practicable method is to carry out germination tests with a small volume of seed, and then to use the same volume for application of diluted seed to each pot. Simple arithmetic will indicate the degree of dilution required to obtain an average of 2-3 seedlings per tube.

Sowing in seedbeds

For preparation of seedbeds the essential requirements are good drainage, light texture, and absence of pests and pathogens. The sowing methods for seedbeds are similar to those used for seed trays, as described above. However, the use of sup-irrigation is more difficult with seedbeds and is not recommended. Also, because seedbeds are fixed, they are less flexible than seed trays which can easily be moved to make work more convenient.

Sowing of small-seeded species should be done by broadcasting not sowing in lines which is more wasteful of space and produces less uniform seedlings due to crowding along sowing lines. Larger-seeded species (for which seedbeds are not usually employed) should be sown individually in lines which are established running across the beds.

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MODULE 16: SEEDLING PRODUCTION FOR BIOLOGICAL GULLY CONSERVATIONS



Seedling production

16.1 Seedling

Seedling is a young plant which can be newly sprouted or several weeks old and ready to set out in the garden. It can be a plant or tree grown in a nursery for transplanting or directly sown and made to grow on its permanent area. Seedlings can be raised in containers (pots or tubes), or as bare-root seedlings grown directly in the soil beds at the nursery site. Some species are better suited to grow in pots and others can be conveniently grown as bare-root seedlings, while many species can be raised by either system. There are many factors to consider when selecting the most appropriate system for raising seedlings of different species. It is important to consider the advantages and disadvantages of the two (potted or bare rooted) alternatives before deciding which to use.

16.2 Types of seedlings (propagation methods)

Seed propagation is not a technique whose primary goal is to produce more seeds. The aim of seed propagation is usually to produce more plants. There are other methods of seedling productions such as the use of plant cuttings or root cuttings, but the use of seeds tends to be the most common. Seed propagation is a technique used all over the world.

Many people buy seeds they want to propagate in the same manner that they buy other gardening supplies. Some people collect the seeds from existing plants that they select for reproductions. The condition of the seed is very important because unhealthy seeds can produce unhealthy plants or may not grow at all. For this reason it is necessary to make sure the seeds obtained are not diseased or outdated. There are also other factors that can have a negative effect on viability of seeds. One example is foreign origin seeds. Some seeds originated from one country may not be able to grow in certain other countries.

Another factor that plays a major role in seed propagation is the soil conditions. In order to be successful, the seeds generally need to be placed in soils that are well aerated and have good moisture. They need also to be placed at a depth that is conducive to their growth.

Propagation can take place either indoors or outdoors. One of the factors that determine the best option is, of course, the type of plant being grown. Both options have their advantages and disadvantages. For example, indoor growing may require the purchase of special lighting or the regular manoeuvre of plant containers to sunny areas. Outdoor seed propagation offers the benefit of free natural light, but the disadvantage is that the weather can determine what is to be grown at a given period of time.

Despite all of the conditions, it is rare for seed propagation to have a 100 percent success rate. This means that every seed will not become a plant. In addition, there are some plants that can only be reproduced by seed and, on the contrary, there are some plants that cannot be reproduced by this method.

Generally, seedlings can be grown in nurseries in 3 different ways

- from seed in plastic pots or as bare rooted;
- from cuttings, usually as bare rooted, or can be propagated; and
- through direct sowing.

Potted seedlings

During the past 20 years, the manual production of potted stock has been well-adapted in every region of Ethiopia. Potted seedlings have clear advantages.

Advantages

- The chain of seedling production is simple to teach to casual labour. Many stages of the work can be paid on a piece-rate basis and nursery management becomes simple;
- Potted seedlings can endure longer transport periods than bare rooted seedlings; The roots are not exposed to air drying during lifting, transporting and planting;
- Under Ethiopian climatic conditions and with difficult planting sites, the survival of potted seedlings is better than with bare rooted stock;
- The time in the nursery is usually less than for bare-root stock;
- They require less space in the nursery than bare-root seedlings of the same size;
- The availability of good soil at the nursery site is not an essential requirement as potting mix ingredients can be imported into the nursery;
- Soil-borne diseases are likely to spread more slowly than in bare-root seedlings;
- A longer planting period is possible than with bare-root seedlings; and
- Satisfactory results are possible with a relatively untrained planting labour force.

Disadvantages

- A great deal of soil is needed to fill the tubes and also a significant amount of soil must be transported with the pots;
 - They require regular root-pruning in the nursery;
 - They are heavy to transport and, consequently, reliable and timely transport to the reforestation site during the planting season is necessary;
 - They are more complicated to raise seedlings especially if seeded in germination beds before pricking-out into tubes;
 - The lack of availability of plastic tubes may be a bottleneck. Containers must be purchased; this will incur some cost and requires appreciable forward planning if they need to come from overseas;
 - They are more expensive to produce than bare-root seedlings; and
 - Foliage and shoot diseases are likely to be more severe due to closer spacing of seedlings resulting in higher air humidity.
- The advantages, however, outweigh the disadvantages, and the final result is vigorous saplings in the field that grow into fully stocked stand.

Bare rooted stock

Bare rooted stock is not common in tropical countries. This method is better suited to temperate zones where seedlings have winter dormancy. During dormancy periods, seedlings can be transported easily, and they can also be stored temporarily at the planting site to wait for planting. In tropical climates, even the transport of bare rooted seedlings, let alone the storage, is difficult because of their non dormant nature.

Bare rooted stock, however, is cheaper to produce than potted stock. The method of bare rooted seedlings has not yet been fully exploited, and it is possible that it will have a future in the planting programs in the moist western regions of Ethiopia.

Advantages

- They are normally less complicated to grow in the nursery;
- They are not so heavy; therefore more seedlings can be loaded on a vehicle for transport to the plantation sites;
- Each planter can carry more seedlings to the planting site;
- They are well suited to mechanization, which is an advantage if labour costs are high;
- They are well suited to large centralized nurseries for economical seedling production; and
- They are cheaper to produce than potted seedlings.

Disadvantages

- They usually have a lower survival rate than potted seedlings when planted on unfavourable sites;
- The roots are susceptible to air drying during lifting, transporting and planting and therefore require more care and supervision during these operations;
- They require more space in the nursery than potted seedlings;
- They need a little more time in the nursery;
- They are more complicated to store at the planting site if, for any reason, planting cannot be done immediately;
- The nursery must have good soil conditions. It is especially important that the soil texture be light and that drainage is good;
- Planting time is more restricted than for potted seedlings; and
- Root diseases are more likely to become a problem because pathogen populations can build up during successive years of using the same soil.

Experience world-wide, indicates that in a semi-arid environment (i.e. with unreliable rainfall below 700 mm per year) survival and establishment is usually improved if containerized (not bare-rooted) seedlings are used. This is especially so if the bare-rooted seedlings are planted on poor soils where watering after planting is not practicable.

Bare-root seedlings, stumps and wildings

Bare-root, or open-root, seedlings are cheaper to produce and plant than stock grown in containers, but they also have numerous disadvantages. The main requirements for successfully using bare-root seedlings are favourable climate and soils, and the availability of reliable transport and labour for planting. These limitations make the use of bare-root stock of limited applicability. A few highland nurseries have grown *Eucalyptus globulus* and *Acacia saligna* as bare-root stock for use by individuals who are able to provide watering after planting. Some species like *Azadirachta indica* (neem) are often produced successfully as bare-root plants even in dry climates. Many aspects of growing bare-root plants are similar to production of container stock, but there are also some major differences.

The soil:- Bare-root seedlings are grown directly in the soil present at the nursery site. Therefore, this soil must be of a suitable sandy loam texture and the site must be very well drained. If repeated crops of seedlings are envisaged, it will be necessary to add some compost, manure or chemical fertilizer annually to replace the nutrients removed with the seedlings. The soil must be cultivated to a depth of 30 cm and weeds should be eliminated.

Plant density and area required:- Plants should be grown in rows 20-25 cm apart, and spacing between seedlings should be 5-10 cm. The area required for bare-root seedlings is, therefore, much greater than that required for tubed seedlings. There should be 50-100 bare-root plants per square meter, compared to 400 per square meter with 5-cm diameter tubes.

Sowing and pricking-out:- Species with large seeds can be sown directly into beds, but for smaller-seeded species pricking-out (transplanting) is preferred. If direct sowing is used, it is important to thin seedlings to the required spacing of 5-10 cm between plants at an early age so that there is no undue competition.

If pricking-out is done, it should use similar methods to those described for tubed seedlings. As there is more room in the open-root bed, it is possible to make larger holes for receiving the roots of the seedlings; therefore the roots can be slightly larger than those used in tubes. Seedlings with roots 5-10 cm long and shoots 3—5 cm tall are suitable for pricking out to produce bare-root stock.

Root-pruning:- This is an essential operation which must be repeated several times during the growing period. Root-pruning can be done by inserting a spade at an angle of about 45 degrees and a distance of approximately 10 cm from the stem of the seedling and lifting slightly after inserting the spade into the soil. This must be done from both sides of the seedling to effectively cut or break roots which have become too long. In addition, insert the spade vertically between seedlings to cut roots that are growing along the direction of the row. This root-pruning should be repeated at intervals of about six weeks.

Lifting and packing:- A spade or flat-pronged fork is inserted vertically about 10 cm from the seedling and pushed deep enough to permit lifting the plant with the majority of its root system intact. The soil is removed by carefully shaking the seedling, and any long roots are pruned with a sharp knife. After grading, which should include an assessment of the root system to ensure it is well developed and in balance with the size of the shoot, plants are packed. It is essential that the roots are not allowed to become dry at any time, so work should be under shade as far as possible. Use of well watered sacks, grasses, sawdust, etc helps to keep the roots moist and healthy.

After this, wrap the roots well in plastic bags to further reduce evaporation. Time taken before seedlings are planted should be as short as possible to minimize desiccation of seedlings. Unless seedlings are of very high quality, watering in any dry spell after planting may be essential to obtain satisfactory survival and establishment.

Cuttings (Vegetative propagation)

Vegetative propagation is the production of new plants directly from vegetative parts of existing ones, not from seeds. There are numerous methods of vegetative propagation including cuttings, layering, division and grafting. The techniques involved in vegetative propagation are usually more technical than propagations using seeds.

Vegetative propagation

Vegetative, or asexual, propagation is used to produce a plant identical in genotype with the source (mother) plant. This is in contrast to propagation from seed where every individual has a different genotype and may, therefore, have properties quite different from the mother

plant. Vegetative reproduction is the production of new plants directly from vegetative parts of existing plants.

There are four broad categories of methods which can be used in vegetative reproduction:

- 1. Cuttings and layers:-** This is a method in which new roots and shoots are developed on sections of shoot, root or leaves taken from the mother plant.
- 2. Grafting and budding:-** This is a method in which the root system of one plant is joined with the shoot of another plant to form a single composite plant, which in effect has two genotypes.
- 3. Division and separation:-** This is a method in which naturally formed special vegetative structures such as rhizomes, runners, suckers, tubers, bulbs, corms, or bulbils, are used to produce new plants.
- 4. Micro propagation:-** This method (also known as "tissue culture" or "in-vitro culture") is a relatively new technique in which new plants are produced from very small structures (embryos, shoot tips, meristems) in aseptic cultures. The method requires considerable technical expertise and equipment but has great potential to produce very large numbers of identical seedlings. It is now used in several countries for establishment of extensive commercial forest plantations with genera such as *Eucalyptus*, *Pinus* and *Populus*. Associated with micro propagation are techniques of *genetic engineering* which enable further improvements in producing genotypes which have desired *ecological* and *commercial* properties. Such technologies have become an important aspect of modern plant propagation and breeding and are included in the term "*biotechnology*".

