ESTABLISH A TREE NURSERY

FORESTRY

TRAINING MANUAL

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

B/C R	Benefit-Cost Ratio
IBA	Indole-3-butyric acid
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
NAA	Naphthaleneacetic acid
pH	Potential of Hydrogen
RP	Rwanda Polytechnic
RTB	Rwanda Technical and Vocational Education and Training Board
RwF	Rwandan Francs
TTZ	Tetrazolium

LEARNING UNIT 1 - PLAN A TREE NURSERY

Learning Outcomes:

1.1. Estimate cost-benefit analysis for establishing a tree nursery

1.2. Proper selection of sources of planting stock

1.3. Proper evaluation of the present nursery market

1.4. Proper description of criteria to consider while selecting a tree nursery location

1.1 Learning outcome 1: Estimate cost-benefit analysis for establishing a tree nursery

1.1.1 Cost-benefit analysis for both temporary and permanent nurseries

Key concept:

> Cost-benefit analysis: Cost-benefit analysis is a framework to assess the merits of an activity (project, policy) from the perspective of society. It involves:

- ✓ Measuring the gains and losses (benefits and costs) from an activity to the community using money as the measuring rod; and
- ✓ Aggregating those values of gains and losses and expressing them as net community gains or losses.

>What is the use of cost-benefit analysis?

Cost-benefit analysis is used to help people make decisions. Depending on when the analysis is undertaken (before, during or after an activity), cost benefit analysis can provide information to help assess:

- Whether a project or activity will be or is useful:
  - ✓ Should we invest in this project?
  - ✓ Which of these two projects should we support?
  - ✓ Which project will give us the best pay off per money invested?
  - ✓ Which project will generate the highest value to society once we have paid for it?
- Whether a project or activity has been worthwhile.

>How to calculate cost benefits analysis

Benefit-Cost analysis is performed by using the following formula:

$$\text{Benefit Cost Ratio} = \frac{\sum_{t=0}^{t=n} \frac{B_t}{(1+r)^t}}{\sum_{t-0}^{t=n} \frac{C_t}{(1+r)^t}}$$

Where:

B = benefit

C = cost

t = time

r = interest rate

The cost-benefit ratio (B/C R) is determined by dividing the revenue generated in the tree nursery by the costs incurred. If Benefit Cost Ration (B/C R) is > 1, then the enterprise is operating at a profit. But if B/CR < 1, it is a non-profitable venture. Thus, the B/CR <1 implies that no one should invest in such business.

>Cost-benefit analysis for a temporary nursery

What is done here is that all the costs incurred should be identified as well as the benefits (output). Hence, the following table presents all the possible costs as well as the benefits to be expected in a temporal tree nursery.

Table 1: Costs/ benefits estimation for a temporal tree nursery of 100 m2 in which the expected production is 20,000 Seedlings

S/No	Item	Unit price/ RwF	Quantity required	Total price/ RwF
Fixed costs				
1	Rake	5000	1	5000
2	Watering can	4500	1	4500
3	Wheel barrow	25000	1	25000
4	Renting land	10000/month	5	50000
Variable costs				
5	Wood stick for nursery establishment	2000	10	20000
6	Bamboo for nursery establishment	500	20	10000
7	Tree seeds/ Eucalyptus	7000	0.5	3500
8	Containers	4000	25	100000
9	Compost	10	200 kg	2000
10	Labour for land preparation	2000	1	2000
11	Labour for nursery shelter and fence making	2000	3	6000
12	Labour for potting soil in the containers	2000	50	100000
13	Labour for dairy care maintenance	2000	50	100000

Total cost				**428,000**
14	Selling seedlings/ Income	50	20000	**1,000,000**

Thus, it is clear that the total cost was estimated to be 428,000 RwF whereas the total income was estimated to be 1,000,000 RwF. Hence, cost-benefits analysis is estimated as follows:

First, we will need to calculate the net income = Total income – Total costs = 1,000,000 – 428,000 RwF = 572,000 RwF

Then, Cost-benefit analysis will be = $\frac{Net\ income}{Total\ costs} = \frac{572000}{428000} = 1.33$

That is to say for every 1 RwF invested in a temporal tree nursery will generate 1.33 RwF.

>Cost benefit analysis for a permanent nursery

For a permanent nursery, the difference is observed in the costs incurred as well as the benefits obtained after selling the production. Table two presents costs/ benefits estimation for a permanent nursery in a period of one year.

Table 2: Costs/benefits estimation for a permanent tree nursery of 100 m2 in which the expected production is 40,000 Seedlings per season

S/No	Item	Unit price/RwF	Quantity required	Total price/ RwF
	Fixed costs			
1	Rake	5000	1	1250
2	Watering can	4500	1	1500
3	Wheel barrow	25000	1	5000
4	Renting land	100000/ year	1	100000
Variable costs				
5	Wood stick for nursery establishment	2000	10	20000
6	Bamboo for nursery establishment	500	20	10000
7	Tree seeds/ Eucalyptus	7000	0.5	3500
8	Containers	4000	50	200000
9	Compost	10	400 kg	4000
10	Labour for land preparation	2000	2	4000
11	Labour for nursery shelter and fence making	2000	6	12000

12	Labour for potting soil in the containers	2000	100	200000
13	Labour for dairy care maintenance	2000	100	200000
Total costs				**761,250**
14	Selling seedlings/ Income	50	40000	**2,000,000**

Note: For the fixed costs rake was estimated to last for four years, watering can 3 years and wheel barrow for five years, thus their respective prices were shared to the number of years that an item will last.

Based on the estimations highlighted in table two the total costs were estimated to be 761,250 RwF whereas the total income is 2,000,000 RwF.

Thus, cost benefits analysis for the permanent nursery is estimated as follows:

First, we will need to calculate the net income = Total income – Total costs = 2,000,000 – 761,250 RwF = 1,238,750 RwF

Then, Cost benefit analysis will be = $\frac{\boldsymbol{Net\ income}}{\boldsymbol{Total\ costs}} = \frac{\mathbf{1{,}238750}}{\mathbf{761{,}250}} = \mathbf{1.62}$

1.1.2 Examples of cost-benefit analysis with reference to major tree species grown in Rwanda

Apart from *Eucalyptus* tree species, the other trees grown in Rwanda include *Pinus spp*, *Grevillea robusta* and *Markhamia lutea* (Just to mention some).
While calculating the cost-benefits analysis, the assumption will be that seedlings of all these tree species will be sold at the same price. Another useful information is that we will consider our example in a permanent nursery.

Table 3 presents costs and benefits estimation for a permanent nursery producing *Pinus patula* seedlings. As long as the necessary costs and benefits have been indicated, the learner can use the following example for calculating cost benefit analysis for any other tree species to be grown.

Table 3: Costs/benefits estimation for a permanent tree nursery of 100 m2 in which the expected production is 44,000 seedlings per season

S/No	Item	Unit price/ RwF	Quantity required	Total price/ RwF
Fixed costs				
1	Rake	5000	1	1250

2	Watering can	4500	1	1500
3	Wheel barrow	25000	1	5000
4	Renting land	100000/year	1	100000
Variable costs				
5	Wood stick for nursery establishment	2000	10	20000
6	Bamboo for nursery establishment	500	20	10000
7	Tree seeds/Eucalyptus	7000	0.5	3500
8	Containers	4000	50	200000
9	Compost	10	400 kg	4000
10	Labour for land preparation	2000	2	4000
11	Labour for nursery shelter and fence making	2000	6	12000
12	Labour for potting soil in the containers	2000	100	200000
13	Labour for dairy care maintenance	2000	100	200000
Total costs				**761,250**
14	Selling seedlings/ Income	50	44000	**2,200,000**

Based on the provided costs/ benefits estimation in table three, the cost-benefit analysis will be estimated as follows:

Total income – Total costs = 2,200,000 – 761250 RwF = 1,438,750 RwF

Then, Cost benefit analysis will be = $\frac{\boldsymbol{Net\ income}}{\boldsymbol{Total\ costs}} = \frac{\mathbf{1{,}438{,}750}}{\mathbf{761{,}250}} = 1.88$

1.1.3 Requirements for a container nursery system

The first step in cost analysis is to identify all the things that are required to operate a nursery. Beginner developers often assume that there is a standard system for growing container seedlings but, in reality, no such thing exists. Each species of tree has its own optimum environmental requirements, and each potential nursery location has a unique climate. Individuals and organizations also have their own goals and constraints that will affect development decisions. Therefore, nursery developers must realize that a container nursery facility must be carefully designed to match specific objectives.

To make sure that all factors are considered, a relatively simple systems analysis approach should be used. A container nursery system consists of a series of processes. A specific process, such as sowing seed, involves a series of sequential operations, such as filling the container with growing medium and placing a calculated number of seeds in each container. Each process and operation in the system has specific requirements including structures, equipment, supplies, and labour.

The objective during the nursery development phase is to understand the system and its processes well enough to identify the requirements and estimate their associated costs. Some requirements will be standard for all types of nurseries, but others will vary. For example, a nursery that is designed to propagate seedlings vegetatively will have slightly different process and operations, and therefore different requirements, than one designed to produce plants from seeds.

To ensure that all of the various requirements are considered, it is often helpful to visualize the nursery system, processes, and operations. This is for facilitating the inclusion of every item which will incur cost. For the learner to have a glimpse on this exercise, it would be better to visit an existing nursery or have a close discussion with those having experience in nursery practices.

1.1.4 Influence of nursery size and space utilization

The production capability of the proposed nursery is obviously an important factor that will affect product cost estimates. Larger facilities are more efficient because of the economies of scale but are also inherently more expensive to develop. Thus, it is prudent to keep growing facilities as small as possible at the beginning, and expand gradually as seedling demand develops and funds are available.

1.1.5 Transportation consideration

Because forest tree seedlings are typically transplanted in distant locations, transportation to the out-planting site can be a significant economic consideration. Therefore, it is recommended that the nursery developer should try his/her best to locate the nursery near the planting area. Otherwise, transportation costs may reduce the benefits which were expected in the total production.

1.2 Learning Outcome 2: Select the best source of planting stock to be used in seedling production

1.2.1 Sources of planting stock

When confronted with a regular demand for tree seedlings, many people think about starting their own nursery. Growing tree seedlings requires a concerted and sustained effort, however all the merits and demerits of starting a nursery should be considered (table 4). The principal benefit of having a nursery is that the quantity, quality, and availability of planting stock can be controlled. Much time must be devoted to developing a new nursery, however, and considerable capital investment will be required. The projected need for seedlings must be long enough to remunerate the investment. Therefore, individuals or organizations that need a steady supply of seedlings should first consider purchasing stock from an established nursery.

Table 4: Careful analysis required before deciding to purchase or establish a tree nursery

Purchase seedlings	
Merits	**Demerits**
✓ Time and capital free for other uses	✓ No control over growing process
✓ No nursery staff needed	✓ Often required to accept high price
✓ No need of buying tools/ equipment	✓ Less control over seedling quality and availability
✓ No need of renting land	✓ Seedlings may not be adapted to your environment
Start your own nursery	

Merits	Demerits
✓ Most control over seedling quality and availability	✓ Large capital investment and time consuming
✓ Can develop local expertise on seedling growing and handling	✓ Long term professional and economic commitment
✓ Produced seedlings will be adapted to the environment	✓ Must hire and maintain staff
✓ Create job opportunities	✓ Seedling markets are notoriously changeable from year to year
✓ Don't have to rely on other individuals or organizations	✓ Could cause unwanted competition

1.2.2 Purchase seedlings

There are a number of advantages to purchase seedlings instead of starting a nursery. First and foremost, time and capital are available for other uses (table 4). Producing tree seedlings can be a risky business venture, and buying planting stock from other nurseries means that many of the risks and day-to-day annoyances associated with growing seedlings can be avoided.

Potential tree nursery developers should carefully observe other operations already in the business and decide if the advantages of starting a nursery outweigh the disadvantages. There are two basic ways to purchase seedlings from nurseries: buying seedlings and seedling contracts.

- **Buying seedlings**

Some nurseries sow a certain percentage of their annual production specifically for the speculation market. Usually, these are species and seed sources that are adaptable to a wide geographical area or have proven to be marketable in the past. Surplus seedlings are also sold as speculation stock. Because of anticipated losses, most forest nurseries over sow their seedling orders and therefore have some seedlings available each year for sale on the open market. The quantity and seed source of this surplus stock varies from year to year, however, and so seedling users must contact different nurseries each season to learn what species and seed sources will be available. This is because the seedlings to be bought should match with the site and objectives of planting.

- **Contracting for seedlings**

Because tree seedlings are perishable product and the market is notoriously changeable, economics dictate that most forest nurseries grow a large proportion of their seedlings on contract. Hence, if you have decided to get your seedlings through a contract, the contract should specify the tree species to be planted, the quantity of seedlings needed, the size of seedlings and the seed source to be used.

1.2.3 Start your own nursery

Once the decision is made to start a nursery, the next question is whether it should be a bareroot or container facility.

- **Bareroot nurseries**

Bareroot seedlings are grown in open fields in native soil, and consequently, the soil, water supply, and climate of the nursery site must be suitable for tree growing. The rate of seedling growth and length of the growing season are largely controlled by the climate at the nursery site. Quality sites are often difficult to find in convenient locations, and good agricultural land is often expensive. A considerable capital investment is usually required to develop a bareroot nursery of any size. Bareroot nurseries are also sensitive to the economies of scale. Once a nursery is established and operations have begun, it is important to function at near-capacity levels to have reasonable unit production costs. Compared to container nurseries, energy requirements and associated expenses are relatively low. Therefore, bareroot nurseries are recommended to be used when the seedlings are grown in their native area, with low number of seedlings to be produced and limited capital investment.

- **Container nurseries**

Container nurseries can be constructed on land with low agricultural value that would be unsuitable for bareroot seedling production. The amount of capital investment varies with the type of facility and quantity of seedlings to be produced. Because container seedlings are grown at high densities, more land is required compared to a bareroot nursery.

Container nurseries are less sensitive to economies of scale and, in extreme situations, part or all of the nursery can be shut down to reduce operating costs. Container seedlings have high growth rates, especially in fully controlled environments, and so seedlings can be produced in one growing season. From a business standpoint, this means that container nursery managers can respond quickly to changes in the market.

- **Select the best alternative**

The decision of whether to start a bareroot or container nursery must be carefully thought out because there are many things to consider. It is helpful to list the various considerations side-by-side for ease of comparison. Table 5 illustrates clearly the criteria to be considered while deciding to use bareroot or container nursery.

