MANUAL ON NURSERY PRACTICES

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**FOREWARD**

For the general public, tree planting is the most visible activity undertaken by the Forestry Department. A growing awareness of the environmental benefits of maintaining forest cover in the island’s watersheds has created widespread support for reforestation and afforestation projects. The provision of tree seedlings for community development projects and for the Private Planting Programme is at the centre of the Department’s forestry extension activities. Meeting the increasing demand for high quality tree seedlings is a challenge the Forestry Department must meet to ensure that tree planting remains a high priority on the national environmental agenda.

Numerous publications are available about tree seedling nurseries, but this Manual on Nursery Practices incorporates ideas and experiences based on local conditions. The manual was prepared for the use of supervisors of the Forestry Department’s nurseries but we hope that others who are engaged in establishing and operating tree nurseries will also find it a useful guide for good tree nursery practices. The focus is on quality therefore the manual includes not only what to do, but also details about physical characteristics of healthy seedlings, proper growing media, and regulation of water, light and nutrients that result in high quality tree seedlings.

The cost of tree seedlings is a major component of any tree planting project and this manual aims to promote the production of quality tree seedlings that have a high survival rate after planting out.

Marilyn Headley
Conservator of Forests
June 2003
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Keats C. Hall
Chapter 1: Introduction

Trees are essential to our lives and are an integral part of our landscape. They play many roles and confer a multitude of benefits to society such as food, shelter, shade, timber, natural beauty to the countryside, conservation of our soil and water resources and improved air quality. With the recent approval and launch of a National Forest Management and Conservation Plan, and the greater awareness of forest and tree values, indications are that there will be an increased demand for tree seedlings to ensure that these benefits continue to contribute to the nation’s well-being.

Purpose and Content

The aim of this manual is to provide information and guidance on how to start a nursery and the steps involved in growing quality tree seedlings for survival under the often dry, nutrient deficient conditions in which the seedlings are sometimes planted. The manual is therefore of special interest not only to nursery workers and nursery supervisors but also to foresters, horticulturists and those involved in planning and managing the production and use of tree seedlings for any of the above mentioned roles and benefits.

Factors related to the selection of the nursery site are discussed in Chapter 2. The topics of site preparation and nursery design and layout are treated in Chapters 3 and 4 respectively.

Seed propagation is the principal mode of plant production in temperate and tropical silviculture. In managing nursery operations based on seed propagation, the main objective is to obtain good germination and provide optimum conditions for their survival and growth into strong healthy trees. Chapter 5 discusses these conditions for producing plants from seed. During germination and the early establishment phase, seedlings are susceptible to stress from improper watering, mechanical damage and infection and advice is provided on how to improve conditions so that seedlings can survive and pass through this vulnerable stage as efficiently as possible. The often overlooked need to gradually apply stress to harden seedlings in preparation for the harsher field environment is also covered.
During the last three decades, vegetative reproduction using parts of growing plants such as branch and tip cuttings, roots and leaf portions has become increasingly popular because of the difficulty of some plants to produce viable seed. This popularity has been enhanced by the development and perfection of mass production techniques involving plant cells (tissue culture) resulting in the world-wide availability of improved varieties of ornamental and horticultural seedlings. Because of its importance in producing seedlings for agroforestry and horticulture, vegetative reproduction is covered in Chapter 6 of the manual.

One of the most important factors that influence the production of high quality seedlings is the growing medium and this topic is covered in Chapter 7. Nursery records contains valuable information and Chapter 8 reviews the basic types of records which should be kept by all nurseries.

The four appendices provide a quick reference for frequently used information. Appendix 1 lists some of the common errors found in tree nurseries. The use of compost to compensate for low quality soil media is emphasised throughout this manual and Appendix 2 gives hints on how best to produce it. A check list of useful nursery tools and equipment makes up Appendix 3 while local sources of commonly used nursery supplies are provided in Appendix 4.
CHAPTER 2: CHOOSING THE NURSERY SITE

TYPES OF NURSERIES

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

- Small-scale nurseries
- Permanent nurseries

Small-scale nurseries, sometimes called ‘temporary nurseries’, were favoured during the formative years of the Forestry Department until the decade of the 1950s to meet small reforestation and tree planting targets, often in remote forest reserves and rural communities.

These were replaced by permanent nurseries at Clydesdale, Twickenham Park, Mt. Airy, Williamsfield and Moneague to allow for more organised production to meet the needs of the much larger reforestation projects of the 1960s and 1970s. The Twickenham Park Nursery, which concentrated on bare root production for over two decades, ceased operations in 1998.