Reasons for using vegetative propagation may include the following:

- Seed is not always available, germination of some seeds is difficult, or successful nursery techniques for a given species (seed) have not been developed;
- An individual mature plant may exhibit very desirable features (e.g. fast growth rate, disease resistance, drought or salinity tolerance, abundant fruit etc) which are genetically determined;
- Multiplication of such individuals, maintaining the exact genotype of the mother plant, is possible only with vegetative reproduction. These genetically identical individuals form a "clone". Cloning thus provides for multiplication of specific selected genotypes;
- The members of the clone should all exhibit the desirable features of the mother plant if they are grown in a similar environment. This represents a much faster method of genetic improvement than is possible through conventional breeding programs based on sexual reproduction and growing successive generations from seed;
- Fruit trees will have the superior quality and quantity of fruit that is evident in the mother tree;
- The age at which fruit trees start to bear fruit is reduced. In general, vegetative reproduction results in earlier maturity;
- It helps to combine the advantageous qualities of two plants by grafting or budding. For example, this enables the shoot to be from a tree which produces a high yield of quality fruit while the root system comes from a tree that is vigorous and disease resistant. This is the reason why the majority of fruit trees in temperate countries are reproduced by vegetative methods;
- In contrast, the majorities of fruit trees in tropical countries are still of seedling origin, and hence often have reduced quality and quantity of fruit;
- Artificial hybrids between two species may have good commercial properties but their seed is often sterile. Vegetative propagation may offer the only practicable method for multiplication of such hybrids; and
- If micro-propagation is used, a large supply of planting material can be produced in a short time from very little mother plant tissue.

There are also disadvantages which may be associated with vegetative reproduction:

- Disease transmission is often associated with vegetative methods. This is especially relevant for viral pathogens which are transmitted through sap. Viruses are relatively rare in forest trees but are quite common in fruit trees. This problem of pathogen transmission, especially with grafting or budding, can be reduced by ensuring that only specially selected pathogen-free mother trees are used.
- Genetic uniformity within monoclonal plantations can lead to uniform susceptibility to insects, diseases or other environmental hazards. Such a monoculture can be particularly vulnerable to the introduction of a new pest or pathogen into the locality, and it might result in extensive losses of plants.
- The technical skill and equipment required to effectively implement vegetative propagation is often greater than that required for propagation from seed.

Cuttings are sections of stems, roots, branches, leaves or twigs gathered from suitable mother trees or shrubs. They are placed with part of their length in a suitable rooting medium to induce the formation of new roots at the basal end and the development of leaves and shoots on the upper portion. A cutting thus grows into a new individual plant which is a clone of the mother plant.

Cuttings are the most important means of propagating ornamental trees and shrubs, deciduous as well as evergreen species. For species that can be propagated easily by cuttings, this method has numerous advantages. Many new plants can be produced in a limited space from a few mother plants. The method is inexpensive, rapid and simple and does not require the special techniques required for grafting, budding or micro propagation. There is no problem of incompatibility with rootstock or of poor graft unions. Greater uniformity is obtained by absence of the variation which sometimes appears as a result of the variable seedling rootstocks of grafted plants.

There are several types of cuttings, which are classified according to the part of the plant from which the parts were obtained, as follows:

- Stem cuttings
- Stem cuttings are further subdivided into hardwood, semi-hardwood, softwood and herbaceous.
- Root cuttings.
- Leaf cuttings.

Cuttings are grown in special beds called propagation beds. Propagation beds for cuttings have to provide excellent environmental conditions that are not only favourable for the formation of new roots, but also for all other life processes within the newly developing plant. The most important environmental factors for successfully growing (striking) cuttings are proper soil aeration (good oxygen supply), adequate moisture content of the rooting medium, as well as a high humidity of the atmosphere, good light conditions and a favourable soil and air temperature. After root growth is initiated, it is also important that there are sufficient nutrients available to enable continued root and shoot growth.

Direct sowing

Direct seeding establishes trees, shrubs, and under storey plants by sowing seed directly onto the site to be re-vegetated. Whether it is sowing by machine or by hand, a good site preparation and effective weed control are essential for the success.

Advantages

The advantages of direct seeding over seedling planting are many:

- Direct seeding is much cheaper (10 - 20% or less of the cost of planting tube stock), and requires minimal labour.
- Existing farm equipment can be used.
- Higher plant density after germination provides better shelter to new seedlings and reduces weed competition. It also allows natural selection to sort out the stronger from the weaker plants without creating gaps to be replanted.
- Plants are able to “self select” suitable establishment sites within the re-vegetation area, particularly if a mixture of species is sown.
- The plants are usually healthier and have stronger, deeper root systems because they are not transplanted and there is no disturbance to root growth. This enables plants to be more tolerant of stressful conditions such as pest attack and drought.
- Final plant cover is random, and looks more natural than planting.
- Little maintenance is required after plants are established, apart from ongoing weed control for at least the first season.

Disadvantages

The disadvantages of direct seeding are:

- Direct seeding is limited to plants that grow readily from seed;
- A large amount of seed is required. Hence, if only minimal seed is available for a particular species, it may be better to raise seedlings for that species in a nursery;
- Plants germinating under field conditions are extremely vulnerable. Frosts, spring droughts, or flooding of the sowed area can dramatically reduce seedling establishment; and
- The initial density of plants is harder to control. This may create undesirable spacing for quality timber production, but can be overcome by “spot” sowing.

Uses for direct seeding

Direct seeding is suited to re-vegetate large areas for:

- Conservation structures on farmlands such as soil bunds, gully and fanyaa juu;
- Rehabilitation of gullies and degraded areas; and
- The application of direct seeding is described in biological soil conservation manual.

16.2 Quality seedlings

Once a nursery is established, there are many management considerations relevant to the effective and economical production of quality seedlings. Nursery management can be viewed as the day-to-day activities which are performed within an annual time frame to produce maximum number of quality seedlings in the most economical way. In order to effectively manage a nursery, the nursery manager must have a clear idea of what type of planting stock the nursery should produce at the end.

The kind of high-quality drought-resistant seedlings that should be produced at the end can be conveniently termed as "target seedlings". Such target seedlings have qualities that give them a high probability of survival after planting and good growth rates after establishment. The desirable characteristics of drought-resistant target seedlings can be specified as follows:

1. Seedling height is approximately twice the height of the container;
2. The root-collar (or stem diameter at soil level) should be thick in relation to the height resulting in a sturdy seedling;

3. The root system should be well developed with an abundance of fine fibrous roots penetrating the whole volume of the container. This will help to produce seedlings with a good root/shoot ratio;
4. There should be minimal development of roots beyond the container, and a vigorous taproot should not be allowed to grow below the container.
5. The seedlings should be adequately hardened-off so that by the time they are planted out they will be adapted to conditions of full sunshine and moisture stress as well as low humidity and increased wind;
6. The appropriate microbial symbionts should be present on the root system. This implies the following for three different taxa of plant species:
 - a. *Most legumes*: should have macroscopically visible nodules formed by symbiosis with *Rhizobium* bacteria, thus allowing nitrogen fixation. The presence of appropriate mycorrhizae will further improve nutrient absorption and drought resistance.
 - b. *Casuarina*: should have macroscopically visible nodules formed by the Actinomycete known as *Frankia*. This will allow symbiotic nitrogen fixation which would otherwise does not occur. Again, the presence of mycorrhizae is beneficial to further stimulate growth and drought resistance.
 - c. *Eucalyptus and most other tree species*: should have suitable mycorrhizae to improve nutrient absorption from infertile soils and the water-absorption capacity of seedlings.
7. The seedlings should have desirable physiological characteristics, including the following:
 - a. High root-growth potential after planting;
 - b. Adequate starch and other food reserves in both stem and roots;
 - c. An adequate nutrient so there is no deficiency in either macro- or micronutrients, nor an imbalance in their proportions;
 - d. Resistance to water logging. This can be important if heavy rains follow planting, causing planting pits to become saturated. Larger plants are more tolerant of water logging;
8. The root system should not have spiralling roots or other deformities which can lead to problems after several years.

As far as possible, the target seedlings should possess all the above seven characteristics of a quality seedling. To achieve this is the primary task of nursery management. Good supervision is essential to the successful management of a nursery and requires good communication at all levels. Good supervision costs little more than poor supervision but can have a profound influence on the quality of the seedlings produced.

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MODULE 17: NURSERY TENDING AND PROTECTION

17.1 Tending operation

The primary requirements for healthy growth of seedlings are appropriate levels of light, moisture, temperature, and the nutrients required for the various stages of growth from seed germination to hardening-off. In addition, there should be minimal weeds, pests and pathogens affecting the seedlings so that they can be grown efficiently and economically to the desired level of quality standards. The major techniques are describes as follows:

17.2 Mulching¹ and shading

After sowing, covering seed and watering it is useful to cover the pots with material that helps to maintain moist conditions. Straw or grass shade frames can be used for this purpose, or straw can be placed directly over the pots. The latter is, however, time consuming to place and is not rapidly removable. This is an important consideration because the shade should be removed for several hours in the morning and afternoon when germination is about 80% completed to allow sufficient sunlight for effective photosynthesis of those germinants that have already emerged. Failure to do this is a major factor in providing conditions that are very conducive to damping-off and other diseases. Fresh straw and grass used for covering sown pots may introduce weed seeds, which will germinate under the favourable moisture conditions. Therefore, efforts should be made to minimize the introduction of weed seed with the mulching material.

Shade is also beneficial for many species at some stages of their early growth. Shades should be 1.3 m wide to provide some overlap at the edge of the beds so that the "edge effect" is minimized. Unfortunately the use of shading is often poorly managed; shades are often too dense (the typical grass shades used in many nurseries only allow about 5-10% of sunlight to penetrate), left on for too long, or left on at the wrong time. Shades reduce the day-time temperature and the rate of evaporation from soil and plants beneath them. The humidity around the plants is also increased.

Shading can be low or high. Low shades are most common in highland nurseries. They are temporary, made of local material, cheap to erect, but they require plenty of manual labor. Support for low shades can be made of bamboo poles. The cover is spread on the supports only 30 to 50cm above the ground. Low shades are adjustable: as the seedlings grow bigger the shades are lifted by changing the supports in to longer ones.

Low shades have a disadvantage in that the shading mats or screens have to be removed to water or weed the pots. Water applied on top of the mats or screens may seep down to the seedlings as heavy drops that do not water the pots evenly and may even compact the soil. High shades are elevated enough so that a laborer can move freely below them. High shades are usually constructed as a permanent installation. They are built of poles or wooden posts about 2m apart and connected at the top by longitudinal beams and cross beams. When seedlings are shaded, shading mats or screens are placed on top of the scaffolding. High shades are not commonly used in Ethiopia.

Shading mats, both for low and high shades can be locally made of bamboo slats. Local shading mats can be prepared by the nursery staff during the silent nursery season the bamboo is cut into pieces of about 1.20m in length since the shading mat should be slightly wider than the standard nursery bed. The bamboo poles are split lengthwise into slats of 15 to 20mm wide.

¹ A protective covering, usually of organic matter such as leaves, straw, or peat, placed around plants to prevent the evaporation of moisture, the freezing of roots, and the growth of weeds.

The slats are then connected with wire or string, and some space is left between each slat. The width of the slats and the space left between determines the degree of shading the mats provide. A mat made of 20mm wide slats with spacing between 20mm permits 50% light to pass through. If the stretches between the slats are reduced to 10mm, shading rises to 67%. Handmade shading mats should not exceed a length of 5m since longer mats are heavy and inconvenient to handle. Shading mats of a suitable length can be spread easily and quickly rolled up when required.

Shade makes conditions more uniform throughout the 24 hours of the day. It also reduces light reaching the plants and thus can decrease photosynthesis to unacceptably low levels if the shade is too dense. If shades are left on too long or are too dense this encourages the growth of tall, thin, weak (etiolated) plants which may even have lost their healthy green color and become yellowish (chlorotic). The plants will also have low food reserves, which results in slower root regeneration after planting. Such plants, which have been growing under comparatively cool, humid conditions and low light intensity in the nursery, are subject to severe shock when they are planted out, especially if subjected to hot or dry conditions. Their chances of survival will be much reduced.