Table 5: Factors to be considered when evaluating the use of bareroot or container nursery

Criteria to consider	Container nursery	Bareroot nursery

1. Elevation (Altitude)	Better for areas with short growing seasons: high elevation or high altitudes	Better for areas with longer growing seasons: low altitudes or low elevations
2. Initial capital investment	Lower land costs, but structures and equipment are expensive	Land cost can be significant and preparation may be extensive, equipment costs vary with degree of mechanization. Thus, lower capital in comparison with container nursery
3. Land requirement	Less land needed due to higher growing densities and lower cull rates produce higher yields	More land required because lower growing densities and higher cull rates produce lower yields
4. Soil quality	Not important here, due to potting media prepared before pricking out	Critical and important here and it is recommended to check if the soil is rich in nutrient
5. Water availability	Less amount required	Higher amount required
6. Labour force	Only few trained staff needed	**Large worker crews needed**
7. Seed use efficiency	Very high efficiencies possible	Poorer yield per quantity of seed
8. Time required	Shorter compared to bareroot nursery	Longer than the period used in container nursery
9.Seedling characteristics	Some species grow better in containers; those with small seeds (eg. Eucalyptus spp), weak germinant, slow growing species (eg. Markhamia lutea)	Some species grow better as bareroot seedlings such as broad - leaved hardwoods that need more growing space.
10. Pests	Fewer pests in comparison with bareroot nursery	Many pests are common in bareroot nurseries
11. Survival rate	High survival rate of seedlings	Low survival rate of seedlings

1.2.4 Seed procurement

For everyone who wishes to involve in seed procurement in Rwanda, he/she needs to contact the Rwanda Forestry Authority (RFA) through its sub unit known as Tree seed center located in Huye town. This centre provides enough information regarding the price of seed for each tree species needed.

- **Quantifying needed seeds**

For quantifying the needed seeds, it is recommended to use the list of available seeds, respective price as well the number of seeds per kilogram. While requesting for seeds the nursery practitioners are urged to add 30% of seeds so that the latter can be used for beating up or replacing dead seedlings after out planting. Table 6 contains a list of available seeds, respective price as well as the quantity of seeds available per kilogram, a list produced by Tree seed centre and has to be updated every six months.

Table 6: Available tree seeds, price and quantity of seedlings per kilogram

No	Tree species	Price RwF /Kg	Seeds/ Kg
1	*Acacia angustisma*	12420	65,963
2	*Acacia koa*	15880	3,253
3	*Acacia mearnsii*	12420	22,687
4	*Acacia melanoxylon*	15880	20,857
5	*Acacia sieberana*	3500	540
6	*Alnus acuminata*	25000	277,000
7	*Araucaria cunninghamiana*	3000	1,085
8	*Caesalpinia decapetala*	2620	1,368
9	*Cajanus cajan*	3020	2,915
10	*Calliandara calothrysus*	12420	8,855
11	*Callitris robusta*	8000	30,250
12	*Casuarina equisetifolia*	12420	210,500
13	*Cedrela serrata*	10000	30,400
14	*Croton megalocarpus*	6960	358
15	*Eucalyptus camaldurensis*	8400	13,1500
16	*Eucalyptus maidenii*	7000	98,833
17	*Eucalyptus mycrocorys*	8400	220,500
18	*Eucalyptus tereticornis*	7000	280,500
19	*Eucalyptus urophylla*	7000	409,000
20	*Gliricida sepium*	17820	1526
21	*Grevillea robusta*	25000	21,960
22	*Jacaranda mimosifolia*	12240	21,855
23	*Leucaena diversifolia*	5240	28,765
24	*Leucaena leucocephala*	5240	4,133
25	*Leucaena tricandra*	5240	32,704
26	*Maesopsis eminii*	1380	245
27	*Markhamia platycalix/lutea*	3840	10,631
28	*Mimosa invisa*	12420	97,422
29	*Mimosa scabrela*	23000	23,518
30	*Mucuna pruriensi*	2620	300
31	*Pinus patula*	38000	55,660
32	*Podocarpus falcatus*	2280	202

33	*Polyscias fulva*	8000	23,728
34	*Prunus africana*	10600	2439
35	*Pterygota mildbraedii*	15000	490
36	*Senna siamea*	8000	17,357
37	*Senna spectabilis*	3960	13,356
38	*Sesbania macrantha*	2620	8,370
39	*Sesbania sesban*	2620	38,160
40	*Spathodea campanulata*	25520	20,900
41	*Tephrosia vogelii*	3000	8,206
42	*Terminalia mantali*	10600	1,400

1.2.5 Seed quality checking

Seed quality testing comprises procedures that determine various aspects of the seed including purity, viability and germination ability. Seed tests are not done on all the seeds but on a sample of them. Some tests will destroy the seed; thus, it is necessary to consider seed testing when calculating the quantity of seeds needed.

- **Seed purity**

Since all other seed tests need to be performed on pure seeds, the purity of the lot must be determined first. Sample should be uniform and representative of the entire seed lot. Hence, it is better to take a sample from several parts of the container, from the top, middle and bottom of the bag or seed lot.

The seed purity percentage is the percentage of the weight of pure seeds within the sample. You need to weigh the sample first, then the impurities and subsequently weigh the pure seed. The seed purity percentage is calculated by the following formula:

$$\text{Purity (\%)} = \frac{\boldsymbol{Weight\ of\ pure\ seed\ (g)}}{\boldsymbol{Total\ weight\ of\ original\ sample\ (g)}} \text{x } 100\%$$

The accepted allowance of impurities in forest –tree seeds vary from 10 to 40 Percent and varies with tree species.

- **Seed germination and viability tests**

Seed germination or seed viability tests indicate the germination ability (potential germination) of seed. Germination of a representative sample will indicate how manay seeds can be expected to germinate in the nursery when the seed is handled properly.

For performing well germination test the following steps should be followed:

1. Randomly pick 400 seeds from the seed lot
2. Sow the seed in trays containing a good germination soil/substrate
3. Keep the soil moist
4. Count the number of germinated seeds each day, especially for species that germinate rapidly. Remove germinates as you count them to facilitate subsequent counting and to avoid possible fungal spread. The test should be continued until no additional seeds germinate.
5. Calculate the percentage of germination as follows:

$$\text{Germination (\%)} = \frac{\textit{Number of germinated seeds}}{\textit{Number of tested seeds}} \times 100$$

Figure 1: Testing germination of Calliandra calothyrsus in a nursery

Viablity test is applied to species that is difficult to germinate. This test can also be used when results are needed quickly to determine the percentage of seed that is alive. Seed that is alive doesn't always germinate, however, the results of the viability test could indicate a higher percentage than those of the germination test.

The most important viability test is the tetrazolium (TTZ) test, a chemical used to stain viable seeds in red color. In this test the sampled seeds are first soaked in water for 24 hours and then the seed are removed from water. Upon their removal from water, each seed is divided into two parts longitudinally. Then seeds are collected in a beaker with tetrazolium as a staining agent.

The beaker is then kept in water bath heater for one hour at 400 degree Celcius. Then the stained and non stained embryos are separated and used for seed viability percentage calculation as follows:

Seed viability = $\frac{\boldsymbol{Number\ of\ stained\ embryos}}{\boldsymbol{Total\ number\ of\ embryos}}\ \boldsymbol{x\ 100}$

1.3 Learning Outcome 3: Evaluate the present nursery market for buying and selling seedlings

1.3.1 Evaluating the present nursery market

Potential nursery developers must be very realistic about the market they are planning to fill. A market analysis should be done to collect facts about demand, competition, and prices of seedlings in the location that they intend to establish a tree nursery.

1.3.2 Demand for seedling

For nurseries that are being developed to meet in-house seedling needs, the demand is already known. But, for nurseries that plan to supply seedlings to other users, potential customers should be surveyed and detailed information collected to answer these questions:

- What species, number, and size of trees are needed?
- When and where will these trees be out planted?
- How long will these needs persist, and will they change over time?

Responding to the aforementioned questions will help nursery practitioners to know whether their productions will have enough customers or not. Thus, having a broad picture of the demand will be a priority for every nursery practitioner before he/she establish a tree nursery. Therefore, potential nursery developers should carefully analyze their potential market and make certain that a sustained demand exists before investing in a nursery.

1.3.3 Competition for seedlings

In addition to surveying the market, potential nursery developers must carefully analyze their competition. That is to say every nursery developer should know all the other practitioners who are producing tree seedlings, the species being produced, their potential customers, their strength and weaknesses and see if he/ she will have a room for selling his/ her production.

After completing gathering information about the existing nursery capacity and markets, compare it with your own projections, and you should be able to decide whether developing a new nursery can be economically justified *(calculate the cost-benefit analysis)*. If the competition is high, it would be better to not invest in nursery establishment in that locality.

1.3.4 Price for seedlings

Potential nursery developers should survey tree seedling prices in the local market and try to determine recent price trends. For instance, the current price of Eucalyptus species, Grevillea robusta, Pinus tree species, Alnus tree species and other exotic species planted in forests or agroforestry in Rwanda varies between 50-100 Rwf whereas for the indigenous tree species like *Markhamia lutea*, *Markhamia platicalyx, Maesopsis eminii, Croton megalocarpus* and other indigenous species the price ranges from 50 -150 Rwf. For ornamental tree species the price ranges from 2,000 – 5,000 Rwf for tree species like *Thuja orientalis*, *Phoenix reclinata* and *Shefflera arboricola.*

Seedling prices may vary from year to year. Be aware that price generally increases with tree species and the location of the nursery. Thus, the examples given above are prices that are currently being considered while selling tree seedlings but are subjected to changes at any time. Price is important for assessing whether the business will be profitable or not (*This has been highlighted in cost-benefits analysis*).

1.4 Learning Outcome 4: Describe the criteria to consider while selecting a tree nursery location

1.4.1 Types of tree nurseries

The criteria to consider while choosing a nursery site are affected by the type of nursery to be established. In general two types of nurseries exist in Rwanda and they include:

- Temporary nursery
- Permanent nursery

Temporary nurseries are known as nurseries established for the purpose of fulfilling small reforestation and tree planting targets, often in remote areas. These nurseries are established for defined period of time. Temporary nursery is generally shifted from one place to another place depending upon the demand in seedlings.

Some benefits associated with temporal nurseries include the following:

- Nearness to planting site improves survival because transit time between nursery and plantation is short and seedlings suffer less;
- Better provision for the range of species and number of seedlings required;
- Transportation cost is less and capital investment is low
- Isolation of disease is much easier.

Permanent nurseries are nurseries established for serving the purpose of supplying seedlings in long time. In most cases permanent nurseries are expected to meet a high quantity and quality of seedlings to be used in reforestation activities. The benefits associated with permanent nurseries include the following:

- High production levels and high seedling survival rates resulting in a more efficient, reliable operation and consequently lower unit cost per plant;
- The availability of permanent installations, propagation techniques and suiatable modern equipment favouring higher quality seedlings and the production of a wide range difficult species;
- Risk of damage and theft minimised due to better on site supervision.

1.4.2 Nursery location criteria

The criteria to consider while selecting a nursery location include water availability, infrastructure, topography, availability of labour and climate.

- **Water**

A reliable and continuous supply of water should be available throughout the year. Water is necessary not only for staff but also it will be used for watering activities in the nursery. Since the need for water is greatest during the dry season, it is necessary to check the source of water during the most critical period to see if the flow of water at that time is adequate. Regardless of the source, it is advisable to have adequate facilities for storage of at least three days' supply.

- **Infrastructure**

The infrastructure expected to be at the nursery site include the road for facilitating the access to and within the nursery at all times; availability of equipment like watering can and wheelbarrow; there must be also a house designed for storing important items for the nursery and the staff as well. School, hospital and sport facilities can also be useful for improving the health of all staff. Electricity and telephone coverage are also necessary for a good nursery location.

- **Topography**

Ideally, the nursery should be on a gentle slope (3-5%) sufficient to allow excess water to run off without causing soil erosion. The general principle here is to direct excess water to the sides and keep the main pathways dry. The nursery should as much as possible be surrounded with a live fence (hedge). The fence helps to reduce water loss from seedlings by acting as a wind break.

- **Availability of labour**

The tree nursery should be located in area which will facilitate the access to labour especially those having the skills in nursery establishment and practices. This is because bringing labour from another location will increase seedlings production cost. All nursery activities demand continuous availability of labour and hence nursery should be located near to a village or area where sustainable work force is available for successful establishment and management of the nursery.

- **Climate**

Due to the fact that tree species have different climatic conditions in which they can grow, it is recommended to choose the area which has got climatic conditions (temperature and rainfall pattern) compatible with the tree species that you intend to produce. Area subjected to strong wind should be avoided.

1.4.3 Timing for a tree nursery

For every nursery developer who wishes to be successful in Rwanda they are supposed to know the exact timing of establishing a nursery based on their location. The locations in Rwanda have been divided in two three zones based on altitude. They include highlands areas (1800 –2300m), middle lands or central plateau (1200 –1800m) and low lands (below 1200 m). Hence, table 7,8 and 9 provide guidance on the timing of establishing a tree nursery in Rwanda.