Besides the adverse effects of shade on seedling quality mentioned above, shade also has a large influence on disease development. Most fungal diseases thrive in conditions of high shade intensity, which result in high air humidity and longer periods of surface wetness of plant tissues. Excessive shade, therefore, tends to encourage many diseases. Heavy textured potting mixes are especially conducive to root rot, and high levels of shade further increase the severity of disease.

The adverse effects of excessive shade can often be clearly seen in nurseries because the healthiest seedlings are evident at the edges of pot beds where they receive relatively more light than the central part of the bed (the edge effect). There is often a consistent gradient from thicker-stemmed, taller, healthy green seedlings at the edges of pot beds to thinner, shorter, chlorotic seedlings at the centre of the bed. In many instances this is the result of excessive shade application. The central seedlings also have a poorer root system, which is an inevitable result of high shading intensity. Consequently the root/shoot ratio will be low and field survival can be expected to be lower than for seedlings raised with plenty of sunshine. In spite of the above negative consequences of shading, there are situations in the nursery when the use of shade is appropriate. Shade is beneficial during germination, just after pricking-out and, of course, for protection from frost, hail and heavy rain.

17.3 Watering

An ample supply of water is essential for a well-operating nursery. The water must be of good quality. It should be clean, the pH value should range from neutral or slightly acidic (5.5 to 6.5) and there should not be too much salt in it. Newly sown seed must not be allowed to dry out at any time as this would kill many germinating seeds, especially when the radicles are just starting to emerge. To maintain moist conditions it is usually necessary to water at least twice a day. If fine sand, which dries out quickly, is used to cover the seed, more frequent watering might be required. If sown seed are not shaded they will also require more frequent watering, and weather factors will obviously have a major effect on rate of drying of seedbeds. Larger seed, which are sown deeper, will be less liable to rapid drying than smaller seeds which are sown with only a thin covering of sand. The seed germination medium should not be too wet as this causes problems with aeration and damping-off. The experience of the foreman and a well-drained germination mix are essential to ensure that there is adequate but not excessive moisture during germination.

The watering of germinating seed and young seedlings must be done with a watering can which has a hose with very fine holes so that it produces a fine water spray which does not disturb the germinating seeds and their short, delicate root systems. When such fine hoses for watering cans are often not available, the usual practice is to water with shades in place to break the force of an erosive coarse water spray.

This is moderately effective in reducing erosion caused by the water spray. It is also difficult to visually assess the relative dryness of soil when shades are in place, and uniform watering of the whole bed is, therefore, more difficult. Shades also cause a degree of unevenness in watering because they tend to concentrate water along drip lines created by the grass stalks. It is therefore important that all nurseries have sufficient fine hoses to enable watering of young seedlings without shades in place. The best fine spray is achieved by a watering can which has the rose with fine holes pointing upwards, so that a very gentle spray that settles with minimum velocity is produced.

As seedlings grow progressively larger in the presence of adequate sunlight, they rapidly develop roots into the lower portions of the potting mix, after which watering can be decreased to once per day. Seedlings with 2—3-cm long shoots should have a sufficiently well developed root system to require watering only once a day. Even if the surface of the tube appears dry, lifting the tube will indicate that there is moisture available in the root zone of even quite small seedlings. Excessive watering is often indicated by abundant growth of algae at the top and sides of tubes, which develop a green color as a result. Watering should be done late in the afternoon or early in the morning to minimize evaporation losses and to prevent leaf scalding, which can occur if seedlings are watered in strong sunlight. If fungal diseases are a problem, it is best to water in the morning as any excess moisture will be quickly evaporated. If watering is done late in the afternoon, high moisture levels conducive to disease are likely to be maintained for more time during the night thus leading to increased disease severity.

When seedlings are growing well, it is essential that watering is sufficient to wet the potting mix in the whole length of the tube. This may require several waterings, allowing a few minutes for the water to infiltrate the potting mix before watering again. If only the top of the tube is moistened there will be very little root growth in the lower levels of the soil mix as they are likely to be too dry. This is particularly relevant when using the longer (20-cm) tubes. However, even with 15-cm long tubes it is common to find tubes with larger seedlings, which after routine watering, do only have the top 5 cm of soil moistened. Frequent light watering (insufficient watering) not only restricts root development but is also a waste of water because a high proportion of water is lost by evaporation from the soil surface. This also causes more rapid salt accumulation as salts are left at the upper part of the root zone after water evaporated.

Thus, it is more economical and conducive for a better root development within the whole volume of the tube if watering is thorough but less frequent. The foreman should lift a number of tubes at random to examine how far the water infiltrated and make sure watering is continued until the whole tube depth is moistened. Watering is essential immediately after root-pruning to help the seedling overcome the shock of losing part of its root system and to encourage growth of new fibrous roots. Unless there is watering immediately after root-pruning, it is obvious seedlings tend to wilt quickly. Thus, watering of seedlings before final dispatch to planting sites should be very thorough to ensure that the seedling has the maximum available moisture reserves within its tube. Such moisture reserve can be critical for survival if dry weather follows after planting in the field.

17.4 Pricking-out

If seeds have not been sown directly into pots, pricking-out (also known as transplanting) must always be done. The aim of pricking-out is to establish a single vigorous seedling, centrally placed in each pot, with minimal disturbance to continued growth of the seedling. When pricking-out, one of the most critical things is to use a size of seedling that is most likely to survive. If a seedling is too large, it is difficult to lift it out with the majority of its roots intact, or to place this large root system in the new pot without distortion to the roots. If a seedling is too small, it is very delicate and may have an inadequate length of root.

In practice the hole made for receiving a new seedling should be about 5 cm deep and 1-1.5 cm in diameter. The correct size of seedling for transplanting should, therefore, be judged primarily by the length of the roots, which should be about 5 cm long, rather than by the height of the shoot. Usually the shoots of seedlings suitable for pricking-out have 2-4 leaves besides the cotyledons. If the roots are approximately 5-cm long, many potential problems associated with pricking-out can be avoided. These include:

- A seedling with 5-cm long roots can be easily lifted with minimal loss of roots;
- Such a small root system does not require any root-pruning before it can be placed in the new tube; and
- Such a small root system can be easily placed into its new position with little chance of root deformation and distortion. Avoiding root deformation is very important as it can cause permanently deformed root systems, which can in turn lead to death of the plant several years after planting. This potential for root deformation is a major disadvantage of the pricking-out method of growing seedlings.

It is an advantage if the seedlings to be used for pricking-out are relatively hard. This is primarily achieved by ensuring that they receive as much sunlight as they can tolerate, starting immediately after germination. This helps to produce relatively robust seedlings with thicker stems that are less easily damaged by handling with fingers. Most importantly, such seedlings with previous exposure to high levels of sunlight have more vigorous roots and some ability to limit excessive water loss from the shoot by transpiration. They, therefore, have a better chance of surviving the shock of pricking-out than thin, weak seedlings such as those produced under dense shading.

Pricking-out is a delicate operation which should be done with great care, preferably by workers with previous experience. It is best if the whole transplanting operation can be done under shade, which can be provided by having a moveable shade to protect both seedlings and workers. If this is not possible, pricking-out should be restricted to the coolest times of the day, such as early morning and late afternoon. Cloudy days with little wind are especially suitable for pricking-out, and on such days this operation can be done throughout the whole day. Encourage workers doing the pricking-out to discard any seedlings which do not have a relatively well-developed root system when judged in relation to the shoot. Some seedlings are genetically predisposed to having relatively poor roots and the sooner such plants are eliminated from routine operations is the better. Even if they survive in the nursery for several months, they have a low chance of survival after planting.

If the good techniques described above are followed, it should be possible to achieve over 80% survival. Some nurseries do in fact achieve such good results, but many experience significant losses after pricking-out and typically have survival below 50%. The most common causes of mortality following pricking-out are:

- Drying out of the roots in the time between lifting and replanting;
- Leaving air pockets around the roots instead of ensuring that the roots are in close contact with the soil;
- Waiting until seedlings are too large before transplanting. Then it is difficult to remove sufficient roots to maintain a satisfactory root/shoot ratio;

- Pulling seedlings out of the soil without the use of a dibble stick to help remove roots intact;
- If seedlings are pulled out, it is common for this to result in the seedlings having only a taproot and no lateral roots. In addition, the force required to pull the seedling frequently causes mechanical stem damage, which in turn predisposes the plant to disease;
- Making a planting hole that is too shallow so the seedling is not planted deep enough. If roots are exposed to air, they dry out rapidly and the seedling dies. Shallow holes also promote root deformation;
- Making a planting hole that is too deep, resulting in the plant stem being partly buried, with consequent greater chance of stem disease, especially if soils become too wet;
- Existence of extremely hot, sunny or windy weather condition especially if shading is ineffective;
- Too little or too much watering. Excessive watering is especially a problem in heavy-textured soils where root-rot disease is also likely to become important. Too little watering is more likely when the potting mix is very well drained due to a sandy texture;
- Leaving dense shades in place for too long; and
- Since the growth of seedlings varies with altitude and rainfall, each nursery must determine - species by species the time needed between sowing and seedlings reaching planting size.

17.5 Weeding

Competition from weeds for nutrients, light and moisture depresses seedling growth and can, if not controlled, lead to seedling deaths. The competition for nutrients is especially critical in nurseries as potting mixes contain only limited nutrients and symptoms of deficiency are common. Competition for light is only important if weeds are allowed to grow unchecked and become large. Likewise, competition for moisture increases as weeds increase in size, so the aim should be to eliminate weeds while they are still small. Weeds can also encourage some pests and diseases.

Weeds propagate either by seeds or by underground rhizomes and stems. Special attention must be given to weeds with underground propagation. These are more difficult to eradicate, and they should be removed with their rhizomes as soon as they appear. Construction of a wind breaks around the nursery and hedges around the compartments decreases weed infestation by wind. Cutting adjacent grassland before the grasses flower decreases the spread of grass seed. Rhizome-infested nursery compartments must be cleaned annually to remove all rhizomes before the nursery beds are laid out. Compost and manure should be allowed to decompose well over a long period. An inside compost temperature of about 70 degrees Celsius kills most of the weed seeds.

Weed seeds can also be introduced with the grass material used for making shades, and by wind and irrigation water. The grass material used for making shades/mulches can be a major source of weeds. Care should be exercised to ensure that seeds are removed before bringing shading/mulching materials into the nursery. Most nurseries have shelterbelts and these help to reduce the incidence of wind-borne weed seed. The whole nursery area should be kept as weed free as possible to reduce dispersal of weeds to seedbeds and pot beds. Weed control also helps to create a neat and tidy looking nursery. In any case, weeds should not be allowed to set seeds within the nursery boundaries as this will only perpetuate the existing weed problem.

In Ethiopia labor is still cheap and hand weeding is usually still the most appropriate way to control weeds. Various chemicals (herbicides) can be used to spray weeds and kill them (e.g. glyphosate, trade name "Roundup") but they are expensive and require exact methods of application. There is always the possibility of spray drifting onto tree seedlings and causing damage. There is also a risk to health of workers if safety precautions are not strictly followed.

If application of herbicides is contemplated, then the following considerations must be taken into account:

- Likelihood of damage to tree seedlings from the herbicide formulation;
- Correct concentrations and dosage rates;
- Timing of herbicide application;
- Prevailing weather conditions; and
- A safe method of application to ensure the workers' health is not affected.