Table 7: Timing/calendar of a tree nursery in highlands of Rwanda (1800-2300 m)

Tree growth categories	Activity	Month											
		1	2	3	4	5	6	7	8	9	10	11	12
Slow growing tree species	**Seed bed preparation**												
	Pricking out												
	Plantation in the field												
Middle growing tree species	**Seed bed preparation**												
	Pricking out												

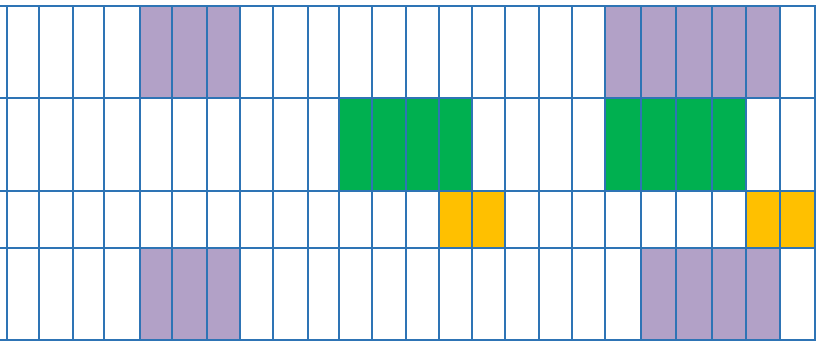
	Plantation in the field	
Fast growing tree species	**Seed bed preparation**	
	Pricking out	
	Plantation in the field	

Table 8: Timing/calendar of a tree nursery in middle lands/central plateau of Rwanda (1200 -1800 m)

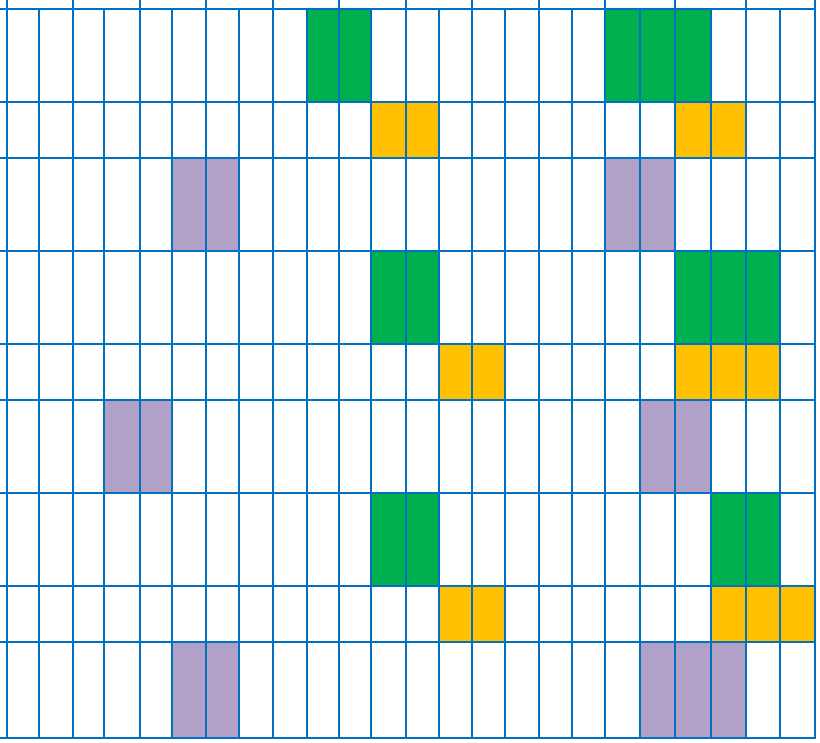
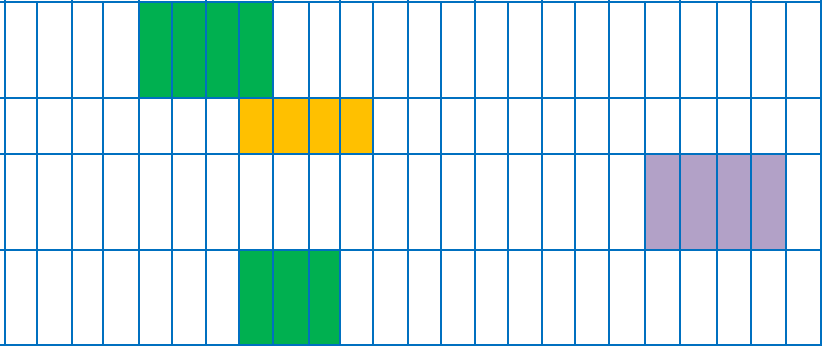
Tree growth categories	**Activity**	**Month**											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Slow growing tree species	**Seed bed preparation**												
	Pricking out												
	Plantation in the field												
Middle growing tree species	**Seed bed preparation**												
	Pricking out												
	Plantation in the field												
Fast growing tree species	**Seed bed preparation**												
	Pricking out												
	Plantation in the field												

Table 9: Timing/calendar of a tree nursery in lowlands of Rwanda (below 1200 m)

Tree growth categories	**Activity**	**Month**											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Slow growing tree species	**Seed bed preparation**												
	Pricking out												
	Plantation in the field												
	Seed bed preparation												

Middle growing tree species	**Pricking out**																							
	Plantation in the field																							
Fast growing tree species	**Seed bed preparation**																							
	Pricking out																							
	Plantation in the field																							

Note: With reference to what is indicated in table 7,8 and 9, slow growing species in Rwanda include tree species like *Callitris robusta*, *Markhamia lutea, Cupressus lustanica* and *Podocarpus falcatus*, middle growing species include *Jacaranda mimosifolia*, *Croton megalocarpus* and *Cedrela serrta* whereas first growing tree species include *Eucalyptus* tree species*, Alnus acuminata* and *Grevillea robusta* just to mention few. Thus, while requesting seeds from Rwanda Tree seed centre, it would be better to ask tree growth category of the seed that you intend to use in your nursery.

LEARNING UNIT 2: DESIGN AND LAYOUT A TREE NURSERY

Learning Outcomes:

2.1. Demarcate suitable nursery size in line with the quantity of seedlings to be produced

2.2. Design and layout of nursery site by incorporating seed beds and pot beds

2.3. Prepare quality and quantity of nursery substrate/soil

2.4. Demarcate suitable nursery size in line with the quantity of seedlings to be produced

2.1.1 Nursery size demarcation

Nursery size demarcation is influenced by a number of factors including level of annual seedling production, methods of raising seedlings and available space. Level of annual seedling production influence nursery size in a way of increasing or reducing the size of the nursery based on number of seedlings to be produced. In fact, the higher the number of seedlings to be produced the larger the size of nursery. For instance, if you wish to produce 20,000 seedlings you will be required to have at least 100 m^2 of land in which you will have 1 seed bed and 7 seedling beds. On the other hand, method of raising seedling is important in a way that if you use container nursery then you will be expected to have more land than if you are using a bare root nursery. The available space will of course help you to decide the size of the nursery. Hence while demarcating nursery size all the aforesaid factors should be kept in mind.

- **Materials used for nursery demarcation**

Before availing materials, the nursery developer should avail first the personal protective equipment including safety helmet, boots and gloves. Materials used in nursery size demarcation include wooden stakes, tape measure and or a rope. Wooden stakes will be used for showing the starting and the end of nursery boundaries whereas a tape measure will be used in measuring the length and width of the nursery as well as for seed bed and pricking out bed and a rope will be used for drawing straight lines on the boundaries.

2.1.2 Site layout and orientation

A nursery should be compact and approximately square to minimize length of boundary, especially if protective fencing is required (Figure 2). Inside the layout there must be the following:

- The centre of water distribution;
- A store for equipment (eg. watering equipment, tools etc)
- A working shed for soil potting, pricking out etc.
- A soil storage and mixing area;
- Seed beds should have at least the following dimensions: Length 10 m, Width 1 to 1.2 m and 15 cm high).
- Seedling beds can also have similar dimensions with those of seed beds.
- Seed beds and seedling beds should be oriented in East – West direction for them to access enough light.

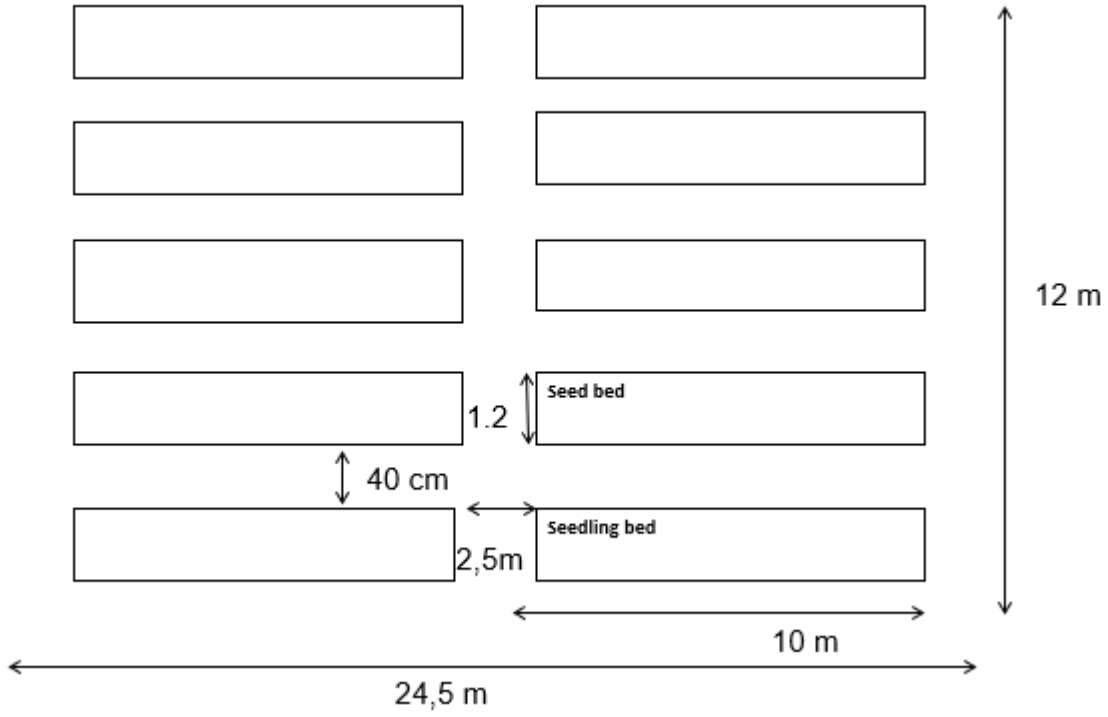


Figure 2: Example of nursery layout in the field

2.1.3 Germination section/ seed bed

Seed beds is designed to facilitate the sowing of seeds. As it has been highlighted above a seed bed should have at least 10 m length, 1.2 m width and 15 cm high (thickness). The sides of a seed bed are fixed using sawn timber or small round logs which are laid parallel on the ground of both ends of the bed. Wooden pegs are used on the outside to hold the timber or logs in place.

Figure 3: A picture showing seedlings in a seed bed

2.1.4 Transplanting area/Seedling bed

In the seedling bed the soil is put into prepared seedling beds (for bare root nursery), polyethylene tubes/bags. These containers should be perforated at both ends to allow water to flow downwards freely and ensures the soil has also some air for root development. Seedling beds can have similar dimensions with the seed beds but their dimensions especially length can increase based on the quantity of seedlings to be produced.

Figure 4: A picture showing seedlings in seedling/ pricking out beds

2.2 Learning outcome 2: Design and layout of nursery site by incorporating seed beds and pot beds

2.2.1 Ideal nursery design

The ideal nursery design should respect the suggested dimensions for both seed bed and seedling beds. The dimensions which make the design ideal are highlighted in the following:

- **Length:** Ideal length should not go beyond 10 m for easy inspection, management, and maintenance of seedlings
- **Width:** 1 m is ideal to avoid stepping on seeds/seedlings during maintenance and transfer operations
- **Height** (elevation): 10 -20 cm high is important to provide good drainage
- **Pathway:** 40 cm – 1m between seed beds or seedling beds should be provided to facilitate inspection, selection, pricking out and maintenance activity for the seedlings

2.2.2 Production capacity of a seed bed

The production capacity of seed bed depends upon many things namely tree species, size of the seed bed and method used for seed sowing. For tree species, there are species which have small seed size and this influence the quantity of seeds to be sown per unit area (Eg Eucalyptus species) whereas there are others which have larger size of the seeds (Eg. Carapa grandiflora, Persea americana) and this has got an important influence on the quantity of seeds to be produced.

In principle the higher the size of the seed the smaller number of seedlings produced per unit area. The size of seed bed of course influence the quantity of seedlings produced and this means that as you increase the size of seed bed you are also increasing the seedlings to be produced. The method used for seed sowing include seed sowing in lines and seed broadcasting.

Seed broadcasting is the one which give high production. For instance, with reference to the size of seed bed having 12m2 (10m length and 1.2 m width) the seedling to be produced for Eucalyptus tree species range between 3500 to 5000 seedlings when the seeds are sown through broadcasting, hence this number will be reduced when seeds are sown on lines.

2.2.3 Production capacity of a seedling bed

Seedling bed production is influenced mainly by the size of the bed and size of the containers used. Normally, a seed bed having 10 m length and 1.2 m width (12 m^2) must produce between 2500 to 2800 seedlings if the size of the container used have 12 cm height and 8 cm in diameter (these containers are known as tubing 4).

When you use containers having 12 cm height and 10 cm in diameter (tubing 5) then the production capacity of a seedling bed become 2000 seedlings. For the size of the bed, it is clear that as you increase the size of the bed you re also increasing the quantity of seedlings to be produced.

2.3 Learning outcome 3: Prepare quality and quantity of nursery substrate/soil

2.3.0 Nursery substrate/soil

Nursery substrate/soil to be used during potting should be collected within 15 cm from the ground in cultivated areas or in mature forests. The soil should be collected and kept in the nursery for at least two months before use. This is for allowing the decomposition of manure. Thereafter, the soil must be sieved before it is mixed with other ingredients to eliminate parts of trees or stones that may have been carried with the soil from the forest.

2.3.1 Soil physical properties

Nursery physical properties should consist of the following ingredients:

- The first thing is that while mixing soil the ingredients used should be mixed as follows:
    - ✓ For heavy textured soil (clay soils) the mixture should consists of 1 part of soil, 2 parts of sand and 2 parts of compost.
    - ✓ For Medium textured soils (loam) the mixture should consists of 1 part of soil 1 part of sand and 1 part of compost
    - ✓ For light textured soi (silt) the mixture should consists of l part of 1soil and 1 part of compost and in this mixture, sand is not needed.
- The other important thing is that while assessing soil physical properties this can be done by touching soil, size of particles and colour can easily give an orientation of the real soil type.

For those who are working in preparing nursery substrate they are supposed to know the following:

- 1 kg of polythene bags give 800 empty pots of 8cm in diameter and 12cm height
- $1m^3$ of soil fill 8000 pots of 8 cm in diameter with 12 cm in height.
- $1m^3$ =12 wheelbarrows of mixed soil.

2.3.2 Soil chemical properties

For soil chemical properties it is recommended that the soil to be used in potting should be mixed with compost or farm manure. The compost or manure should be mixed with the soil two weeks before soil potting activity. The ideal soil pH should be in the range of 4.5 to 5.0.

2.3.3 Soil biological properties

The biological properties which need to be prepared while preparing nursery soil include the provision/inoculation of mycorrhizae strains in the mixture. This is specifically done when you want to produce seedlings of any Pinus tree species. Thus, for pines tree species mix soil collected from the top 15 cm of a mature pine plantation (1 part of pine soil and 10 parts of nursery soil) for inoculation with mycorrhizae.

LEARNING UNIT 3: APPLY SEEDLING PRODUCTION METHODS

Learning Outcomes:

3.1. Produce seedlings by using wildings

3.2. Produce seedlings by using seeds

3.3. Produce seedlings by using vegetative methods

3.1 Learning outcome 1: Produce seedlings by using wildings

3.1.0 Key definition:

Wildings: Wildings are seedlings that have grown naturally from dispersed seeds either in a natural forest or a plantation forest. Such seedlings are often found under mature trees, but may also be found far from the mother tree if the seeds were dispersed by birds or wind.

3.1.1 Use of wildings

Using wildings consists of collecting all those seedlings grown naturally and use them in tree production. One way of having wildings is to protect young seedlings that come up naturally and help them to reach the mature size which can be planted. Another way of producing wildings is to transplant them from their natural environment and grow them in another environment. The wildings do not come only from natural seeds they may also be produced as root suckers.

- **Leave wildings in the field and protect them**

As mentioned above one way of producing wildings consists of leaving the naturally produced seedlings and protect them in the field. The protection of wildings consists of creating enough space for them to grow. That is to say, if wildings are at high density they are reduced to a normal density (2m x 2m or 3mx3m) depending upon the objective of growing those wildings.

- **Transplant wildings to the desired site**

If wildings are available in the surroundings but not growing exactly where they are wanted, they can be uprooted and transplanted to the desired site or in a tree nursery. If wildings of a certain species are wanted, the area under a seeding tree can be cleared of weeds and the soil loosened to help the seeds to germinate.

When the rains start, the seeds will germinate and the wildings can be collected soon thereafter. Wildings can be collected when they are very small, e.g., with only three to four leaves. However, such a small wilding requires good care, including weeding, after transplanting, and therefore it is more common to transplant bigger wildings of up to 25 cm.

If bigger wildings are transplanted, they must be carefully uprooted, leaving soil around the roots, and planted on the farm in the same way as seedlings from a nursery. The indigenous tree species which produces wildings in Rwanda is *Podocapus/Afrocarpus fraxinifolius* where by its wildings are collected in Gishwati-Mukura National Park. For the exotic species *Callitris robusta*, *Acacia melanoxylon*, *Acacia mearnsii* and different Eucalyptus species (*E. maidenii, E.saligna, E. maculata*) are potential tree species that farmers use for collecting wildings in their plantations.

3.1.2 Why to use wildings?

- **Wildings are used due to the following reasons:**
  - **The need for more native species**: Collection of wildlings must be viewed within the wider context of sourcing high quality germplasm for indigenous tree species which usually presents particular difficulties in their propagation (Eg. propagation of *Entendrophragma excelsum*). Thus, collecting wildings can help in increasing the number of indigenous tree species in Rwanda especially in man-made forests.
  - **Limited access to quality planting material**: There are tree species which present challenges of producing quality seeds and this reduce the possibility of producing them in nursery. Thus, using wildings may help in accessing quality planting material.
  - **Wilding propagation as an alternative**: Normally, trees are produced by using seedlings produced in nurseries using seeds or by using vegetative means (cutting, grafting, layering) using wildings can be another potential means of propagation which can be an alternative solution especially when other methods are not successful.

3.2 Learning outcome 2: Produce seedlings by using seeds

3.2.1 Seed pre-treatments

Seeds of many species do not germinate well unless they are exposed to certain conditions. This state of not germinating unless the required conditions are met is called dormancy. In the natural environment the conditions may be exposure to fire or being eaten by animals. When seeds are eaten, they are exposed to the hydrochloric acid in the stomach of the animal, and this breaks the dormancy without damaging the seed.

Similar methods are used by man to treat seeds and break the dormancy of seeds they wish to germinate. There are several methods of pre-treating tree seeds and these include hot water treatment, cold water treatment, chemical treatment and mechanical scarification.

- **Hot water pre-treatment**

For tree seeds requiring hot water pre-treatment the procedure is as follows:

- Heat water to near boiling point and then take it off the fire.
- Pour the hot water over the seed in another pot and leave the seed to soak for about 24 hours. (Do not boil the seed.)
- The seed will absorb water, swell and sink to the bottom of the pot. All swollen seeds should be removed and sown immediately, whilst those which are not swollen should be left in the pot for a further 24 hours. After they have swelled up, they should be sown too.

This pre-treatment is designed for most leguminous trees with pods and more-or-less flat seeds with a hard seed coat. Normally, such seeds germinate faster and better if treated with hot water.

- **Cold water pre-treatment**

For cold water pre-treatment the procedure consists of taking seeds and immerse them in cold water for a period of 48 hours (two days) then after absorbing water all the swollen seeds will sink at the bottom of the pot. All swollen seeds should be removed and sown immediately and the remaining unswollen seeds should not be used.

- **Chemical pre-treatment**

In this pre-treatment, seeds are soaked in the chemical substance for 5 - 60 minutes depending on tree species. The common chemicals used in this method are sulfuric acid, nitric acid, Hydrogen peroxide and potassium nitrate. After removing seeds from chemical, they should be washed with cold water for 5-10 minutes with the purpose of removing all traces of the chemical. Seeds should then be soaked in cold water for 24 hours. Thereafter, seeds can be sown.

- **Mechanical scarification**

Mechanical scarification consists of nicking, piercing, chipping or filing, cracking, dewinging or burning the seed. A knife, needle, file, hot wire, burner, abrasive paper (sanding paper) or secateurs can be used. Scarification can be done by machine where larger quantities of seeds are required. This method involves tumbling seeds in a concrete mixer with gravel or sand.

Figure 5: Nicking seeds of Calliandra calothyrsus

Figure 6: Filing seeds of Screlocarya birrea

Figure 7: Cracking seeds of Melia tree species seeds

Figure 8: Dewinging tree seeds of Combretum spp.

3.2.2 Examples of seed pre-treatment methods for major tree species grown in Rwanda

- Hot water pre-treatment is commonly applied to different tree species in Rwanda such as Calliandra calothyrsus, Tamarindus indica, Sesbania sesban, Leucaena trichandra, Leucaena diversifolia and Tephrosia vogelli.
- Cold water pre-treatment is applied to tree species namely Dalbegia melanoxylon, Calliandra calothyrsus, Tephrosia vogelli and Gmelina arborea.
- Chemical pre-treatment is applied to tree species including Acacia nilotica, Albizia lebbeck, Leucaena leucocephala and Tamarindus indica.
- There are also tree species which do not require any pre-treatment in Rwanda and those species include Eucalyptus spp, Casuarina equisetifolia, Cupressus lusitanica, Jacaranda mimosifolia, Pinus spp, Psidium guajava, Erythrina abyssinica, Prunus africana and Syzygium parvifolium.

3.2.3 Direct seed sowing in the field

Direct seed sowing in the field is a simple way of getting more trees on a farm. This is an important method for species and technologies which require very many trees or shrubs, e.g., live fences or dense woodlots.

In this method seeds are directly sown in the field where a forest plantation is going to be established. One important information here is that a good seed supply is a must since normally a certain number of seed will be wasted. Normally, directly sown seedlings cannot be as well cared for as seedlings in a nursery, and one must also expect accidents, e.g., seeds being washed away by rain, being eaten by birds, or young seedlings being mistaken for weeds and removed.

Occasionally there may be rainfall problem soon after germination and if watering cannot be easily arranged such problem may result in almost total failure. It is then necessary to have access to plenty of seed so that the sowing can be repeated.

Criteria for species and technologies where direct-seed sowing is recommended are:

- Many seedlings are required; hence transport of seedlings is difficult;
- A good seed supply, allowing for waste of some seed;
- Fast initial growth of seedlings;
- Large seeds are better than small seeds since they are not so easily washed away by rain.

Some species and technologies that meet most of the criteria in Rwanda are:

- Croton megalocarpus for fencing;
- *Acacia mearnsii* for wood lots;
- Balanites aegyptiaca generally;
- Caesalpinia decapetala for fencing;
- Sesbania sesban and Leucaena spp. Generally;
- Cajanus cajan generally.

Apart from climatic factors, sowing depth is a factor which frequently causes problems when directly sowing seeds. If seeds are sown too deep, the seedlings may not reach the soil surface after germination, and if they are sown too shallow the risk of the seeds being washed away by rain increases as well as the risk of drying out during germination. As a general rule, a sowing depth about twice the seed diameter is recommended.

It is also important that sowing be done as soon as the rains are well established to give the seedlings time to grow as big as possible before the dry season. If there is rainfall problem, a little supplementary watering may make a big difference to survival. Weeding is even more essential after direct seed sowing than with any other tree-planting method since the seedlings are very small initially.

Weeds and grasses need to be controlled for at least 30cm radius around seedlings for 2-3 years or until the tree reaches 4 m tall. One advantage of direct seeding is with the higher seeding rates per unit area, the tree crop will shade out its competition sooner. Weed controls are still needed for the first 2-3 years.

- **Advantages of direct seed sowing in the field**
  - Lower Initial Cost as compared to planting seedlings. The cost of direct seeding is usually one-third to one-half of the cost of planting seedlings. Seed is less expensive than seedlings, and sowing costs are usually less than planting costs.
  - Easier to Use in Remote Areas. Another advantage is that direct seeding is easier to use in remote or inaccessible areas. There are areas where it is difficult to move equipment, supplies, and labour. In those situations, it is easier to broadcast seed by hand or from the air than to plant seedlings.
  - Root Systems of Trees are Natural thus seedlings develop as fast as possible in comparison to the planted seedlings. When seedlings are planted, the root system may be distorted or end up in an “L” or “J” shape if the planting hole is not deep enough. A distorted root system reduces the growth of the seedling, and shallow planting usually reduces the survival rate of the trees.
- **Disadvantages of direct seed sowing**
  - **Reduced control of spacing and stocking:** The most notable disadvantage of direct seeding is reduced control over spacing and stocking (number of trees per unit area).
  - **High mortality in droughty soils**: Another disadvantage of direct seeding is the high mortality rate on extremely droughty sites, especially sandy soils. During the first month after germination, the root system of the seedling is still near the soil surface. If the soil dries out excessively, the tiny seedling dies, so direct seeding is not recommended for excessively droughty areas.

3.2.4 Raise seedlings in a nursery

Raising seedlings in a nursery can be achieved through two methods namely growing seedlings in a bareroot system and growing seedlings in containers. Each method has got its advantages and disadvantages.

- **Grow seedlings in bareroot system**

In bareroot system the first thing is site preparation which consists of tillage of the soil. Tillage aims at weed control and to loosen the soil, making planting easier and ensuring good root growth. Tillage should be done two weeks before seed sowing. After tillage, the next step is seed bed preparation and this consists of laying out beds which have ideally 1.2 m wide, 10 m long and 15 cm high. Hence, the following step is to establish shade for the seed bed. The wooden stakes used for shading must have at most 1.3m height and the shade can be made by different materials where by the common one in Rwanda is to use a mat made of bamboo stakes.

After establishing shade, then seeds sowing follows and after sowing and covering seeds with soils, mulching should be done in order to help the soil keeping the moisture and reduce transpiration of the soil. At this step watering needed and is supposed to be done twice a day.

Mulch is removed one week after sowing or just after the first seeds have germinated of course this depends upon the tree species (Eg. For Eucalyptus tree species 8 days are enough for the first seeds to germinate). Another management practice done in bareroot is weed control, and this consists of removing all unwanted seedlings in the seed bed. Seedlings are pricked out upon having 3 to 4 leaves and transplanted in a seedling bed where they can spend 2 to 3 months before being planted in the field. In Rwanda this practice is rarely used by nursery developers due to the fact that the survival rate of seedlings is lower when compared to raising seedlings in a container.

Figure 9: A picture showing bareroot seedlings of Pinus patula

- **Grow seedlings in container**

Growing seedlings in container falls into two methods such direct seed sowing in container and seed sowing in a seed bed. The details of the two methods are found in the following.

- ✓ **Direct seed sowing in a container:** In this method tree seeds are directly sown into containers. The containers are first filled with the prepared nursery substrate, watered and then seed sowing follows. This method is mostly recommended to tree species which have larger sized seeds (Eg. *Persea americana and Mangifera indica*). The other tree species which are propagated in this method include *Acacia spp, Leucaena spp* and *Azadirachta indica.* The maintenance activities performed in this method include weed control, loosening soil, culling and root pruning. Weed control consists of removing all unwanted seedlings in the container. Loosening soil consists of using small wooden stick in creating small holes in the container and this practice help to increase soil aeration.

Culling consists of removing unhealthy seedling in the container and replace them in case the pot has received more than one seed. Root pruning consists of cutting seedling roots which go at the bottom of the container. This practice facilitates to keep seedlings in a nursery for a longer time, just in case plantation has been delayed.

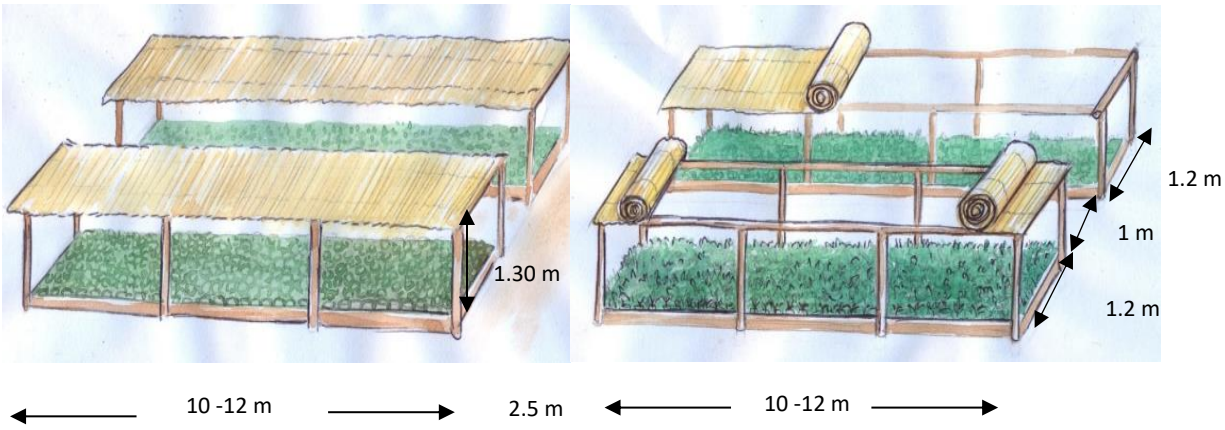


Figure 10: Layout of seedling beds and dimensions in a nursery

- **Seed sowing in a seed bed**

Sowing seeds in a seed bed is method which consists of sowing seeds in seed bed and thereafter seedling will have to be transplanted in a seedling bed. In Rwanda almost all the seeds which are not directly sown they are sown in seed bed through broadcasting. In this method the first step is site preparation through tillage, followed by layout out seed beds with prescribed dimensions (Figure 10), then after shading is established to every seed bed and two weeks after preparation seeds are sown in nursery beds.

After sowing seeds are covered with thin soil and then mulching is also done. After covering soil with mulch watering is needed and has to be done twice a day. After germination of seeds, mulch is removed and seedling will stay in the seed bed until they have 3 to 4 leaves. At this stage that is when pricking out should be done. Prior to pricking out activity that is when the nursery substrate should be prepared at least 2 to 3 weeks before.

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. In practice the hole made for receiving a new seedling should be about 5 cm deep and 1- 1.5 cm in diameter.

For good survival after pricking-out, the following sequence of procedures is necessary:

1. The afternoon before pricking out, thoroughly water the containers into which the seedlings will be pricked out and ensure that shades are available and in good order.