Despite these limitations for using chemical weed killers, they are useful for control of weeds which produce rhizomes or underground stems and which are therefore difficult to eliminate by simply digging the plant out. Where such weeds occur within seedbeds or pot beds, they can be sprayed with Roundup when the beds are empty. Spot spraying of individual weeds is all that is required. If this is done, it obviates the need for digging up whole pot beds annually to control weeds. If weeds growing up from the base of pot beds are a problem, then placing a strong sheet of black plastic under the pots is also an option. This plastic sheeting has the dual benefit of preventing taproot growth below the tubes and therefore reduces root-pruning costs.

If it is anticipated that there will be a large number of weeds in the germination or potting mix, it is advisable to pre-germinate them. This can be achieved by watering pots and seedbeds for several weeks before sowing. The weeds can then be killed by stopping watering and letting them die from drought. Alternatively, they can be sprayed with herbicide or removed by hand before sowing when they can still be relatively easy to remove.

It is best to remove weeds while they are still small because this minimizes their adverse effects on tree seedlings due to competition, and it is also easier and cheaper to remove weeds while they are still small. If weeds are allowed to grow large they develop large roots which are difficult to remove and also more likely to result in root disturbance of the tree seedlings. The potting mix should be moist when weeding to enable easier removal of roots. A pointed stick, dibble, flattened piece of wire or similar tool can help to remove weeds with their roots so that they do not grow again.

If there is crusting of the soil surface in pots, this is a good time to combine cultivation of the surface with removal of weeds. Weeding must be done repeatedly - at intervals of about two weeks when seedlings are small, but at longer intervals as the seedlings become larger, weeds tend to be suppressed and fewer weeds are germinating. Frequent inspection by the foreman will indicate when and where weeding is required, and this can vary widely between nurseries and seasons.

17.6 Thinning the Stand

As a plantation matures, trees become crowded and competition among trees causes growth rates to decline. Thinning is the selective process of removing or killing of some trees to allow the remaining trees to maintain a steady growth rate. Thinning also provides the opportunity to selectively remove poorly formed trees and species of lower value. The need for thinning will arise faster and be more important for high density plantation on good sites with high survival. If there is a lot of variation in growth and survival, thinning may be necessary only in areas where the trees are very dense. In some cases, thinning will be

directed at trees that grow above and shade out smaller higher quality trees. Some species may drop out of a mixed species planting if competition becomes too great and thinning is not practiced. The goal of thinning is to maintain a steady growth rate and monitor the growth rate of the trees.

17.7 Root pruning

A good root system, with a well-developed mass of fine feeder roots, is an essential feature of quality "target seedlings" we want to grow. It should be emphasized that a good root system of the right size is the single most important factor in determining a good survival rate of the seedling at the reforestation site.

Root-pruning of tubed seedlings is an essential operation that should be an integral part of good nursery management. The purpose of root-pruning is to:

- Prevent the development of a taproot system outside the tubes;
- Encourage the growth of a compact, fibrous root system within the tube with many active rootlets that are able to absorb water and nutrients;
- Maintain a favourable root/shoot ratio (the higher the better); and
- Produce sturdy seedlings that have a thick stem diameter relative to their height.

After germination, many species in nurseries quickly develop a taproot that grows vertically downwards within the tube. *Acacia* and other drought-resistant species such as *Leucaena* are particularly able to develop a taproot very quickly. If tubed seedlings are not root-pruned, the roots will extend into the soil below the tubes constituting the base of the pot bed. This extended root system supports fast development of a succulent, soft, shoot system. The result of this is that a substantial portion of the root system will remain in the nursery bed after removing seedlings at planting time. The roots remaining within the tube are often only a short section of woody taproot that has few lateral roots. Such un-pruned seedlings have a low root/shoot ratio. The relatively few roots remaining within the tube are then insufficient to supply this once vigorous seedling with enough water to prevent wilting, and possibly death, after planting.

Often the problem with unpruned seedlings is not apparent while seedlings are still in the nursery. In fact, to the casual observer, a tall and "soft" seedling resulting from inadequate root pruning may look better than a smaller, quality, seedling that has been consistently root pruned. Regular root-pruning should prevent the growth of a taproot below the bottom of the tube. It also results in the formation of a more branched root system, with many small active rootlets within the tube. Whenever a seedling is root-pruned there is a physiological response by the plant to regenerate new lateral rootlets above the point where the roots were cut (i.e. within the tube). Root-pruning, therefore, increases the root/shoot ratio, and in particular the proportion of fine roots compared to woody roots. Root-pruning also helps to limit height growth of seedlings but encourages diameter growth of the stem, so producing more sturdy seedlings, which is an important desirable character of target seedlings.

Seedlings should be root-pruned for the first time when the taproot has emerged from the base of the tube and is no more than 1 mm thick. The time required for the seedling to grow to this point varies greatly depending on the species, and may be as soon as 6 weeks after germination. The foreman must periodically lift tubes at random to determine the extent of root growth and then begin root-pruning accordingly. After the initial root-pruning, another taproot will develop with time, so repeated root-pruning is necessary at intervals of 2-4 weeks, depending on species. The final root-pruning should be made about 2 weeks before the anticipated planting date, which should allow further new rootlets to regenerate before planting. A thick, strong, taproot several millimetres in diameter should never be allowed to develop below the tube.

Repeated root-pruning is a labour-intensive task, and this is one reason why insufficient pruning is done in many nurseries. As mentioned previously, the correct sowing date is critical to minimize the number of root-pruning that will be needed. Sowing too early will, of course, increase the number of root-pruning required.

Root-pruning, if done at the correct stage of seedling growth, often results in subsequent slight wilting of the seedlings. Hence, in order to avoid this problem, it should be done on cloudy days or late in the afternoon. It is also best if the potting mix is moist at the time of pruning but not so moist that soil loss from tubes occurs when lifting the seedlings. After pruning, the seedlings should be thoroughly watered to help them recover after the shock of losing part of the root system. If for some reason root-pruning has been unduly delayed, there might be severe wilting and it may be necessary to shade the seedlings to help them recover.

17.8 Hardening-off

In a well-managed nursery, seedlings grow under favorable conditions and with continuous care. They are sheltered from excess sun and dry season winds, they are regularly watered, and they are even fertilized according to their needs. By contrast, the plants are often subjected to extremely difficult conditions when they are planted out. The most likely situation is that seedlings will experience severe moisture stress and increased heat stress after planting. This can be caused by a lack of rainfall after planting, as well as increased wind, sunshine and lower relative humidity in plantations. Management of the seedlings in the nursery must be designed to accustom them to, and be able to tolerate, these difficult conditions before they are planted. This is done by the process known as "hardening-off". Hardening-off is the process of gradually increasing the moisture and heat stress to which seedlings are subjected. The aim is eventually to create in the artificially controlled environment of the nursery conditions similar to those that will be experienced by the seedlings in the natural environment of the plantation.

Hardening-off should start at least four weeks before planting is anticipated, which in most of Ethiopia starts in July. Therefore, hardening-off should start in early June at the latest, and if possible in mid-May. After starting hardening there should not be any significant increase in height of seedlings, but their diameter should continue to increase. At the completion of hardening the seedlings should have well-lignified tissues; the leaves should have a thick cuticle and be hard and leathery; the stem should be brown, not green, and as thick as possible; and there should be a much-branched fine root system within the tube with no evidence of recent taproot growth below the tube. The essential actions needed to induce hardening-off in seedlings are described below.

i. Removal of shade

In previous sections it has been suggested that shading should only be required during germination and after pricking-out. The majority of the seedlings' life in the nursery should therefore be under conditions of full sunshine. If for any reason, however, seedlings are still shaded when planting time is approaching, urgent action must be taken to reduce the shading in gradual steps. This gradual removal of shade is critical because if seedlings go from 90% shade to sudden full sunshine there is insufficient time for them to adapt to the sudden severe conditions, resulting in appreciable mortality. For at least the last month in the nursery seedlings must be exposed to full sunshine, even in the lowlands.

ii. Root-pruning

Even if there has been little root-pruning in the early stages of the seedlings' growth, it is essential that root-pruning is carried out during the weeks of hardening-off. If a taproot grows below the tube, a seedling continues rapid growth and produces "soft" shoots, which make it impossible to adequately harden-off. Thus, final root-pruning should be made about two weeks before planting is anticipated.

iii. Reduction of watering

The watering frequency must be gradually reduced so that physiological changes can occur in the seedlings in response to the imposed water stress. After watering, the foreman must observe the seedlings closely for the first signs of wilting before watering again. This cycle of watering and then waiting until seedlings start to wilt is repeated, waiting a little longer before re-watering with each successive cycle. It is important to not wait too long before watering again as seedling death may occur if wilting is allowed to continue for too long. This requirement to apply sufficient moisture stress to induce hardening without also causing significant mortality is a delicate balance, and requires good judgment from an experienced foreman. In this manner, seedlings gradually develop appropriate morphological and physiological characteristics and become accustomed to water stress. The development of a thicker leaf cuticle, which reduces water loss from wilted leaves, is one very important consequence of hardening-off.

17.9 Protection: pests and diseases

A nursery place is a place which can be a source for numerous categories of destructive agents. Seed, germinating seed, and seedlings (up to the time of dispatch) might be used as a food source by many biological agents. In the process of using the seedlings for food, considerable damage can be inflicted. Loss in vigour and mortality of seedlings are possible. There is also distinct possibility that some harmful agents such as fungi and insects can be dispersed with the nursery seedlings to new locations. This is a major reason why many countries now have a policy of producing pest- and pathogen-free seedlings so that undesirable biological agents are not dispersed along with the seedling.

The major categories of biological agents which might damage seedlings in nurseries are the following:

- Insects,
- Pathogens: These are microscopic organisms that include fungi, bacteria, viruses and nematodes, and
- Animals: These include mice, rats and squirrels.

There might also be damage from birds, snails and slugs but these appear to be of very minor importance. Large domestic and farm animals can, of course, devastate a nursery but adequate fencing should exclude them.

Insects:

There are many insects that are potential pests in nurseries, but relatively few appear to be of economic importance to seedling production. In the majority of nurseries insects are a nuisance but they do not regularly cause major plant losses. The nursery foreman should, however, be constantly vigilant to detect any pest/disease problem at an early stage so that preparations can be made for control if this should become necessary. There are several insects, which may at times become a significant problem in some nurseries, and these are considered below.

a. Grasshoppers and crickets

These insects are common in low numbers in many nurseries and do cause some damage by chewing leaves and shoots, especially of tender young seedlings. Grasshoppers vary in size from 1 cm to over 8 cm and the damage they cause individually varies accordingly. The presence of grasshoppers is encouraged by other vegetation which provides shelter and food.

The presence of dead vegetation, especially branches and long grass, can also provide a suitable habitat for grasshoppers. The dense grass shades typical in nurseries also

encourage grasshopper attack on the seedlings being shaded. Simple measures to limit grasshopper damage should, therefore, include keeping the area around pot beds clean and minimizing shading of seedlings. If insect numbers and damage are high, it may be necessary to spray with an insecticide such as Fenitrothion.

Crickets can be a nuisance in some instances. These insects tend to hide between and below the tubes during the day and come out to feed at night. If insecticide needs to be used for severe infestations, Fenitrothion applied late in the afternoon should be effective.

b. Cutworms and other caterpillars

Cutworms are the larvae of a moth (*Agrotis*) which lays its eggs on the stem or soil surface and when the small caterpillars (larvae) hatch from the eggs they initially feed and live on the leaves, which may become skeletonized. As the caterpillars become older they spend the day in the soil and only emerge at night to feed. They then frequently cut the stem of small seedlings slightly above soil level, thus giving them their name "*cutworm*". These insects are frequent in many nurseries and show a distinct preference for eucalyptus. The larvae can be found by careful examination of the soil beneath seedlings which have been cut. The larvae are hairless, grey or brown, 1-2 cm long, and curl up immediately when touched.