2. About one hour before starting, water the seedlings to be pricked-out. This is done because roots are more easily removed from wet soil and it will ensure seedlings have high internal water content.
3. Remove the seedlings by using a sharpened dibble stick. This dibble should be inserted into the soil underneath the seedling and then gently lifted, taking care to do as little damage to the roots as possible. Hold the seedling by the leaves and do not touch the stem or roots as these parts are very delicate and can be easily damaged, and also disease is encouraged. Immediately place these seedlings into a small container where the roots can be immersed in water.
4. Using the dibble stick, make a hole in the potting mix at the center of the tube which is large enough to accommodate the roots of the seedling to be transplanted without bending the roots.
5. Holding the seedling by a leaf, lower the roots into the hole ensuring that they go straight down and are not bent upwards. If the roots are too long to go straight into the hole, they can be trimmed with the finger nails or a sharp blade. The final depth of the seedling should be such that the root collar is level with or a few millimetres below the surface of the soil in the pot.
6. Refill the space around the roots with fine dry mixture which flows easily and so eliminates the formation of air pockets around the roots.
7. Then immediately water the freshly transplanted seedling to wet the dry soil that was used to refill the hole. Watering should be done twice a day for several days after pricking out, but excessive watering should be avoided as this leads to a lack of oxygen required for new root growth.
8. Erect some shade over the pricked-out seedlings. It is best if shading which provides about 50% sunlight is also available as this hastens and simplifies the process of shade reduction and returning seedlings to conditions of full sunlight.
9. Three or four days after pricking-out, replace any seedlings that have died by repeating the above procedure.

If the good techniques described above are followed, it should be possible to achieve over 80% survival. In pricking out, 1 man-day should transplant 600 seedlings.

3.3 Learning Outcomes 3: Produce seedlings by using vegetative methods

3.3.0 Key definition

Vegetative propagation is the reproduction from the vegetative parts of the tree such as stem, branch and root which are used to produce new individual plants. All vegetative propagation techniques are grouped into clonal propagation.

3.3.1 Clonal propagation

Clonal propagation means a vegetative propagation method in which the planting material is genetically uniform plant material derived from a single individual and propagated exclusively by vegetative means. Propagation through cuttings, grafting, layering and tissue culture are part of clonal propagation.

3.3.2 Advantages and limitation of clonal propagation

- **Advantages of clonal propagation**

Advantages of clonal propagation include the following:

- **Production of quality planting stock:** In the intensive management of forests, it is very important of develop fast and economical methods of raising superior planting stock, clonal propagation is thus suitable for producing superior planting stock.
- **Propagation of problem trees:** There are many tree species, which normally produce little or no viable seeds, and some tree seeds have poor germination capacity. Such trees can easily be propagated vegetatively. Propagation by vegetative means is easy, more rapid and economical than by seed. In some tree species, germination is very poor or slow or there may exist complex dormancy problems or the seed may lose its viability very quickly. Moreover, seedlings of many species grow slowly and take a long time to reach marketable size. In all these cases, use of vegetative multiplication is a more convenient method of propagation.
- **Maintenance of genetic uniformity:** Most of the tree species are cross-pollinated and naturally they are highly heterozygous. The progenies of such cross-pollinated trees are not true to type and loose many of their unique characteristics. Hence, asexual clonal propagation helps in maintaining the genetic characteristics of each species.
- **Production of disease-free plants:** Certain tree species are often susceptible to some pests and diseases and others may be partially or entirely resistant. Vegetative approaches using grafting will help to produce resistant clones.

- **Early flower induction:** Vegetatively propagated plants are precocious in bearing i.e. Flower earlier than seed propagated plants. This will help to reduce the rotation of the tree species and also to increase the productivity. This will ultimately help to speed up the reproductive cycle for accelerated breeding and testing.
- **Maintenance of genetic gain:** Vegetative propagation ultimately helps to capture maximum genetic gains when used for regeneration in operational planting program.

- **Limitation of clonal propagation**

- Clonal propagation in many forestry tree species is more expensive than seed propagation. It is a specialist's job and requires special training and knowledge on the part of the propagator.
- Vegetatively propagated plants are comparatively short lived. Lack of tap root system in vegetatively propagated trees results in poor anchorage in the soil; consequently, such trees are easily uprooted during heavy winds or storms.

3.3.3 Seedlings production by using cuttings

A cutting is the portion of a plant that is collected, treated, and planted to develop into a new intact plant complete with stems, leaves, and roots. Cuttings are usually placed into a suitable rooting substrate and kept under high humidity until roots and shoots have formed. Cuttings can be collected from mother plants in the wild, or special donor plants can be cultivated in the nursery. Selection of mother plants must be done carefully; it is as important as the origin of seeds.

Stem cuttings are most common used in tree propagation and they are classified as softwood or hardwood cuttings. Softwood cuttings are taken from a growing shoot, not far below the shoot tip, e.g., tea. Such tender, leafy cuttings require intensive nursing. Hardwood refers to the propagating and planting trees wood of resting shoots, after the termination of a flush. It includes older twigs and branches, formed in earlier flushes.

- **Guidelines for collecting and planting cuttings**

The guidelines for collecting and planting cuttings are detailed in the following:

Step 1: Identify donor plants/Mother tree

In this step it important that you select the right species, healthy, having good outstanding, free from pest and diseases. Identify donor plants during the growing season specifically

during the dry period. Determine if poles (stems) are of adequate diameter (>5-8 cm) and sufficient length (2m).

Step 2: Harvest cuttings

Cuttings must be harvested during the dormant season (after leaf fall, but before bud swell). Make clean cuts on wood at least 1 year old. Avoid using very old wood, suckers, and current year's growth. Again, diameter of cuttings should be (>5-8 cm) and length should be >2m f. Do not remove more than 1/3 of any individual donor plant.

Step 3: Prepare cuttings

- Trim all side branches off cuttings.
- Place cutting quickly into polyethylene bags containing a label, marked with the species name and cutting number; and moist paper or other damp material. In absence of damp material, humidify the inside of the bag using a sprayer. Keep the bag closed at all times.
- To avoid heating up of the cuttings during transport, store them in a cool box but avoid direct contact with the cooling element.
- In the nursery, put the shoots into a bucket of water or spray them frequently until they are used.
- Using a sharp knife or secateur, cut single or double node cuttings. Cut the basal end of the cutting squarely – avoid cutting the base slanted as this may result in a one-sided root system.
- Dip the basal 0.5 to 1 cm of the cutting into the required rooting powder (Auxin specifically indole-3-butyric acid -IBA).

Step 4: Storage of cuttings

- It is best to harvest cuttings in early spring and plant immediately but if this is not possible, cuttings can be stored safely for about 4 months.
- Store cuttings in a cool, dark, and moist place. Do NOT store in a wet area as this will promote root growth and weaken the cutting.
- Soak the bottom 1/3 of cutting in water for 1-5 days prior to planting.

Step 5: Plant cuttings

- Ideally, cuttings should be planted in dry season after high water level drops, although, they can be planted in rainy season with lower success.

- Ensure that top of cutting is pointing up. Plant cuttings to the depth of the low water table. At least half of the cutting should be in the ground (2/3 in, 1/3 out is best).
- It is essential to have good contact between the cutting and the soil; air pockets will kill the roots. Pour mud into the planting hole with the cutting if soil is not moist.
- Label the cuttings with the species name, clone number, date of setting and treatment(s) applied.
- Cuttings should not be allowed to dry or desiccate and should be grown under high humidity.

- **Plant cutting directly at the desired site**

Following the guidelines for preparation of cuttings highlighted above, cuttings can be collected and planted directly in the field. When cuttings are to be directly planted in the field the following should be kept in the mind:

- It is not every tree species which can be directly planted in the field. In Rwanda the tree species which can easily be directly planted as cuttings are *Euphorbia tirucalli, Erytrina abyssinica*, *Iboza riparia, Gliricidia sepium*, *Ficus thonningii* and *Dracaena afromontana*. The cuttings of the aforesaid trees do not need special substrate for rooting. For the other tree species, it is recommended to use rooting hormones for the successful cutting plantation. Otherwise, you may have leaves only and fail to get the roots.
- Most cuttings to be directly planted in the field are longer than the normal size of the cuttings. For instance, you will find that in Rwanda all mentioned tree species must have at least **1m** long.
- The reason for direct planting of cuttings is for establishing a live fence around a certain compound. Farmers often plant cuttings directly on the spot required, for instance to establish a hedge round a garden or field. Examples: *Gliricidia sepium, Euphorbia species.* Very large cuttings, so-called live stakes, are up to 2 m long with a diameter of up to 10 cm. They are planted directly along a field boundary: to support a fence (e.g., *Erythrina abyssinica*); around a cattle pen where livestock will be kept during the night (e.g., *Grazing land*); in a field as shade trees producer; to support climbing crop plants such as chayote or passion fruits.

- **Grow cuttings in a nursery**

When it comes to growing cuttings in nursery, cuttings are prepared as it has been highlighted in guidelines for preparation and planting cuttings. One important item that a nursery developer growing cuttings should know is that the size of cuttings to be used in a nursery is 15-25 cm long and 1-2cm thick. This can be used to both stem and root cuttings.

After preparation of cuttings to be grown in nursery the next step is rooting cuttings detailed as follows:

- Cuttings should generally consist of the current or past season's growth. Avoid material with flower buds if possible. Remove any flowers and flower buds when preparing cuttings so the cutting's energy can be used in producing new roots rather than flowers. Take cuttings from healthy, disease-free plants, preferably from the upper part of the plant.
- Early morning is the best time to take cuttings, because the plant is fully turgid. It is important to keep the cuttings cool and moist until they are stuck. An ice chest or dark plastic bag with wet paper towels may be used to store cuttings. If there will be a delay in sticking cuttings, store them in a plastic bag in a refrigerator.
- While terminal parts of the stem are best, a long shoot can be divided into several cuttings. Cuttings are generally 12 to 18 cm long. Use a sharp, thin-bladed pocket knife or sharp pruning shears. If necessary, dip the cutting tool in a disinfectant.
- Remove the leaves from the lower one-third to one-half of the cutting. On large-leafed plants, the remaining leaves may be cut in half to reduce water loss and conserve space. Species difficult to root should be wounded. In wounding the cutting, the bark should be removed on the part that will be put into the rooting hormone.
- Treating cuttings with root-promoting hormones (Eg:IBA) can be a valuable tool in stimulating rooting of some plants that might otherwise be difficult to root. Prevent possible contamination of the entire supply of rooting hormone by putting some in a separate container before treating cuttings. Any material that remains after treatment should be discarded and not returned to the original container. Be sure to tap the cuttings to remove excess hormone when using a powder formulation.
- The rooting medium should be sterile, low in fertility, and well-drained to provide sufficient aeration. It should also retain enough moisture so that watering does not have to be done too frequently. Materials commonly used are coarse sand, a mixture of one part peat and one part perlite. Media should be watered while being used.

- Insert the cuttings one-third to one-half their length into the medium. Maintain the vertical orientation of the stem. Make sure the buds are pointed up. Water again after inserting the cuttings in the containers or frames. Cover the cuttings with plastic and place in indirect light. Avoid direct sun. Keep the medium moist until the cuttings have rooted. Rooting will be improved if the cuttings are misted on a regular basis.
- Rooting time varies with the type of cutting, the species being rooted, and environmental conditions. Conifers require more time than broadleaves plants.
- Newly rooted cuttings should not be transplanted directly into the field. Instead, transplant them into containers or into a bed. Growing them to a larger size before transplanting to a permanent location will increase the chances for survival.

- **Tree species which have potential of producing cuttings in Rwanda**

In Rwanda there are different tree species which are used for producing cuttings namely:

- Erythrina abyssinica
- Ficus thonningii
- Dracaena afromontana
- Iboza riparia
- Euphorbia tirucalli
- Gliricidia sepium
- Eucalyptus tree species
- Moringa oleifera
- Casualina equisetifolia
- Persea americana
- Psidium guajava
- Etc.

Stem cuttings: The preferred time to take hardwood cuttings is generally during the dry or cool season, when shoot growth is minimal. In deciduous trees the cuttings are best taken when the trees are leafless. Most woody plants are evergreen and the leaves have to be stripped from the part of the cutting that is inserted in the soil: about two/third of the length of the cutting. Usually, a few leaves are left at the tip of the cutting, the number depending on growing conditions (shade, humidity, etc.). Leaves generally stimulate root growth, but cuttings are likely to dry out if the leaf area is large.

The tip of the shoot or twig is usually discarded, but a vigorous shoot can still yield several cuttings of 15 - 50 cm. Commonly, the diameter of cuttings ranges from pencil-thick to about 3 cm. The upper cut is oblique so rainwater runs off (see Figure 11). The lower cut is usually made just below a node, because rooting generally occurs mainly at the node.

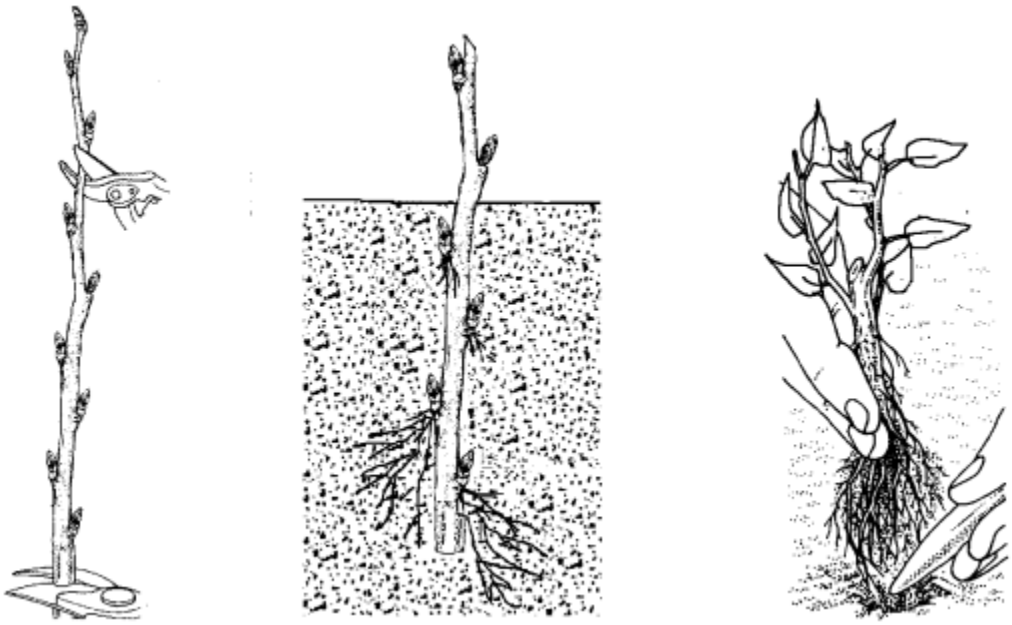


Figure 11: The cuts, the rooting and the rooted cutting

Always use clean tools: disinfect your cutting tool in boiling water before use. Never use a blunt knife or machete for taking cuttings. If a cut is not smooth and clean, rot may lead to failure of the cutting; it can also infect the wound on the mother tree. Upright branches and twigs are preferred for cuttings, because they grow upright after rooting, forming a tree with a proper trunk. Cuttings taken from horizontal or drooping branches often do not grow upright.