If control is required this can be done with an insecticide such as Dursban or Trichlorophon when the larvae are still small and have not reached the stage of entering the soil during the day. After the larvae grow larger and enter the soil they are less easily controlled by a contact insecticide and, therefore, a systemic insecticide such as Rogor should be used. All caterpillars are the larvae of various moths and butterflies, and many of these different species of caterpillar may occasionally cause damage in nurseries. Control can be achieved by picking the caterpillars off by hand, but if the infestation is severe, spraying with a contact insecticide such as Fenitrothion may be required.

c. Termites and ants

Both these insects form colonies with a single queen and numerous workers. Termites (also known as white ants) can cause severe damage to saplings and larger trees by attacking the woody roots. They may be present in nurseries but do not appear to attack seedlings, probably because the roots of seedlings are not sufficiently woody to provide suitable food for them. If grass is used to cover germinating seed, termites sometimes consume part of the grass and build tunnels into the grass covering. This can result in disturbance of seed, which will be reflected in poorer germination. In some instances the termites build such extensive tunnels within pots that subsequent soil collapse follows, exposing roots of seedlings.

Ants are not usually a problem, but instances have occurred where they collect small seeds after sowing. Such ants are known as harvester ants. Ants may also increase the spread of insects such as scales and mealy bugs to adjacent seedlings within the nursery. The most efficient way to control termites and ants is to locate the nest of the colony and destroy it, including the queen. Insecticide such as Dursban can be applied to the soil forming the base of pot beds if it is not possible to locate the colony and destroy it. A termiticide called Marshall SusCon is very effective and has relatively low toxicity to humans.

Pesticides such as DDT, Dieldrin, Chlordane and Aldrin (known collectively as chlorinated hydrocarbon compounds) are very effective against termites but they are also very toxic to humans and animals and they are very persistent in the environment. Their use is, therefore, not recommended. Relatively high concentrations of pesticide can be used when spraying soil because there is no problem with phytotoxicity if the spraying is done before tubes are placed in the pot beds.

Pathogens:

Pathogens include microscopic organisms such as fungi, bacteria, viruses, nematodes and mycoplasmas. These organisms are too small to be seen with the naked eye and must be viewed with a microscope if they are to be studied and identified. In forest nurseries worldwide by far the most important group of pathogens are the fungi. Fungi comprise many different genera and there are thousands of different species that can cause disease of plants. Fungi are plants that lack chlorophyll so they must obtain their food from dead organic matter (saprophytes) or living plants (pathogens). Most fungi are composed of fine threads (hyphae) that grow within soil and also within and over the surface of plants in the case of pathogens. Fungi reproduce by means of tiny spores which can be disseminated with air, water, seed, compost or soil depending on the species of fungus involved.

For a disease to develop in plants three basic requirements must be fulfilled:

- 1) The plant must be susceptible to infection;
- 2) A pathogen must be present; and
- 3) The environment must be favorable for infection and colonization of the host plant by the pathogen.

Disease only develops if all three of these conditions are fulfilled. If even one of the conditions is unfulfilled there will be no disease. In practice it is usual to find that the above prerequisites for disease are partially fulfilled, leading to varying degrees of disease severity. For example, a plant might be slightly susceptible, the population of pathogens is low, and the environment is only marginally conducive to infection; this would result in such a low level of disease that it might not even be noticed in a nursery. By contrast, a highly susceptible host plant, high pathogen population and favorable environment for infection could result in epidemic losses. In practice, all gradations between negligible and severe disease are likely to occur at different times in different species and locations.

In general, fungal diseases are favored by moist and warm conditions such as are typical in high-rainfall tropical areas. This applies especially to diseases of leaves and stems. It is usual to have relatively little plant disease in dry climates for most of the year. In the artificial environment of a nursery there is a high density of genetically similar, closely spaced plants, and watering and shading can create an environment which is relatively favorable for disease. Also, in a nursery that has existed for some years, there is likely to be a build-up of pathogen populations with time so that disease problems also increase.

Disease can occur in any part of a plant, including germinating seed, roots, leaves, stems, flowers and fruit. One system of disease classification is based on the plant organs affected and the type of symptoms that are evident. Thus, we have diseases such as "root rot" or "leaf spot", each of which can be caused by numerous different pathogens. Another system of disease classification is based on the identity of the pathogen; this requires expert knowledge and laboratory facilities.

a. Damping-off

Damping-off is the single most important disease in nurseries. Foremen should become familiar with the symptoms of damping-off and its control. Currently, it is usual for foremen to blame "frost" or poor-quality seed for problems, which are in fact due to fungi. Damping-off is a disease of germinating seed and young seedlings, and is normally most prevalent during the first two or three weeks after germination. It is usual to distinguish two types of damping-off disease:

i) Pre-emergence damping-off

In this disease the seed either rots before it germinates or the pathogen kills the root and shoot (hypocotyl) once it has emerged from the seed but before it has broken through the soil surface. This disease often goes undetected and it is very easy to be misled and wrongly

conclude that the seed is not viable. Pre-emergence damping-off can be especially common if seed is sown too deep in cold, wet soil that is poorly aerated.

ii) Post-emergence damping-off

Post-emergence damping-off is characterized by infection and rotting of the stem of young seedlings close to ground level. Typically there is discoloration and reduction in the diameter of the stem at the infection site, which is best observed by gently removing the seedlings root from the soil by carefully washing with water. The discoloration (usually brownish and contrasting with the white color of healthy stems) and diameter shrinkage are due to cell death following invasion by fungal hyphae. This type of infection often causes the small seedlings to fall over because there is little strength left in the rotted stem section, insufficient even to support a tiny shoot that may only have two cotyledons.

Damping-off can affect most species of plant, but small-seeded species, which initially have very delicate stems, are most likely to become affected. *Eucalyptus* and *Cupressus* are often severely affected. Moderate and severe losses occur in nurseries as a result of damping-off. Damping-off can be caused by any of over 30 different fungi, but the three genera *Rhizoctonia*, *Pythium* and *Phytophthora* are of particular importance. The most likely source of the damping-off fungi is the soil that is used to prepare the germination mix. However, they can also originate from the irrigation water, compost, seed, dust, soil splash, and some are able to cause infection from airborne spores.

In highland nurseries there is also frequent damping-off caused by a fungus known as grey mould [*Botrytis cineria*]. If this pathogen is causing the problem, the infection point on the stem is often slightly above ground level and results in moist lesions (infected areas of plant tissue) which quickly develop a mass of grayish spores. These spores are easily dispersed in even the slightest air currents and this can very rapidly lead to widespread infection of other seedlings.

A feature of damping-off disease is that it tends to occur in spreading patches. This is because from an initial infection the fungal hyphae are able to spread out and infect adjacent seedlings without having to first produce spores. The rate of spread of such patches can be very rapid so that in a few days extensive mortality can occur in seed trays and seedbeds. If seed is sown directly in tubes, this tends to restrict most damping-off from spreading beyond individual tubes and this is a distinct advantage of direct sowing. There is, however, an exception to this limited spreading between tubes if the damping-off is caused by *Botrytis* (and to a lesser extent by *Fusarium* and other fungi with airborne or splash-dispersed spores). This is because *Botrytis* rapidly produces large numbers of airborne spores which can easily pass over the polythene tubing, which is an effective barrier to hyphal growth.

In the simplest terms, damping-off is a disease that is particularly likely in wet, humid, shaded environments. In general, the following cultural and environmental factors tend to increase the severity of damping-off:

- *Sowing seed too deeply*:- Sowing depth should be no more than 2-3 times the diameter of the seed;
- *Sowing seed too densely*:- This tends to create crowded growing conditions, which favour the creation of a humid microclimate around seedlings, which in turn favours infection;
- *Direct contact and hyphal growth*:- Also, crowded seedlings make it easy for the pathogen to spread rapidly to adjacent plants by direct contact and hyphal growth;
- *Poor sterilization*:- Using a germination mix that has not been sterilized or pasteurized;

- *Poor soil mix*:- A germination mix that is of heavy texture (i.e. containing too much clay and silt and not enough sand) which results in poor aeration and slow drainage of excess water;
- *Excessive watering resulting in prolonged wetness*:- The potting mix should always be moist, but not excessively wet, during germination;
- *Poor ventilation around seedlings*:- resulting in high air humidity and continued wetness of the soil surface and root collar;
- *Excessive shading*:- tends to maintain wet conditions and high humidity. Lack of sunshine also makes the plant physiologically weak and so more susceptible to infection. Lack of light also lengthens the period in which seedlings are in the soft, succulent, growth stage during which they are most susceptible to damping-off;
- *Alkaline soil* (pH over 7);
- *High nitrogen content in germination mix; Manure that is not well decomposed; and too much compost in the germination mix;*
- *Too many weeds*:- help to maintain a humid microclimate; and
- *High salinity* in the germination mix or irrigation water.

iii) Control of damping-off

The above conditions favouring development of damping-off should be minimized in every nursery. The specific changes that can economically be made will depend on the circumstances prevailing at each nursery. A major improvement in control of damping-off is usual if it is possible to sterilize or pasteurize soil. The use of solarization to heat soil is relatively simple and is recommended especially if seed trays are used for germination. Care must be taken to prevent re-infestation of treated soil with pathogens, which can easily occur if strict hygiene is not practiced.

In most nurseries it should be relatively easy to ensure that the following simple measures are taken to minimize damping-off:

- Use well-drained germination mix of light texture (i.e. with a high proportion of sand);
- Sowing density should give a spacing of 1-2 cm between seedlings;
- Watering frequency should be carefully controlled to avoid excess wetness; and
- Shading should be reduced as soon as possible.

The following practices can further help to reduce damping-off disease:

- After sowing seeds, cover them with fine sand. Sand contains few pathogens and helps to maintain good drainage and aeration. It also enables rapid emergence of the hypocotyls (shoot), and thereby reduces the time available for development of pre-emergent damping-off;
- If watering is done late in the afternoon, high air humidity and a wet soil surface might prevail throughout the night and favour damping-off. Watering should be done in the mornings and early enough in the afternoon to allow drainage and evaporation of excess water before the onset of evening;
- The seed-bed germination mix should be replaced periodically to prevent build-up of pathogen populations in successive years. Careful observation of the incidence of damping-off in the previous year will indicate when replacement is required; and
- During pricking-out, seedlings should be held by a leaf and not the stem. The stem is very delicate and if slightly damaged through touching with the fingers is more liable to infection from damping-off fungi.

If adequate control of damping-off is not achieved by implementing cultural methods as suggested above, it might be necessary to use chemical fungicides. Fungicides are expensive and need to be used with care to prevent health hazards to workers. It is, therefore, not recommended to rely on fungicides for control of damping-off but rather to concentrate on improving cultural methods. Damping-off can develop very quickly and high

losses can occur within a few days. As a last resort, spraying with a fungicide should help to slow down the development of damping-off. However, once disease is well established in a favourable environment, even repeated spraying may not effectively control it. The most suitable fungicide to use depends on knowing the species of fungus involved. Fungicides such as Captan, Dexon, PCNB, Dithane M-45, or Benlate could be used on a trial basis to see if they control the disease. With time, each nursery should accumulate information about which fungicides are effective in its specific circumstances. If experience from previous years indicates persistent damping-off, treating the seed with fungicide before sowing should be considered. A suitable fungicide for seed dressing is Thiram.

It is also possible to apply a fungicide drench to the soil before sowing. Prophylactic spraying with fungicides before damping-off develops is possible but should only be considered for valuable seed or where all other attempts at control have failed.

Higher animals:

Besides straying domestic stock such as goats, sheep, donkeys and cattle, which may enter nurseries if fencing used is inadequate. Rats, mice and squirrels are a problem in some nurseries. Rats, mice and squirrels (all rodents) might eat stored seed if it is not placed in vermin-proof containers such as metal tins. Seed stored in plastic bags or plastic jars can be eaten because the rodents have sharp teeth that allow them to gnaw through soft materials. Alternatively, the store itself can be made rodent proof.