If cuttings cannot be planted straight away, they may be stored in a cool shaded place under damp jute bags, grass or leaves. Leafy cuttings should be planted without delay.

Root cuttings: Tree roots can also be used to take cuttings, e.g., *Casuarina* species. Some trees (e.g., *Acacia melanoxylon*) even produce root suckers spontaneously. These suckers form their own roots, they can start life on their own.
To encourage the emergence of root suckers, roots are cut using a spade or small axe. The piece of root cut off may form a rooted sucker (see Figure 12 A). These cuttings are planted in a shaded spot in the nursery. If a high humidity is maintained rooted suckers will be ready after a couple of months (see Figure 12 B).

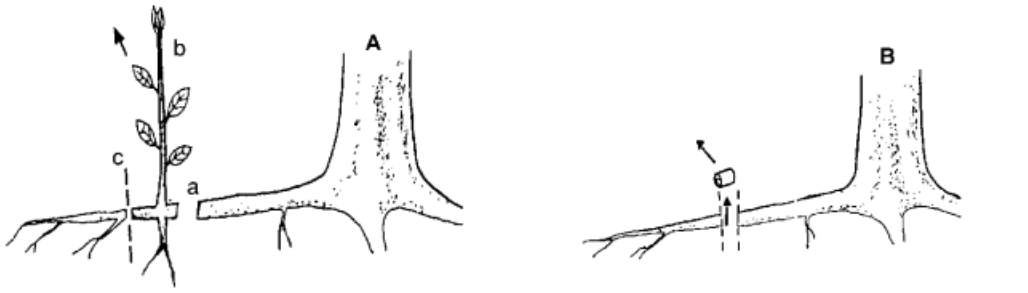


Figure 12: [12A and 12B] Root cuttings

3.3.4 Grafting technique

- **Definitions:**

Grafting is a tree improvement technique that allows the combination of two or more plants. It is the technique of choice when a single tree does not possess all the required characteristics, such as disease resistance of and/or high yield from the above ground parts (wood, leaves, fruits).

Scion*:* The aerial part of a tree that will form the crown of the new plant. This part contains the dormant buds of the tree whose desired characteristics need to be multiplied.

Rootstock*:* The belowground or lower part of a tree, sometimes including part of the stem and some branches that will form the root system of the new plant. This part may also contain dormant buds, which should not be allowed to develop in the new plant since they do not have the desired characteristics that need to be multiplied.

- **Principal grafting techniques:**

  - **Top-wedge grafting**

This is the most commonly used method, as it is simple and usually successful with both seedlings and older trees. It is often used in top working older trees as it can be used with scions considerably thinner than the rootstock. In top working older trees, two small scions are usually inserted at either side of the cleft. In these cases, it is important that the scions are cut so that the outside of the wedge is slightly thicker than the inside to allow for the larger circumference.

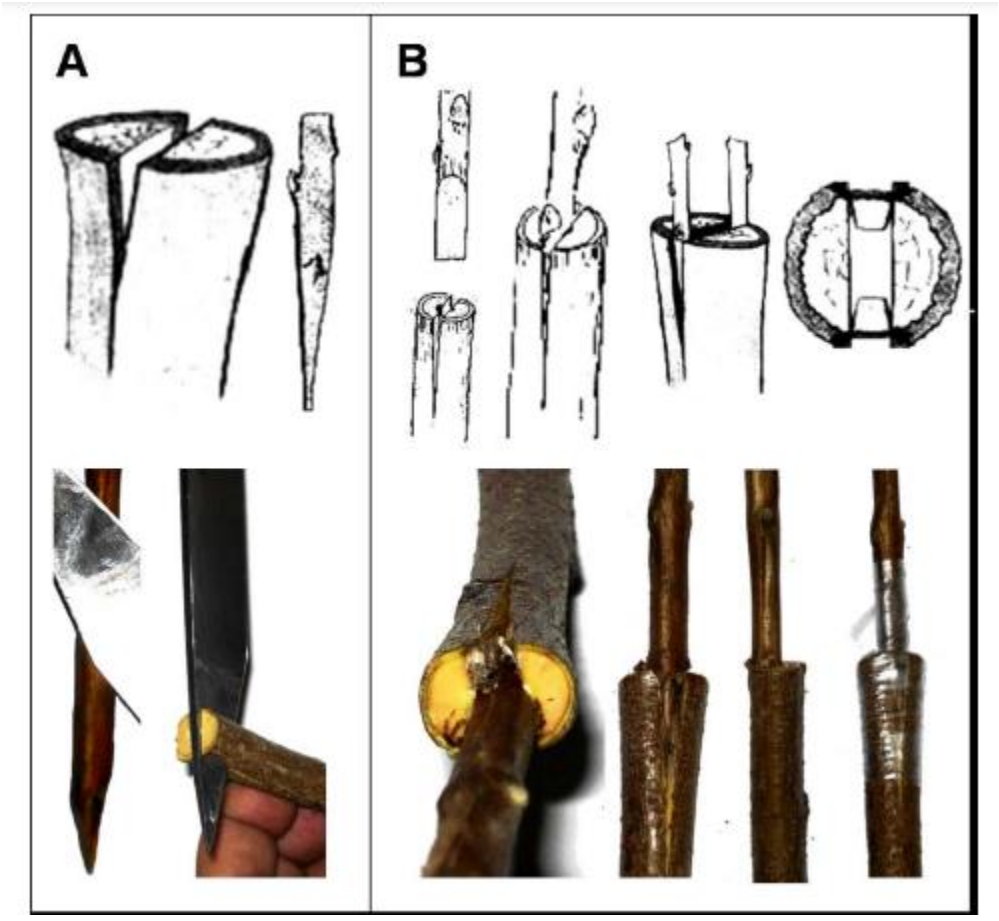


Figure 13: Top -wedge grafting

  - **Splice grafting**

A long, slanting cut is made in both scion and rootstock and these are tied together. This method is simple but needs some practice to allow for evenly slanting cuts and for matching scions and rootstocks. When tying-in, care is needed to prevent inadvertently slipping when joining the pieces.

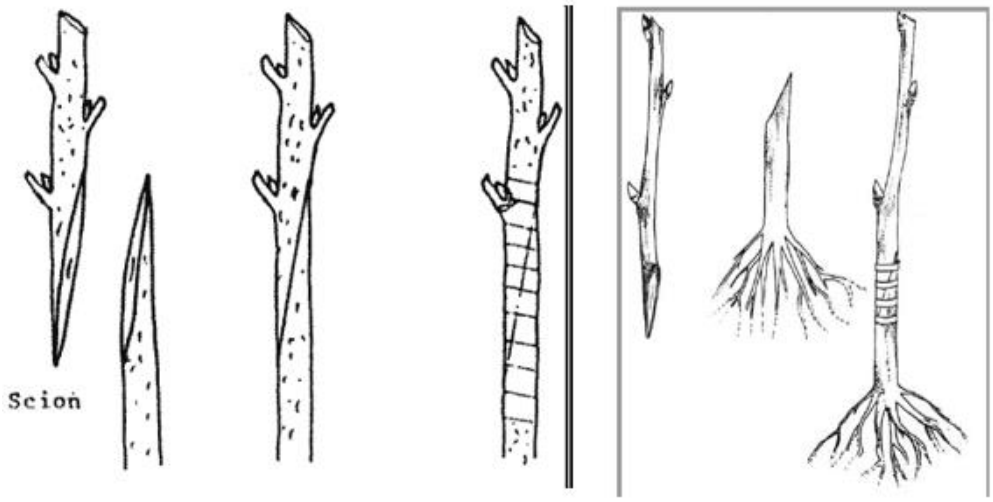


Figure 14: Splice grafting

- **Whip and tongue grafting**

This method is more common in practice used to graft thin stems. It may be used on roots, stems or tops. The scion should have two or three buds with the graft made below the bottom bud. The first cut is a 2-5 cm sloping cut at the bottom of the scion. The second cut is made with a distance 1/3cm from the tip of the first cut. The same process is repeated on the rootstock.

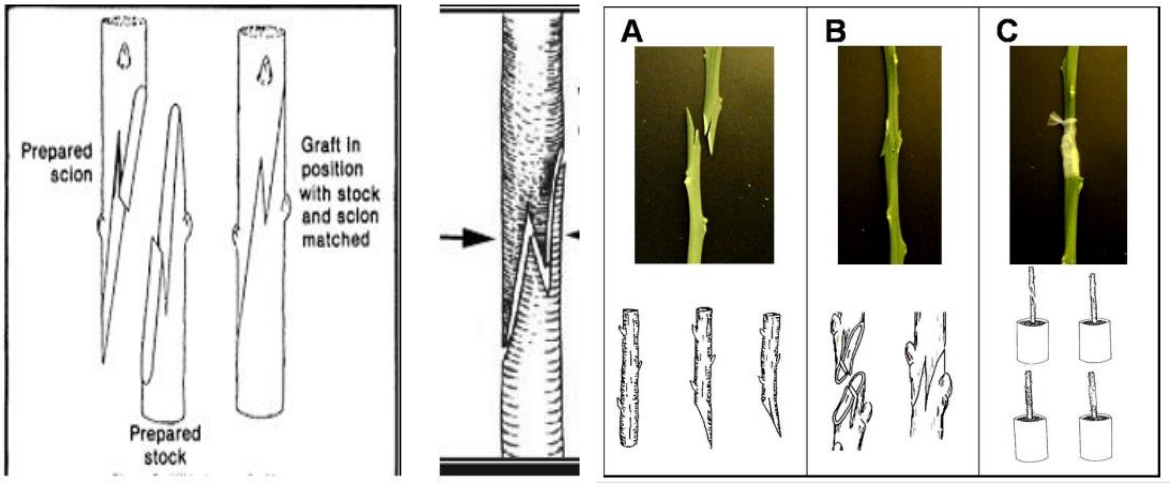


Figure 15: Whip and tongue grafting

- **Approach grafting**

Some trees are very difficult to graft such as mango (Mangifera indica) and macadamia. In this case approach grafting method is used. The main difference between this technique and other methods is that the scion is attached to its root system during the grafting process. Take two plants. One will be the rootstock and the other the scion. Make the same cut on both stems at the same height. Hold the two stems together and tie them with tape. When the grafts have joined, remove the top of the rootstock plant with a cut above the joining point and remove the bottom of the scion plant with a cut below the joining point.

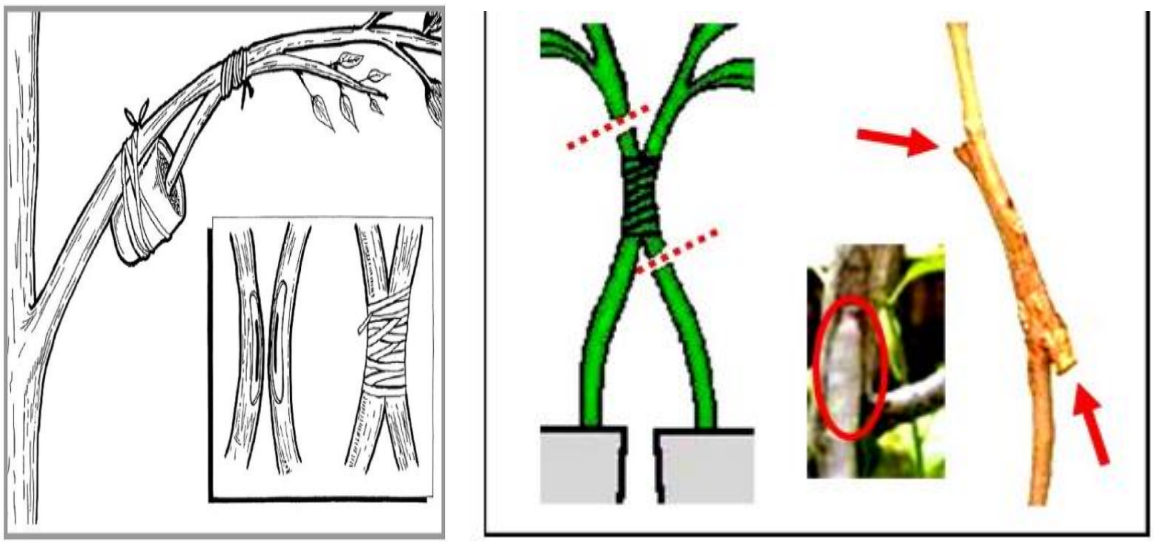


Figure 16: Approach grafting

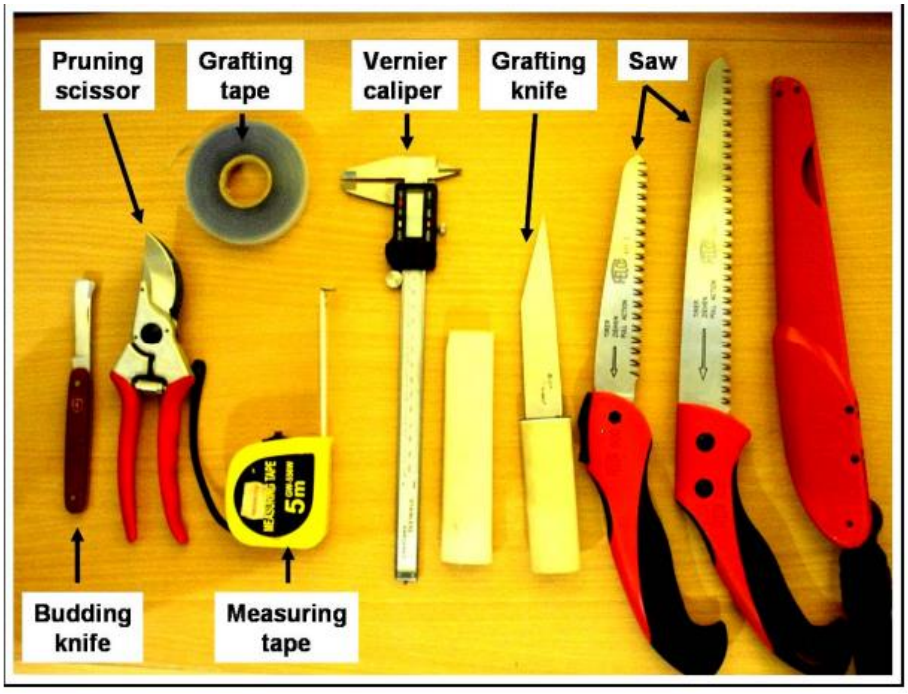


Figure 17: Tools used in grafting

3.3.5 Layering

Layering is a form of rooting of cuttings in which adventitious roots are initiated on a stem while it is still attached to the plant. The rooted stem (layer) is then detached, transplanted, while later becomes a separate plant on its own roots. It is natural mean of propagation in blackberries or it may be induced artificially in many plants. In general, better rooting in layering can be obtained by ringing or wounding or by the use of rooting hormones known as auxins (IBA and -naphthaleneacetic acid -NAA).

- **Types of layering**

The types of layering include the following:

- Simple layering;
- Air layering;
- Mound/stool layering;
- Compound layering/serpentine

- **Simple layering**

Simple layering consists of bending an intact shoot to the ground to cause adventitious roots to form (Figure 18). This method is used to propagate a wide range of plants that produce numerous suckers. Layering is usually done in the early spring using flexible, dormant, one-year-old shoot-branches of the plant that can be bent easily to the ground. These shoots are bent and “pegged down” at a location 15 to 20 cm from the tip forming a “U”shape. Bending, twisting, cutting, or girdling at the bottom of the “U” stimulates rooting at that location. The base of the layer is covered with soil or other media, leaving the tip exposed.

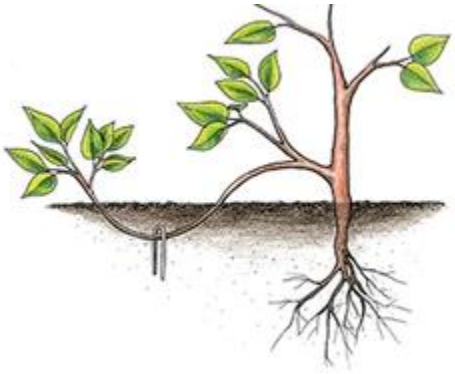


Figure 18: Simple layering

- **Air layering**

It is used on tree branches and other elevated stems that cannot be bent to ground level, and for plants that are difficult to root by other means. This method is successful on branches that are at least pencil-width. After selecting a branch to be used, remove the leaves in the section to be rooted, wound the bark, and cover the site with a 10 cm -thick layer of moist sphagnum moss or soil substrate with growth hormones.

Then enclose the moss or soil substrate in a rooter pot or sturdy plastic wrap that is sealed on both ends. Once roots have been formed and are visible through the plastic, remove the plastic (but not the moss or soil layer). Prune off the branch just below the moss and transplant it. This can take a period of two months up to a full year depending on the tree species.

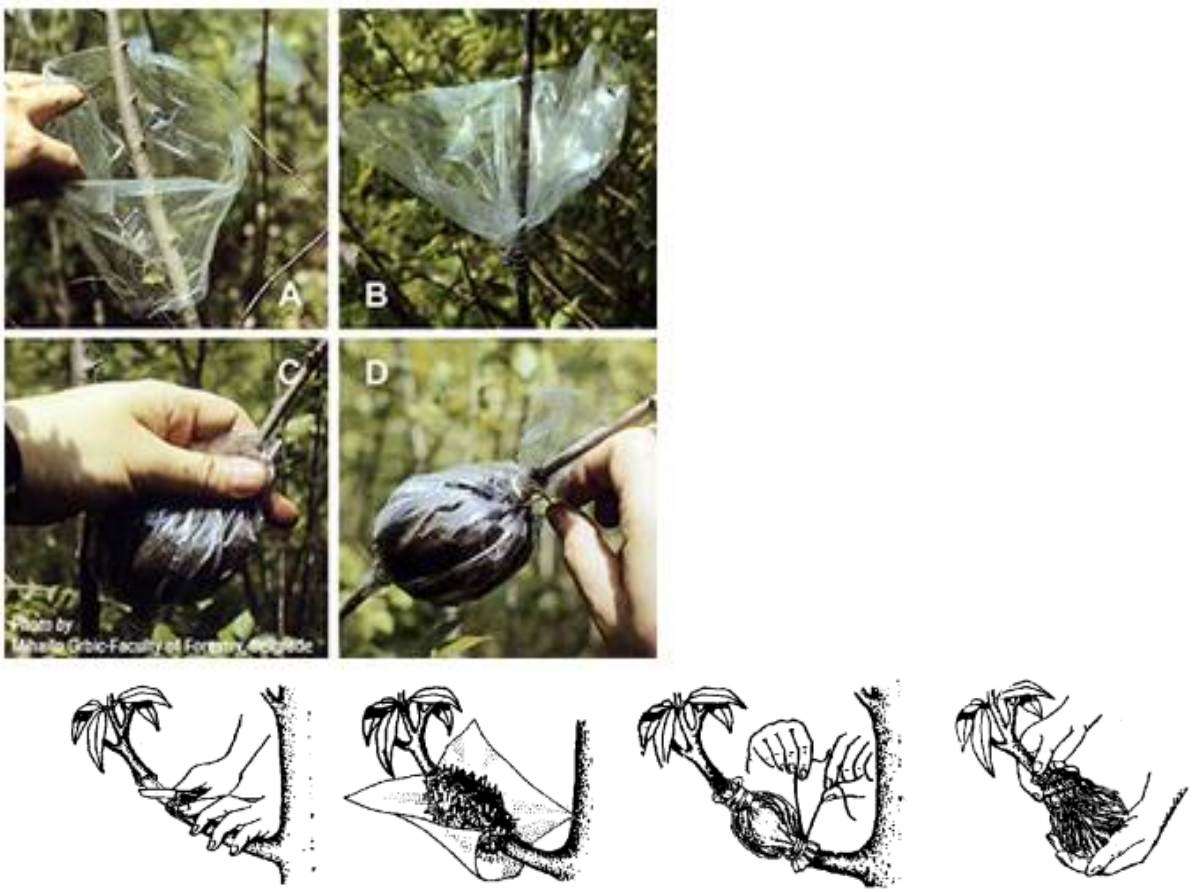


Figure 19: Air layering: From left to right: ringing the branch; polythene with moist rooting medium is wrapped around the wound; tie firmly so that the medium does not dry out; the rooted cutting, 2- 6 months later.

- **Mound/stool layering**

It is a method of propagation in which the shoots/plants are cut back to the ground and soil or rooting medium is mounded around new sprouts/shoots to stimulate roots to develop at their bases. In stooling, the mother plant is headed back to 15 to 20 cm above ground level during dormant season.

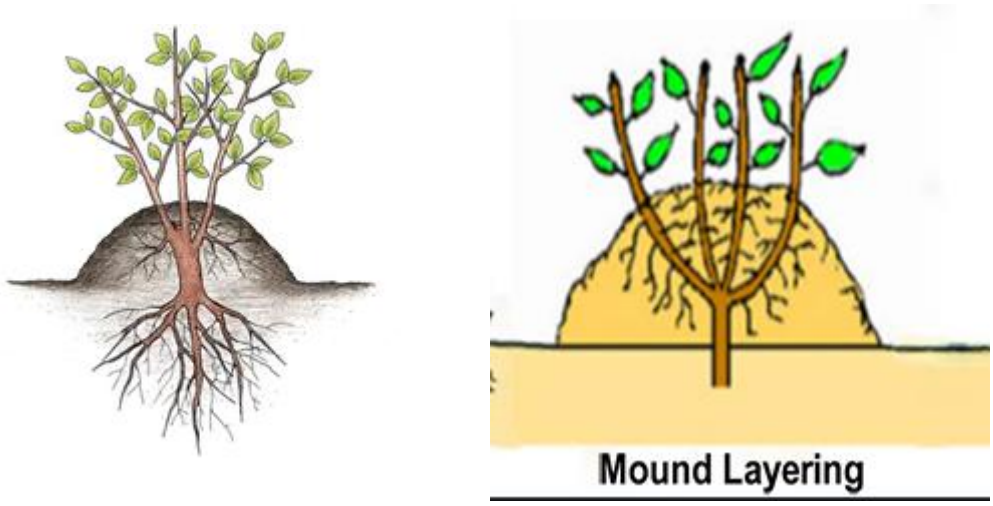


Figure 20: Stool – Mound layering

Then, the new sprouts will arise within 2 months. The sprouts are then girdled near the base and rooting hormone (IBA) is applied to the upper portion of the ring.

The concentration of IBA depends on species to species but generally; 3,000 to 5,000 ppm is commonly used. These shoots are left as such for two days for proper absorption of rooting hormone, before they are covered with moist soil.

Care should be taken to keep the soil heaps moist all the times. It facilitates rooting in the stools. The roots in shoots may emerge within 30 to 40 days. However, the rooted shoots should be separated from the mother plants only after 60 to 70 days and then planted in the nursery or field.

- **Serpentine (Compound) Layering Method**

Done in the same way as simple layering except that, multiple points are rooted along the same stem. This method is good for producing more daughter plants than simple layering. To achieve this, wound and bury the stem (in the same way as with simple layering) between each node or bud. Good for plants that produce vine-like growth like grapes (Figure 21).

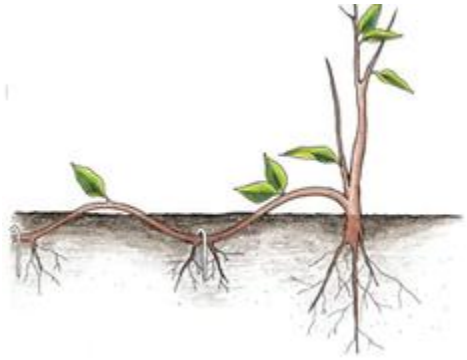


Figure 21: Serpentine (Compound) Layering Method

Tissue culture is the procedure for maintaining and growing plant tissues and organs in an aseptic culture in which the environment, nutrient and hormones levels are tightly controlled. A small piece of vegetative material called the explant is used to create a new entire plant.

In principle the explant is taken from the mother tree and dipped into an auxin hormone and this will facilitate the rooting process required for the new plant to be raised in the nursery. But this this technique highly requires well equipped laboratory.

LEARNING UNIT 4: PERFORM NURSERY MANAGEMENT PRACTICES

Learning Outcomes:

4.1. Implement pricking out activity

4.2. Apply tending/management practices for seedlings

4.3. Organize nursery record keeping document

4.1 Learning outcome 1: Implement pricking out activity

4.1.0 Pricking out

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. In practice the hole made for receiving a new seedling should be about 5 cm deep and 1- 1.5 cm in diameter. The seedlings which eligible for pricking out should have at least 3 to 4 leaves.

4.1.1 Preparation of seedlings before pricking out

Before pricking out seedlings the following should be done:

- Before starting to prick out seedlings from the seed bed, you should ensure that your pots in the nursery bed are ready to receive seedlings;
- The day before pricking out both seed bed and seedling bed (pot bed) should be watered with enough water;
- Prepare shade to reduce the exposure of the seedlings to direct sunlight;
- Use a dibble or pencil-sized stick to loosen the soil in the containers;
- Plan the pricking out activity during 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.
- If you are transporting seedlings for a longer distance before pricking out you need to prepare cow dung or mud soil in which you will transport the seedlings.

4.1.2 Tools needed for pricking out activity

The tools needed for pricking out seedlings include the following:

- A dibble or pencil sized stick used to loosen soil;
- In case you intend to transport seedlings, you need to have buckets in which you will put cow dung/mud soil and seedlings will be transported with enough moisture content.

- An old spoon/a small piece of timber may also be necessary while removing seedlings from the seed bed;
- Labels which contain information regarding tree species and their respective dates of plantation.
- Containers in which seedlings will be planted;
- A well-prepared nursery substrate/soil which will be used as a growing medium for seedlings.
- A sharp knife/blade to be used while doing some cutting operations
- Wheelbarrow to be used to transport soil.

4.1.3 Pricking out process

For the successful pricking out activity the following steps should be done:

- About one hour before starting, water the seedlings to be pricked-out. This is done because roots are more easily removed from wet soil and it will ensure seedlings have high internal water content.
- Remove the seedlings in the seedbed by using a sharpened dibble stick or an old spoon. This dibble/old spoon should be inserted into the soil underneath the seedling and then gently lifted, taking care to do as little damage to the roots as possible.
- Hold the seedling by the leaves or cotyledons. Do not touch the stem or roots as these parts are very delicate and can be easily damaged, and also disease is encouraged.
- Immediately place these seedlings into a small container/bucket where the roots can be immersed in cow dung or mud soil. Accumulate up to 50 seedlings in this small container before proceeding to transplant them into containers.
- Using the dibble stick, make a hole in the potting mix at the centre of the tube which is large enough to accommodate the roots of the seedling to be transplanted without bending the roots.
- Holding the seedling by a leaf, lower the roots into the hole ensuring that they go straight down and are not bent upwards. If the roots are too long to go straight into the hole, they can be trimmed with the finger nails or a sharp blade.
- Refill the space around the roots with fine dry mixture which flows easily and so eliminates the formation of air pockets around the roots.
- Then immediately water the freshly transplanted seedling to wet the dry soil that was used to refill the hole;
- Three or four days after pricking-out, replace any seedlings that have died (beating-up) by repeating the above procedure.

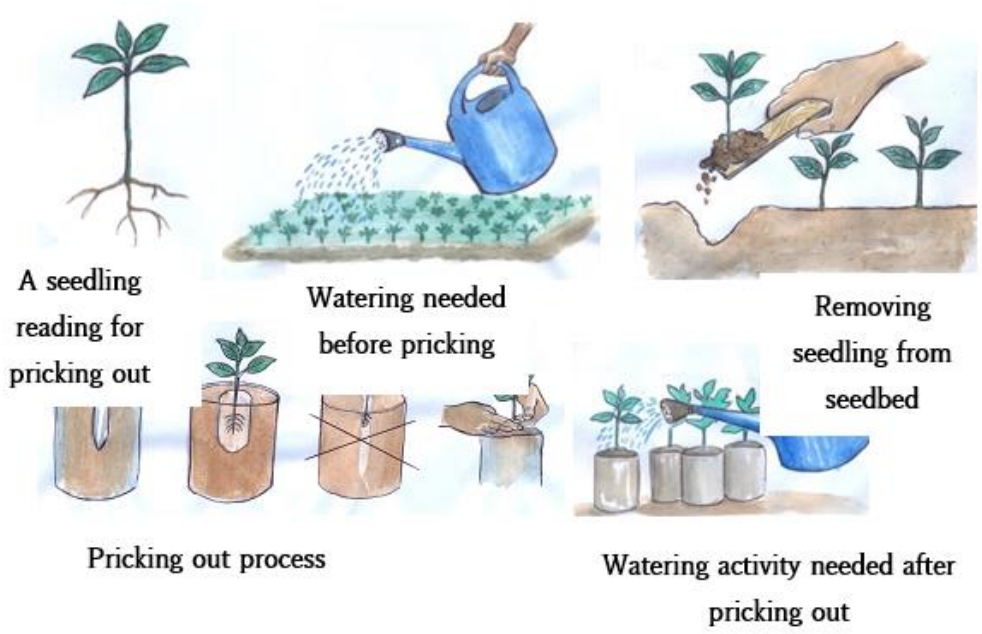


Figure 22: Pricking out process

4.2 Learning Outcome 2: Apply tending/management practices for seedlings

4.2.1 Management practices for seedlings

- **Watering**

An adequate supply of good-quality water is essential for any nursery. Watering is commonly conducted twice a day, i.e., at 06h00 – 07h00 and at 16h00-18h00. In both seed bed and seedling bed respecting timing of watering is important. It is not mandatory to always water twice a day, once it has rained watering can be reduced to once a day.