Those nurseries which provide a suitable habitat for rodents close to seedling beds are most likely to suffer significant damage. Such habitats include, particularly, stone walls close to seedbeds and pot beds, as well as long grass and heaps of rubbish. Reductions in rodent populations can be achieved by keeping grass short, removing rubbish to heaps some distance from the seedling areas (and composting all organic materials), and not building stone walls close to seedling-production areas. Food scraps should not be left lying around to discourage rodents.

More direct control methods can include the setting of traps and laying of poison baits such as coumarine or warfarin. The baits must be sheltered to protect them from rain. Rodent poisons are toxic to humans as well as domestic animals, so precautions are required to limit access only to rodents. A cat can be useful to help in control of rats and mice. A covering of wire mesh supported on a suitable frame should prevent rodent damage, but this is an expensive solution and would only be feasible for protecting small numbers of valuable seedlings. Birds are not usually important in damaging seed or seedlings. Indeed, birds are frequently seen feeding on insects on seedling foliage and, therefore, they have a beneficial effect and should be encouraged.

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MODULE 18: SEEDLING TRANSPORTATION & HANDLING



Grading, packing and transportation

18.1 Grading

In any nursery there are always some poor-quality seedlings which would have a low chance of survival if planted out. Such seedlings should not be planted at all as this is a waste of money and will incur the further cost of replacement planting (beating-up). The process of separating poor-quality seedlings from those of reasonable and high quality is known as "grading" or "culling". It is usual to expect 10-20% of the seedlings produced to fall short of minimum quality standards and these should be culled. The reasons for poor quality include both genetic and nursery-management factors.

In many nurseries there is often very little culling, and in many instances virtually all living seedlings are dispatched for planting. This is a major reason for the frequent poor survival in plantations. The solution is to plan excess production sufficient to allow for a culling of 20% of seedlings. If pits have been dug, there is a strong temptation to plant them even if only inferior seedlings are available.

The best-quality seedlings should be used on the most difficult sites, areas with difficult access, and areas which are of particular importance. Seedlings of slightly poorer quality can be planted on more favourable or less important sites. If supplementary watering after planting is possible (e.g. private plantings around homes, schools, churches), then you may still use lower-quality seedlings and obtain good survival.

In order to be practicable, the culling must be based on shoot characteristics that can be very rapidly assessed by the relatively untrained labour force working in nurseries. From experience in many countries, seedling height, collar diameter and general appearance of seedlings have been found useful criteria on which to base culling.

Seedling height: The seedling should be about twice the height of the tube. The tubes in the majority of nurseries are 15-cm long, so the seedlings should be about 30-cm tall. Excessively tall (over 40 cm) and short (less than 15 cm) seedlings should be culled.

Collar diameter: The collar diameter (stem diameter at soil level) should be as large as possible; and the thin, etiolated plants should be discarded. The collar diameter should be at least 2 mm, and with good nursery management it should be possible to adopt 3 mm as the minimum acceptable standard.

General appearance: Seedlings should have a balanced and symmetrical growth of normal healthy green leaves without yellowing or other discoloration. There should be no evidence of insect pests, disease, or obvious mechanical damage.

Single seedling per tube: At an early stage in growth seedlings should have been reduced to one per tube. If, for whatever reason, this has not been done, then such tubes should be thinned to one seedling at this stage. This, of course, assumes that the tube contains one seedling which meets the above three culling criteria.

18.2 Packing and transporting seedlings for planting out

Preparing seedlings for planting requires packing, which if not done carefully can result in appreciable deterioration of seedling quality, with consequent reduction in survival. The other principal reasons for poor survival rate are that seedlings are mishandled during transport, loading and unloading operations. One must not expect a high survival rate from seedlings that are broken or damaged mechanically. In many places seedlings have been treated like any other commodity especially while being transported and unloaded by dump trucks. Maximum care must be taken for the seedlings when they are transported from nursery to planting sites. The best quality seedlings could be damaged if they are handled carelessly.

On the other hand it is also common to transport seedlings on donkey back or carried by people. Since people cannot afford carrying many seedlings with pots; because of the weight of the soil, they remove the plastic pots with the soil in order to carry as many seedlings as they can. This can tremendously affect the survival rate of seedlings. Therefore, proper care must be taken during transporting the seedlings as safe as possible to the planting site. To achieve acceptable results the following should be done:

- Only send those seedlings to the field which have passed the grading standards; and
- Water the seedlings thoroughly the day before lifting the tubes.

Ensure that the whole depth of the tube has been moistened by lifting random seedlings and examining them to ensure that the wetting front has passed all the way to the bottom of the tube. This usually requires repeated watering with a little time difference between each to allow infiltration. For instance, for dry 20-cm long tubes it will require 3-4 successive watering to wet the whole tube. Moisture stored within the tube is a major reason why tubed seedlings have an advantage over open-rooted seedlings and this advantage is largely lost if tubes are not thoroughly watered before dispatch.

This moisture reserve will help the seedling to better tolerate dry periods if there should be several days without rain following planting. The following critical issues must be considered during lifting and transport:

- When lifting seedlings they should always be handled by holding the tube and not by pulling on the stem as this can easily damage the shoot, and also lead to subsequent pathogenic infections.

- Transport seedlings in a vertical position by placing them closely stacked in boxes. This minimizes shoot damage and soil loss from both the bottom and top of open-ended tubes.
- Placing trays full of seedlings horizontally into trucks can result in significant soil loss from tubes, often exposing roots to air drying, as well as mechanical damage to shoots. Metal platforms on vehicles can become very hot and kill roots that come into contact with them. Pouring water over the platform or spreading a layer of straw, grass, soil or similar material on it helps to reduce this problem.
- If there are sufficient numbers of boxes, they are loaded onto trucks with minimal further loss of soil during transportation and unloading. To increase the carrying capacity of trucks, shelving is required so that several layers of boxes can be accommodated, one above the other, and so make transportation more economical.
- The seedlings should be covered so that they are not exposed to sun and wind during the trip from nursery to plantation. There should be some space between the seedlings and the cover to minimize mechanical damage. Covering is especially important if the distance from nursery to plantation is appreciable as desiccation of seedlings depends largely on the length of time they are exposed. If covers are not available, the effects of desiccation can be reduced by transporting on rainy or cloudy days.
- Potted plants can be transported safe if they are stacked on the floor of trucks or other vehicles in an upright position. This consumes a lot of space and requires quite frequent travel to and from the planting site. Instead, the seedlings can be laid one on top of the other, the shoots of two rows facing each other. In this manner the seedlings can be transported when the distance is reasonably short but should be unloaded and stacked in an upright position and the planting needs to start soon.
- Bare-rooted seedlings can be laid down on wet banana or false banana (enset) leaves, sacks or other materials with the roots puddle with soil and water. The bundles of seedlings can be stacked upright on the vehicle floor. In this way, quite a large number of seedlings can be transported at a time. Where the planting site is far away and vehicles are not available, the bundles can be transported by donkeys, horses or mules.
- Normally, plants arrive one day ahead of planting. Where shade and watering facilities are available, planting stock can be brought in several days before planting is to take place. As soon as the plants arrive at the planting site, they must be watered and stored in cool, moist and shaded place until they are planted.
- Only dispatch the number of seedlings from the nursery that can be planted in one day.
- The seedlings should be planted as soon as possible, preferably within hours of arriving at the plantation site. After carefully unloading the seedlings, they should be placed in a shaded, sheltered, position which is the coolest available. If there is any delay in planting, it is essential that the moisture content of tubes be constantly monitored, and if they become dry supplementary watering is carried out. If seedlings are planted with low tube-moisture content this will have a detrimental effect on survival if good rains do not immediately follow planting. It is common in Ethiopia to observe several days of dry weather after planting. Thus, it is essential that each seedling has adequate water stored in the potting mix at planting time.

The general lack of boxes is a significant problem for efficient transport of seedlings. Firstly, it necessitates repeated handling of seedlings, which is not only labour intensive but increases the probability of additional soil loss from tubes with each handling. To reduce this

soil loss from tubes, nursery managers tend to transport seedlings that are not adequately watered because relatively dry soil is less likely to be lost from tubes. Thus the lack of boxes is indirectly responsible not only for loss of soil but also for planting seedlings with a relatively dry potting mix. The situation can only be improved if money is made available for purchase of sufficient numbers of suitable boxes.

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MODULE 19: BIOLOGICAL GULLY REHABILITATION MEASURES



Green gold behind the Gabion checkdam

19.1 Concepts and definitions of biological gully rehabilitation measures

Biological soil and water conservation can be defined as a conservation measure designed to prevent the loss of soil and water through improved soil management and farming practices that eventually help maintain/restore agricultural productivity and agro-ecosystem stability. It includes vegetative barriers, agronomic and soil fertility improvement practices. The underlying factor for the effectiveness of biological soil conservation is the application of land husbandry techniques that guarantee adequate ground cover in space and time, and the recycling of organic matter and nutrients in the agro ecosystem. In general, it is a rational land use, proper land and crop management practice to increase agricultural productivity and ecological stability.

Similarly, biological gully control is the application of biological principles in the gully as a solution to soil and water management problems or any practices that check surface water flow velocity. It is nothing but the application of vegetative measures including agro-forestry and forestry. Permanent vegetation, particularly trees and shrubs, can play a major role in stabilizing artificial waterways and gullies, as well as natural stream banks. Woody vegetation is important in the channel section along the channel edges and trees, shrubs and grasses are in small channels - even in extremely steep slopes. Therefore, vegetation can be established in a gully by a natural recovery or use of planting materials.

19.2 Purposes of biological conservation measures

Similar to the physical gully control measures, biological gully control practice has its own purposes. The basic contribution that trees and shrubs in gully erosion control is physical/mechanical. Vegetation reduces water-induced erosion by intercepting rainfall, increasing water infiltration, reducing runoff at soil surface level and stabilizing the soil by roots. Especially for incisive erosion processes such as rill and gully erosion, roots are at least as important for the reduction of soil losses as the aboveground vegetation cover. This is especially important in the upper reaches of gullies where water moves quickly, since the erosive force of water is directly proportional to its velocity. The larger infiltration capacity and the higher surface roughness caused by roots reduce the volume and velocity of surface runoff. Mechanically, roots reduce soil erosion by binding together the soil particles at the soil surface.

The use of vegetative material in gully control measures offers an inexpensive and permanent protection. Vegetation will protect the gully floor and banks from scouring. Grasses on the gully floor slows down the velocity of the runoff and causes deposition of silt. The long-term success of gully stabilization work depends on establishing a good vegetative cover on the gully floor which prevents further gullying and allows the gully floor to gradually silt up, hence reducing the fall over of the gully head. As the flow velocity reduced, sediment is deposited, forming an ideal environment for new vegetative growth. Nearly all structural measures used, particularly in grassland areas, depend upon vegetation covers to support them and stabilize the soil exposed to excessive runoff. Generally, biological conservation measure has the following immediate benefits in terms of SWC and fertility of the soil:-

- Provides plant cover for the land and prevent direct impact of raindrops (splash erosion);
- Increases soil roughness, which further reduces the velocity of surface runoff and their by the soil erosion;
- Reduces surface runoff, which facilitates infiltration rates and enhance in- situ water conservation;
- Better helps deposition of silt by reducing and protecting the soil particles from being washed away;
- Prevents soil erosion and thereby enhance effectiveness of physical control measures when it is applied properly;
- Increases soil organic matter and thereby improves soil properties and soil fertility levels,
- Provides protection against scouring and minimizes expansion of the gully due to further erosion risk; and
- Helps to retain water/subsurface reservoirs and increases the soil recharging capacity or contributes to general soil moisture in the vicinity in a sustainable manner.

On top of the soil and water conservation, biological gully and drainage conservation has valuable by-products for the livelihood of the farmer. Trees and other biomass produced along gully/waterways can be used for fuel wood, poles, fodder for livestock or bees, gums, fibre etc. Bamboo from gullies, for instance, can be used for weaving mats and several species of Eucalyptus for poles and timbers. The understory grass and bushes may also provide some fodder.

People who are landless can benefit quite significantly from gully areas. For instance, a series of stabilized gullies with a size of 2kms long and 2.5 meters wide could cover an area of 5000 square meters. In just one year, this area could produce enough fuel wood for 10 to 15 people, enough roofing poles for 10 people and enough fodder for 5 cows.

Generally, after gullies are conserved by biological conservation measures there are other advantages that farmers can obtain other than the SWC and soil fertility related benefits mentioned above. These are:

- Production of planting material for fruits, vegetables, fibers, medicinal plants, consumable goods, and others;
- Source of forage/fodder, fuel wood/small poles, organic fertilizer etc;
- Reduction of pollution and availability of clean environment for recreational use;
- Income generations from the sale of various biomass, vegetables, fruits, planting materials, tourism/recreation site visitors etc;
- Suitable for apiculture and other livelihood options; and
- Serve as a research and touristic site/place etc.

19.3 Place of biological treatments in gullies

The survival rate of plantation in the gully area is directly related to the availability of moisture during peak dry seasons and amount of water flow in the different sections of the gully during the peak rainy seasons. Vegetations, as biological gully control measures, can be combined with physical measures and/or be used alone for gully rehabilitation depending on the amount of peak discharge coming from the upper catchment and nature of the gully.

The best planting material for the bottom of gullies is the vegetative propagated planting materials such as stem and/or root cuttings. Examples of successful plant species in stabilizing gully bottoms include *Korch* (*Erythrina brucei*) for the highlands, elephant grass (*Pennisetum purpureum*) for mid altitudes with relatively high rainfall > 800mm, sisal (*Agave sisalina*) for mid and low altitudes, reed (*Arundo donax*) for medium and high rainfall areas and vetiver (*Vetiveria zizanioides*) for medium and low land areas with high rainfall. Each of these plant species, in combination with check dams or alone can be put across the bottom of a gully at certain intervals to check/obstruct the force of runoff and allow deposition of the soil particles behind.

19.4 Time of implementation of biological measures in gullies

It is not only the type of plant species but also the time of planting influences the successes in gully rehabilitations. Time of implementation of biological control measures in gullies is directly related to the availability of moisture, the type of soil and the amount of flow in the different sections of the gully. As a result, the general recommendation is to undertake planting on the offset and sidewall parts of the gully immediately when the rain starts. The gully bed should be planted when the water flow reduces and the main rainy season ceases. Unless and otherwise, the planted seedlings and seeds sown will be easily washed away by the running water. Furthermore, if the gully sides are steep, re-vegetation may not be easy to establish. Hence, gully wall reshaping may be combined to carry out planting of seedlings or direct sowing of seeds.

19.5 Design principles, species selection and gully plantation techniques

Principles of gully prevention and control using biological measures

Retention of water in the watershed through mechanical and vegetative measures is a useful tool for effective gully control program. It is advisable to retain as much runoff water as possible in the gully catchment through different moisture retention techniques. Proper management of runoff water and increasing vegetative cover of the watershed improves the

watershed hydrology through increasing of water infiltration and reducing of overland flow. This also enhances the gully healing process.

In gully control, the following three methods must be applied in order of priority:

- Reduce and regulate the run-off volume and peak rates;
- Diversion of runoff water from upstream side of the gully area; and
- Stabilization of gullies by both structural measures and accompanying re-vegetations.

In some areas, the first and/or second methods may be sufficient to stabilize small or incipient gullies. In some other areas which receive large rains, all three methods may have to be used for successful gully control. Runoff control is the first, foremost and effective way of gully control. If runoff entering into a gully can be controlled, then it is possible to grow vegetation in the gully. In performing biological soil and water conservation the following are key principles:

- Reduce raindrop impact (splash erosion) on the soil;
- Reduce runoff volume and velocity;
- Reduce wind velocity; and
- Increase the soil resistance to erosion.

In biological/vegetative control, the first step to be performed is avoiding free livestock grazing. The area should be fenced. A live fence of thorn bush, cactus, euphorbia and sisal etc could be established. The fence should be established far enough, from the bank of the gully, at a distance of about twice the depth of the gully. The following are some points important to be considered in biological conservation practices:

- Gully will normally restore the natural vegetation if properly protected from free livestock grazing;
- During initial stages of vegetation establishment, water that flows from gully head has to be diverted to safe outlets;
- Biological SWC measures should be integrated with physical measures for effective gully erosion control;
- Vegetation that establishes easily by shoot cutting or root suckers is best suited;
- Tree seedlings should be planted on stable gully banks, if the soil is deep enough;
- Priority should be given to indigenous species of trees, grasses and shrubs;
- For planting of gully walls, grasses are best suited;
- Sloping of the bank through scraping, to natural angle of repose may be necessary for steep gully walls; and
- Stabilized gully can be used as a waterway. For this purpose, the gully should be shaped properly and erosion resistant grasses should be established.

Points to be considered in the effectively implementation of gully biological control measures

In order to properly implementing biological conservation measures the following points need to be considered:

- Identify and consider existing gaps/problems in the designing of appropriate strategies;
- Develop appropriate strategies for the multiplication and distribution of quality planting materials;
- Involve communities in selecting of appropriate conservation practices. Focus on techniques and technologies, which are well accepted and tested by the communities;
- Integrate biological conservation measures with physical soil and water conservation structures;

- Establish close monitoring and evaluation systems to monitor and evaluate the effectiveness of biological conservation measure;
- All structural measures should be completed in the dry season and the accompanying biological measures undertaken during the following rainy season;
- Suitable tree seedlings and cuttings must be planted just behind the structural measures;
- Shrub and grass cuttings must be planted between the structural measures;
- Tree and grass seeds should be sown between the structural measures, and on gentle, bare slopes which have sufficient soil; and
- Gentle slopes, which do not need any structural measures, should be planted with tree seedlings, and grass and shrub cuttings.

Design, species selection and application of biological measures

The use of gully after rehabilitation measures depends on whether the gully is established to serve as a waterway/channel or its water is diverted and the gully purposely made to stabilize for other uses. Under the condition when the water is discharged through the gully, after the necessary stabilization activities have been undertaken, the side of the gully can be used for growing of grass or fodder. But in conditions where the gully is not used as a waterway, it can be used for growing horticultural crops and other plants. Wide gullies can have trees planted on the side slopes provided they are not too steep.

During the initial stages of vegetation establishment, the water flow from gully head should be diverted to allow safe disposal of water wherever possible. Grasses are most effective for initial stabilization of gullies. But gully walls crumble due to the steep slopes and alternate wetting and drying processes taking place. Moreover, steep slopes do not permit the seeds or cuttings to hold themselves to the soil and there is a danger of being washed away. Thus, sharply steep gully walls should be reshaped to convert the steepness to acceptable range of gradient (1:2) to allow easy establishment of the vegetation and better stabilization of the site against soil erosion. That is, if the depth of the gully is 3m, the gully wall reshaping extends up to 6m sideways to make the gradient 1:2.

Bottom of the gullies are planted with vegetative forms of planting materials from suitable species. Planting materials recommended for bed/floor part of the gully should be tolerant to water logging, with high root biomass and, resistant to soil sedimentation and high flow of water. A lot of biological materials which can fit to the condition can be found at the local condition in consultation with the farmers. Seeds cannot be used to stabilize the bottom of gullies as the seeds could be washed away and/or buried by sedimentations.

Areas within the boundary of the gully can be well stabilized with low growing grasses, preferably creeping types and capable of rooting from their stubble. Introduction of other productive species including trees and shrubs for fuel and construction purposes, fruit trees and other income/cash generating high value crops is crucial to optimize the productivity of the gully.

However, the growing of income generating trees must not be dense that suppress the growth of under story vegetation (e.g. grasses), which are effective in controlling soil erosion and stabilization of the site. All the gully areas including gully bottoms and sides can be vegetated with productive species. While fruit trees and tree crops demanding more moisture can be planted in gully bottoms, plant species that can perform well under relatively low moisture supply can be planted on gully sides.

Techniques of biological gully control measures

In gully treatment natural re-vegetation or recovery is too slow. Hence, planting should be undertaken to cope with erosion hazard. The establishment of vegetation, either naturally or artificially, has to contend with conditions in the environment. In this connection, the type of planting material to be used should be properly selected based on the specific environmental condition of the gully. Conservationists and farmers should properly assess the soil and moisture conditions in the gully head, gully floor/bed, gully sidewall and gully offset/gully buffer zone. Practically speaking, these different locations of a gully do have different soil and hydrological characteristics which determines the type of plant species (grass, shrubs/bushes and trees) to be planted.

Having the aforementioned suggestions in mind, the following biological measures can be taken as potential alternatives for gully rehabilitations. They can be combined with physical measures and/or used alone for gully rehabilitations depending on the amount of peak discharge coming from the upper catchment and nature of the gully.

a. Reinforced bundling (or wattle)

Bundling or wattle is a technique where fresh stems of plants (e.g. Elephant and Bana grass, Green gold, Spanish reed, Elderberry, Poplar, and Willow) are bound together in bundles and planted across the gully bed or the sidewall. In order to minimize planting materials wastage, bundles (also called wattles) may be combined with other bulky organic materials (filling materials) such as dry grass or straw, or dried branches, stems such as Acacia saligna, Sesbania etc. Series of live bundles supported with wooden poles are helpful to treat small gullies.

Reinforced bundling requires that mature poplar or willow stems or truncheons (branches), 70 cm in length, are inserted 20 cm deep next to each other across the gully floor or bed in two rows, spaced 50 cm apart. Downstream buttressing (support) should be provided for stability. The space between the two rows of truncheons should then be filled with bundles consisting of approximately 30% vegetative (fresh) bundles of planting material, and 70% of filling material. Withering of the planting material can be prevented by lightly covering the material with moist soil. As soon as the poplar or willow stems have exhibited adequate vertical growth, the space between the stems can again be filled with bundling material. There will thus be an incremental growth in the height of the structure, which will in turn add to the level and amount of siltation. This technique should only be applied when the rainy season has commenced. Through time, the bundles grow and serve as live check dams (photo 1). Bundles of willow, popular, green gold, bana and elephant grass species are simple and effective means's to control small sized gullies.



Photo 1: Sample photos on biological gully rehabilitation practices using wattle techniques

b. Layering

Layering is the horizontal planting of fresh stems of plants (e.g. elephant and bana grass, green gold, spanish reed, elderberry, poplar, willow) across the gully floor and/or reshaped sidewall, or at the base of gully walls. This technique is applied when a satisfactory level of sedimentation has been achieved. The stems of these plants root very easily and initiate shoot quickly. Sedimentation increased as the shoot growth forms a dense barrier that checks and breaks the flow of water. This in turn leads to a gradual build-up of the gully floor/bed as a result of siltation.