Germination and pricking out: watering twice a day

Early morning watering

Evening watering

Good watering

Bad watering

Figure 23: Best watering practices

- **Mulching**

Mulching consists of covering the seeds planted in the seedbed with grass. Mulching aims at facilitating the soil to keep moisture content and reduce evapo-transpiration. Mulching is done only in a seedbed and it has to stay until when the seeds start to germinate. For instance, for Eucalyptus tree species it will take only 7 days for the seeds to germinate and after 7 days the mulch has to be removed.

Figure 24: Mulching of seeds in seed bed

- **Shading:** Shading consists of establishing a shade on seed bed or a seedling bed. The wooden stakes used for constructing a shade should have 1.3m height and be covered with a mat made of bamboo. The shade should not be tightly established, it has to allow some light and water to penetrate in the nursery.
- **Weed control:** Weed control consists of removing all undesirable plants either in a seedbed or in containers. Weed should be removed in a nursery at least every two weeks for suppressing their competition with the planted seeds.
- **Culling and thinning:** Culling consists of removing or discard poor quality seedlings as soon as you detect them. Such poor seedlings can be a source of infection. Here the best nursery developer must select the best seedlings for planting, and then reject the

bad ones. Thinning is done where two or more seedling occur in one container especially where direct sowing of seedlings into containers is done.

- **Root pruning**: Root pruning is carried out for three reasons: namely to encourage development of lateral roots – Fibrous root system; to prevent roots of seedlings from becoming entangled and to prevent deep growth of seedling roots into the seedling bed or out of containers (at the bottom of the pot). The root pruning should be conducted as follows:
    - ✓ Water the seedlings properly before root pruning.
    - ✓ Cut the long roots underneath the container using a sharp knife, scissors or available cutting material.
    - ✓ Water the seedlings well after root pruning. This watering helps the plant withstand moisture stress.
    - ✓ Some nursery managers choose to place the seedlings on stones or polythene sheets to reduce the need for root pruning.
    - ✓ Seedings on a raised bed can be pruned by using a sharp object underneath the bed after watering.

Figure 25: Seedling with delayed root pruning activity

- **Hardening off:** This practice consists of conditioning the seedlings to survive outside the nursery. The process of hardening-off aims at acclimatizing tree seedlings to the harsh conditions of the field. Two weeks before planting, it is important to condition the seedlings so they are better adapted to harsher conditions in the field. Thus, hardening off consists of reducing the frequency of watering and the quantity of

shading so that the seedlings can get used to the future environment. The hardening off process should be conducted as follows:

- ✓ The shade should be removed for some period before the seedling is planted out. Shade reduction should be a gradual process. The sudden removal of the shade may cause burning of the seedlings.
- ✓ Reduction in watering intensity (quantity) and frequency e.g., water twice a week and later once a week.
- ✓ Before planting out, root pruning should be carried out frequently or re-arrangement of pots to allow more adoption to stress.
- ✓ Good preparation for out planting results in good field survival, therefore hardening off should be done 2 – 4 weeks before out planting time.

4.3 Learning Outcome 3: Organize nursery record keeping document

4.3.1 Types of nursery records

For being efficient in nursery practices there a number of record documents that should be with the nursery developer including nursery calendar, seed and plant identification, nursery production record and nursery diary book.

- **Nursery calendar**

A nursery calendar is document that specifies the timeframe of doing nursery activities for the whole year. Nursery calendars are helpful tools in scheduling necessary activities such as seed sowing dates, pricking out and seedling plantation. Specifically in Rwanda, every nursery developer should have a record showing him important dates to be respected in nursery activities with reference to the altitude range of his/her region. The nursery calendar is presented in learning outcome 1.4, specifically in table 7,8 and 9.

- **Seed and plant identification**

It is particularly important that the record on seed and seedlings cover the entire period from the day the seed arrives in the nursery until the seedlings are dispatched to be planted. An identity number should be given to each seed lot which arrives in the nursery. The easiest method is to use serially consecutive numbers on an arrival basis. For example, the first batch to arrive in 2021 would be No. 1/21, the second lot No. 2/21 and so on. The first lot in year 2022 would be No. 1/22.

These numbers in conjunction with the species name are sufficient to identify any particular batch of seed or plants in the nursery. In addition to the use of identity number and species name, it is customary to include the date of sowing and transplanting. An example of a Seed and Plant Identification Record is shown in the following table.

Table 10: Typical example of seed and plant identification in a nursery

Nursery				
Officer				
Location				
Seed and plant identification record				
Particulars	**Species**			
	Eucalyptus	***Grevillea***	***Senna***	***Acacia***
Identification number	1/21	2/21	3/21	4/21
Date of sowing	15/06/2021	15/06/2021	15/06/2021	15/06/2021
Quantity sown	0.5 Kg	1 Kg	0.5 Kg	2 Kg
Method of sowing	Broadcast	Broadcast	Broadcast	Broadcast
Date of first germination	22/06/2021	27/06/2021	25/06/2021	30/06/2021
Date of last germination	30/06/2021	3/07/2021	30/06/2021	5/07/2021
Germination percentage	90	75	85	72
Date of pricking out	15/07/2021	18/07/2021	14/07/2021	20/07/2021
Number of pricked out seedlings	16000	18000	3800	7500
% of dead seedlings after 2 months	5	8	12	10
Culls/rejects	100	150	120	300
Number of planted seedlings	15900	17850	3680	7200
Disease observed	-	-	-	-

- **Nursery production record**

This record is necessary to keep track of the species and number of seedlings in different stages of survival, development and distribution. A well-kept, and up-to-date production record helps to assess whether the nursery is operated as planned and alerts the nursery manager in good time if seedlings are under or over produced so that remedial action can be taken in due time. It should therefore be prepared in a tabular form, suitable for collection. The following table shows an example of a Nursery Production Record.

Table 11: Nursery production record format

Seedling's readiness in two weeks											
Nursery											
Location											
Nursery production record											
Tree species	**Number of seedlings pricked out**		**No of weeks before ready to plant out**								
	Not ready	Ready	16	12	10	8	6	4	2	Not ready	Ready

- **Nursery diary book**

The nursery diary book is used for recording nursery daily activities and they include the following:

- Number of pricked out seedlings;
- Number of dead seedlings;
- Number of seedlings sold;
- Free issue;
- Available nursery tools and equipment;
- Disease outbreak and pest attack;

4.3.2 Placement of labels

It is useful to make seed and plant labels for each transplant unit of container grown or bare root seedlings. The method often seen in local nurseries is to paint detailed information on rectangular piece of timber or use a laminated paper and fix it on the piece of wood. Each seed bed should contain information regarding tree species sown, date of sowing and quantity of seed sown. For the seedling bed, it should have a label showing the tree species pricked out, the number of seedlings and date of pricking out.

LEARNING UNIT 5: CONTROL PESTS AND DISEASES IN A NURSERY

Learning Outcomes:

5.1. Identify pests attacking seedlings in a tree nursery

5.2. Identify diseases attacking seedlings in a tree nursery

5.3. Control pests and diseases attacking seedlings in a tree nursery

5.1 Learning outcome 1: Identify pests attacking seedlings in a tree nursery

5.1.1 Key definition

Pests: Pest are defined as living organisms that cause weakening or disease among seedlings. In Rwanda there are possible pests attacking seedlings in a nursery namely: Termites, cutworms, caterpillars and sucking insects.

5.1.2 Pests attacking seedlings in a tree nursery in Rwanda

- **Termites**

Termites are the most important insect pests which attack seedlings in a tree nursery especially in both East and Southern provinces of Rwanda. While attacking seedlings termites feed on underground roots and stem of tree seedlings. Termite species responsible for injuries and damage in tree nurseries are known as underground termites (subterranean termites).

Termites are attracted by different factors including presence of waste from dry grasses, wood or shading material that is falling in the nursery.

Termites cause wide spread damage to seedlings and cuttings in a nursery; however, the incidence and extent of damage varies from species to species and from locality to locality. The damage occurs below the ground level mainly in the upper 20 cm of the soil layer by hollowing out or severely ring barking the tap root which results in the death of the seedlings. In case of cuttings, the underground woody portion is decayed and attacked by the subterranean termites. The affected seedlings show sign of yellowing, wilting and finally resulting in die back.

Figure 26: Termites attacking tree seedlings in a nursery

- **Cutworms**

These are insect larvae that live in the soil but which emerge in the night to eat the shoots of seedlings, leaving only stumps. The following figure illustrates a cutworm after attacking a seedling.

Figure 27: A cutworm after attacking a seedling

- **Caterpillars**

These are insect larvae that attacking seedlings through leaves consumption. Once they have attacked the seedlings you will find foliage with chewing damage; moths may be visible around plants. Damages from caterpillars in Rwanda are not high in attacking tree seedlings but once found in a nursery they are very destructive to nursery growing seedlings.

Figure 28: A caterpillar and moth attacking tree seedlings

- **Sucking insects**

Sucking insects such as aphids may damage the seedlings by sucking the sap of the stems, causing the seedlings to wilt. The attacked seedlings will show distorted new growth, sticky honeydew, and/or sooty mold.

Figure 29: Aphids on a citrus tree

5.2 Learning Outcome 2: Identify diseases attacking seedlings in a tree nursery

5.2.1 Diseases attacking seedlings in a tree nursery in Rwanda

The most common disease that affects nursery grown seedlings in Rwanda is known as "damping off". The symptom of damping off is the development of a zone of weakness at a point on the young seedlings where the stem and the root meet. The seedling rapidly loses turgidity, bends over and soon dies.

- **Damping off**

Damping-off is a collective name for a number of non-specific fungal diseases that cause a serious threat to seedlings after germination. The seedlings begin to rot from the stem tissue just above the root collar resulting in the seedlings toppling over. The disease begins in patches and finally spreads to the entire bed. The humid environment created for the maximum growth of the seedlings also favours the growth of the fungi. The common fungi, causing disease include: *Pythium, Fusarium* and *Rhizoctonia.*

The disease can be either pre-emergent – when the seed rots before germination begins or it can be post-emergent – in which case the young shoot rots at soil level, causing the seedling to topple over and die.

If the seedlings are affected by "damping off", the most likely causes are: poor nursery hygiene, the condition of the soil used and poor general nursery management techniques.

Damping off is most often associated with the following conditions, all of which can be prevented.

- The soil may be too rich in organic matter, providing an ideal medium for the proliferation of fungi. The recommended proportion of manure to soil is not supposed to go beyond 1:4.
- The nursery may have been overwatered, providing an ideal, damp environment for fungi. The nursery should be watered 2 times in the morning and evening but too much watering should be avoided.
- The seeds may have been sown too densely, resulting in overcrowded seedlings. This should be avoided by good spacing and thinning out densely grown seedlings.

- Damping off may be introduced by rough handling of the seedlings, or through the use of dirty tools.

- **Physiological disorders**

Physiological disorders are caused by a lack of plant nutrients, or the presence of nutrients at levels toxic to the seedlings. They affect the functioning of the plant system. When suffering from nutrient or physiological disorders, the seedling exhibits disease-like symptoms; therefore, nutrient disorders are sometimes mistaken for a disease. Nutrient disorders may result in a loss of many seedlings. One way to confirm a nutrient deficiency (or toxicity) is to see colour change in the leaves of seedlings.

5.3 Learning Outcome 3: Control pests and diseases attacking seedlings in a tree nursery

5.3.1 Control of pests attacking seedlings

- **Termites**

For controlling termites' nursery grower should do the following:

- For preventing termites to enter in the nursery, a live fence made of *Euphorbia tirucalli* cuttings should be done;
- While seed sowing mix soil with wood fire ash and cow dung;
- While preparing soil substrate for pricking out, mix also soil with wood fire ash and cow dung;
- Remove all dead materials including wood, grasses and shading material inside the nursery and make sure that nursery hygiene well controlled.
- Chemicals used to control termites include aldrin, chlordane or heptachlor. But environmentalists are now discouraging the use of those chemicals.

- **Cutworms**

For controlling cutworms, the following should be done:

- The use of Neem solution (powder) to spray the nursery seedlings is strongly recommended.
- Larvae can be simply dugout of the soil and be killed;
- Chemicals can be used to destroy the larvae, but these are not encouraged for use.

- **Caterpillars**

For controlling caterpillars, the following should be done:

- Manage weeds and reduce other alternative hosts in the nursery area and surrounding. Good weed management will also help reduce a variety of other pest problems including aphids.
- Prune out heavily damaged leaves or stems, if necessary, this is particularly important for leaf mining pests like caterpillars. The larvae will fall off plants. Remove and destroy heavily infested, seedlings.
- There are many pesticides that can be used to manage caterpillars in production nurseries. Most of the products available are contact products that do not move into the plant. Many contact products (*Spinetoram, Indoxacarb, Chlorantraniliprole*) also are active when caterpillars ingest the product that is present on the leaf.

- **Sucking insects**

For controlling sucking insects, the following has to be done:

- Good nursery hygiene will reduce the threat from aphids, but at the first signs of an attack the infested seedlings should be removed and destroyed.
- Spraying chemicals like cypermethrin once the attack is detected can also be helpful.

5.3.2 Control of diseases attacking seedlings

- **Damping off**

For controlling damping off this should be done:

- Damping-off can be prevented by controlling humidity, shading, watering, and thorough cleaning of sowing tools and equipment.
- Use sterile media and containers;
- Avoid over-sowing, crowding of seedlings, or planting seeds too deeply;
- Damping off may be controlled by using fungicides.

- **Physiological disorders**

For controlling physiological disorders this should be done:

- The key to avoiding physiological disorders is to ensure that the soil is healthy and contains plenty of well-rotted organic matter/compost. Testing and correcting soil pH is also important because it has an effect on the availability of plant nutrients. In slightly acidic to neutral soil the availability of plant nutrients is not restricted by pH. In moderately to strongly acidic soil, and as the soil becomes more alkaline, the availability of many plant nutrients decreases or increases to toxic levels. The other important thing here is to see if the shading of the nursery has been done in the right way.