Photo 2: Planting of elephant grass by layering to rehabilitate gully bed

c. Direct sowing or broadcasting

Direct sowing (broadcasting) of seeds on gully beds and into the cracks of sidewalls during the rainy season results in an almost immediate cover of these fragile areas. Seeds of *Sesbania sesban*, *Acacia saligna*, *Cajanus cajan* (Pigeon pea), common vetch and other can be mixed together and sown on different sections of the gully. To assure an economical use, and to avoid over-planting, seeds should be mixed with dry sand during sowing.

d. Planting of water loving species on gully beds

The planting of water-loving or marshy area tolerant trees, shrubs and grasses such as *Paraserianthes lophantha*, *Salix* spp., *Acacia melanoxylon*, *Phalaris aquatica*, *Pennisetum clandestinum*, *Pennisetum riparium*, *Pennisetum purpureum* and Green gold grass in the gully beds can:- break the run-off velocity, trap sediments, and protect gully bed from erosion especially when done with adequate spacing. Biomass production can be astonishingly high during the second rainy season if the environment is conducive. A lot of biological materials which can fit to this condition can be found for gully bed/floor treatment. Experts should identify them in consultation with farmers at the local level.

e. Planting at the bottom of gully side walls with the support of bamboo-mat made retaining walls

In gully rehabilitation scheme, the difficult part is to control the lateral flows which are coming from farm fields, footpaths, degraded grazing areas and other miscellaneous land use types. In order to protect the lateral flows and mass movement due to soil sliding/melting from fragile sidewalls of a gully, retaining walls made of reed/bamboo mat can be installed along the foot of the sidewalls. The mat can be strengthened on the lower side by wooden sticks, possibly using vegetative propagating species like poplar, willow and other indigenous species. Truncheons/branches of various species can be layered on the upper part of the

mat. This technology facilitates self reshaping of gully and quick rehabilitations. "Mini" bundles, with or without pegging, are also employed in small pocket areas. *Arundo donax* and *Hyparrhenia* stems, consisting of three to four nodes, proved particularly useful for this purposes. Retaining, bundling and pegging activities should commence with the onset of the rainy season.

f. Planting of trees, shrubs and grasses on gully sidewalls

The long-term stabilization of gully sidewalls also requires the establishment of woody perennial plants. Multipurpose trees like *Dodonea angustifolia*, *Acacia saligna*, and *Teline* spp. are recommended for treating reshaped gully sidewalls. Successful results have been achieved by planting Bana Grass and Green Gold Grass in rows across the gully slope. Planting of kikuyu around the lower sidewall and crown vetch even on steep side walls have shown promising results.

g. Gully off-set plantations

The gully off-set is the area that extends from the top edge of the gully wall up to five meters away from the gully. Adequate stabilization is essential to prevent the sideway extension of the gully and further encroachment of good arable lands. Generally, gully offsets are moisture deficient. Thus, drought tolerant multi-purpose species of trees, shrubs, grasses, and fodder legumes are suggested for stabilizing this fragile area. Recommended species include: *Lespedeza sericea*, *Medicago sativa*, *Coronilla varia*, *Atriplex nummularia*, *Teline canariensis* and *madeirensis*, *Acacia saligna*, *Acacia abyssinica*, *Acacia angustissima*, *Paraserianthes lophantha*, *Chamaecytisus palmensis*, *Grevillia robusta*, *Sesbania sesban*, *Lupinus arboreus*, *Tephrosia vogelli*, *Leucaena leucocephala*, *Tamarix* spp etc.

In general, plant species with moderate tolerance to dryness and wetness are recommended for the treatment of gully offset; species which have invading characteristics, with light foliage and steam biomass and have high tolerance to drought are recommend for gully side walls after the land is reshaped and the gully offset converted into potential areas for multiple purposes; and whereas, the biological conservation materials recommended for gully bed/floor should be those tolerant to water logging, with high root biomass and, resistant to soil sedimentation and high flow of water.

Integrated treatment of physical with biological measures will also help in stabilizing the gully head. Some creeping plant species can be used to better reinforcing the structures constructed. Biological measures play a role in rehabilitating this section of the gully. It can be applied after re-shaping of the gully.

19.6 Natural re-vegetation through gully closure techniques

The first thing that should be done to foster the natural recovery of vegetation is keeping out of livestock and avoiding of mechanical disturbances of the gullied area. Protection against such disturbances of the gully is the slowest and gradual but the cheapest method of gully erosion control. Good results may be obtained and heavy expenses can be avoided by simply fencing the gully area and prohibit free livestock grazing or cultivation. Any gully, regardless of its size or condition, usually regains its natural vegetation cover if it is properly protected and the area is suitable for vegetation growth. Diversion or retention of water which passes through the gully, protection from grazing or trampling by livestock, protection from fire and removal of other causes of disturbances usually result in the re-growth of natural vegetation, which will, in time, cover the gully and heal the scars of erosion.

However, many gullied areas or gully banks are unfavourable for vegetative growth. Because the fertile topsoil is washed away, slopes are steep, and the impacts of raindrops on the unprotected soil create adverse conditions to the plant survival. Gullies often dry out very rapidly and usually have infertile sub-soils. Hence, bank sloping may be necessary before any vegetations for better gully stabilization. One must be very careful, of course, when reshaping of the gully wall as the practice may even widen the gully since the soil may simply be washed away in the first rain shower unless timely planting undertaken and structures well maintained.

In summary, gully area can re-vegetate naturally if the water causing erosion problem is conserved or diverted to another channel before it reaches the gully. Obviously, livestock should also be kept away. Costs are minimal when one applies natural re-vegetation methods. But such natural recovery of vegetation is very gradual and a slow process of recovery especially if the soil is poor.

Gully closure

Area closure is a conservation measure that helps to protect and improve the gully area or any other land use type with degraded vegetation and/or soil through natural regenerations over time. No livestock is allowed to graze, and no human interference allowed for 3-5 years, until 80% of the natural grass recovers. The use of such areas can be planned as soon as a satisfactory state of recovery achieved. Initially, some farmers may frustrate due to their inability to access grazing lands and other associated problems in the short term. The responsibility of protecting closed areas is that of the community. Communities are also responsible for the management and planning of future use of closed areas.

Fencing is one of the indispensable elements in the process of establishment of closures. The fence should be established far enough, from the bank of the gully, at a distance of about twice the depth of the gully. Area closure alone (without support measures) is a slow recovery process and may not be seen as very beneficial. However, area closure combined with various conservation and management measures could become an attractive investment. Trees planted in one closure should be at least of different species that would allow for undergrowth to explore different soil depths. For example a mixture of *Grevillea robusta*, *Acacia Saligna* and *Acacia melanoxylon* can be tried in middle altitudes. Tree species such as *Acacia senegal* (for gums), *Cordia africana*, *Croton macrostachyus*, *Albizia lebbek*, and other countless species may be planted in different combinations depending on the agro-ecological zones.

In each site medicinal species (for example *Hagenia abyssinica*) and other valuable trees for integrated pest management practices (such as *Azadiracta indica* or *Neem*, etc.) or valuable indigenous species (*Olea africana*, etc.) can also be sparsely planted (every 25-50 trees). Under such circumstances, bee-keeping can also supported through diversification of species for staggered flowering periods.

Application of area closures

- Area closure is a temporary action to protect degraded land until a certain degree of recovery has been attained
- In area closure no specific actions are taken, except that all human and livestock interference is excluded
- Sometime, after natural recovery, the grass may be cut regularly to minimize fire incidence. Hay can be prepared and shared among the members for livestock feed
- Closure has to be decided in consultation and prior agreement of the beneficiary communities
- There are three possibilities for the management of area closures:

- Use it as grassland while applying proper grassland conservation and development measures
- Develop forestland while applying forest conservation and development measures
- It would also be necessary in certain conditions that the planting of nitrogen fixing species will be useful in order to speed up the recovery rate.

Period for implementation of closures

The area should be closed before the rainy season. Other supplementary measures must be performed as per their specific requirements.

Main land use and agro-ecology

Area closure is applied in most agro-climatic areas where there are degraded hillsides and large gully networks to increase the production and productivities. Area closure is commonly practiced in Ethiopia at different levels of performances. Best closed areas are found in places where the gully is directly managed by interested community and/or group of farmers. Combined with different soil and water conservation measures, area closure restores sufficient productivity for the growth of multipurpose trees, grass and specific cash crops. Area closure protects downstream fertile fields from floods and contributes to recharge aquifers. When properly managed, area closure can provide significant income to the poorest households. It is a potential for better impacts in environmental protection and rehabilitation activities.

Main measures taken for area closure

- **Guarding:** No livestock is allowed to graze for 3-5 years, and only very limited (close to nil) human interference is tolerated until 80% grass coverage is obtained,
- **Control measures:** Improved pits for fodder and tree plantation or check dams and brush woods in gullies dissecting the closure are necessary. Cut-off drains and waterways for excess runoff control in sensitive parts of closure also important.
- **Fencing:** Vegetative fencing and dry fencing if encroachment is difficult to control
- **Manuring:** Manuring of planting pits and young seedlings is good
- **Firebreaks:** Firebreaks should be considered as precaution measures
- **Land sharing and certification:** is essential to enhance sense of ownership and avoid illicit destructions.

Technical preparedness

Area closure requires a combination of skills and techniques depending on the type of measures that need to be established. Some of them are provision of training on area closure management, various SWC measures, and others based on the nature of the gully and rehabilitation related activities required as well as interest of farmers. Gap analysis study may help to see and identify areas for capacity building activities.

Norms: Work norm for site guards, if only strictly necessary is: 4 person days/ha/year.

19.7 Reasons for failure in biological gully control measures

Previous efforts to establish vegetation as gully control measures was not successful due to poor survival rate of seedlings after plantations. Some of the important causes for the low survival rate are:

- Poor integration of both physical and biological measures
- Use of limited variety of species for biological measures
- Nursery management problems
- Distantly located nurseries: If possible, it is advisable to establish nurseries nearby/inside the area to be treated

- Planting whatever type of seedlings without any purpose
- Planting of biological measure in times when there is less or no moisture
- Failure of rain after the measure taken
- Lack of sense of ownership and accountability in communally owned gully areas
- Free/open grazing because of the difficulty to break the free grazing culture in short period
- Lack of equal participation of farmers in the watersheds
- Low participation of women
- Absence of community bye-law or low enforcement power
- The commitment of the experts/officials at different levels
- Focus on planting, not on infilling (replanting) in places where seedlings died

19.8 Sustainability of biological measures

Integration of physical measure with biological gully control measure

The combination of biophysical measures is the best solution for effective gully control and productive use of the gully area. Planting of certain species like Agave (Eret) and fast-growing forage plants is a good option in order to prevent the undermining effect of erosion, immediately. If this fails, the physical gully control measures which are executed with huge investment will fail as well. Therefore, attention must always be given to integrate both measures and keeping the gully catchment well vegetated for sustainable development of the gully. In areas where rock and cement are in short supply, trees and shrubs can serve as the only available conservation tools. The natural regeneration which is coming after the gullies are protected and enclosed should also be considered in the overall rehabilitation of the scheme.

Management of biologically treated gullies

Management of vegetation planted along waterways and gullies often focuses on controlling access, rather than managing the plants themselves. Whether plants along waterways are protected by a physical barrier or fence or by social agreement, people and animal interferences must be prevented for at least two to three rainy seasons depending on the situation. Once a waterway is stabilised and the plants along its edges are well established, then it is possible to begin harvesting of plant products. This might include controlled grazing, cut and carry systems of harvesting, and collecting fruits, fuel wood and timber from trees.

Access and control are important aspects of management of gullies and waterways. The rights and responsibilities of local people to maintain waterways and use produces need to be clearly defined and widely recognized. Without well defined use rights, the people who maintain the channels cannot prevent others from destroying the structures and the vegetation through over-grazing or overharvesting. The rights and responsibilities may be assigned for specific families or larger community groups, perhaps organised in an informal association. Such a group could decide how to use the site and agree on maintenance tasks and accessing of produces of the gully.

The other important issue in the management of biological control measures is the identification of user groups and development of a use concept or management plan. In most cases, gullies cross different land uses owned by many land users. Therefore, before treatment of gullies, the users should be objective oriented and carefully plan and agreed upon responsibilities to managing, maintaining and utilizing the gully and its produces. The management of a waterway requires a clear agreement not only among the community members but also between the community and the relevant departments of the government. In general, techniques of plantation are not always successful. Applicability and

effectiveness strongly depend on the type of gully and specific circumstances, which have to be very well studied and understood. The size of the gully catchment area, the gradient and length of the gully channel are some of the main criteria for selecting control measures.

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