Now that the scope of community forestry has widened and local groups and NGOs are being encouraged to be self-reliant under the Forestry Department’s revised Forest Policy (2001), a resurgence of small-scale nurseries is anticipated that will also be growing agroforestry and orchard crops as well as ornamental plants.

Some benefits of small-scale nurseries are:

- Nearness to planting site improves survival because transit time between nursery and plantation is short and plants suffer less from overheating, windburn, soil loss and vibration caused by long journeys
- Better provision for the range of species and numbers of seedlings required by different farmers
- Transport cost is less and capital investment is low
- Isolation of disease is much easier
The main advantages of permanent nurseries are:

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

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

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

**Water**

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

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

Equally as important as the quantity of water is the quality of the water. It is necessary to measure the pH which should be between 5.5 to 7. Water with pH
CHOOSING THE NURSERY SITE

greater than 7 favours attacks of ‘damping off’ fungi in the seed beds and tends to raise the pH of the soil which in turn can reduce the growth of seedlings.

LOCATION

The nursery should have a central location as near to the planting site or demand centre as possible to avoid the transportation of seedlings over long distances. In order to reduce the problems of transport, food and accommodation, and to encourage better supervision, most forest nurseries are located close to or within population centres. This avoids the need to construct dwellings and living facilities for nursery workers thus reducing costs.

Sites with exposure to excessive wind should be avoided as well as valleys and old water courses that may be liable to flooding.

TOPOGRAPHY

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

SIZE OF NURSERY

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

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

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

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

Although each can be evaluated separately, they are all interrelated. The presence of organic matter is perhaps the most obvious indication of a healthy soil and is an essential ingredient in maintaining satisfactory moisture relationships necessary for plant growth. Soil that is not porous encourages water-logging, hence oxygen, which is essential for root development and respiration, becomes unavailable to the plant. The role of pH is discussed in Chapter 7 under ‘Growing Media’.
CHAPTER 3: PREPARATION OF THE SITE

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

REMOVAL OF TREE AND VEGETATION COVER

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

REMOVAL OF TOP SOIL

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

EROSION CONTROL AND WIND DAMAGE

Exposed slopes and the ridges of terraces should be grassed as soon as possible and during the dry season if necessary since irrigation water should be available. If there is a threat of wind damage, a wind-break should be planted around the perimeter of the nursery. A low hedge could also be considered around key sections to further reduce wind, control or prevent wind borne weed seeds and damage from dust. The species used as a wind-break and in the hedge should be relatively free of disease and insect attacks. The species to be grown in the nursery should not be used as a wind-break since they could harbour injurious mature trees of the same species as those grown in the nursery are a source of fungal and insect pests.
pests to which the young seedlings may be susceptible. Two coniferous species, Cupressus lusitanica and A rhor vitae, have been used successfully and flowering hibiscus was for many years used at the Williamsfield Nursery.

Slower growing hedge plants are preferred, particularly those that withstand heavy pruning and maintain a tidy appearance. For this reason, flowering hibiscus shrubs used to be popular until the threat of the ‘pink mealy bug’ and cotton cushiony scale insect, which thrives on this plant, discouraged its use. Any disease or insect outbreak in wind-breaks should be controlled quickly to reduce the risk of spreading to nearby nursery seedlings.

Since most tall trees tend to lose their lower branches after a few years, a practical hedge can be made either by planting a row of trees with one or two rows of a low growing species (see Figure 1); or by planting three rows of trees using a species that coppices freely. Every 2 to 3 years, depending on its rate of growth, one of the outer rows is cut back and the coppice regrowth will provide the required low hedge protection. This type of hedge provides extra fuelwood as well as raw material for making compost.

Figure 1: Windbreak using a row of trees with one or two rows of a low growing species.
**Surface Dressing**

Sometimes, due to the nature of the nursery soil, it may be necessary to apply a firm hard surface material over the whole area or between the transplant lines. The material must resist wear and be porous enough to allow drainage of excess water. This surface dressing can be quite expensive but the cost is usually justified under those conditions where the nursery surface requires special pre-treatment. Granite, often called black stone in 1/2 or 3/4 inch size can serve the purpose. The imported woven black plastic ground cover material used at Mt. Airy and at the Hope Gardens Nursery also provides excellent weed control. Sources of supply are listed in Appendix 4.

**Shape**

The nursery should be compact and can be square or rectangular. Rectangular nurseries are sometimes preferred as they allow for longer working lines but often there is no choice and one has to comply with the area available and the topography.

**Fencing**

The entire nursery area should be surrounded by a durable fence adequate to keep out animals and provide a measure of security. Where fence posts are used, they should be of durable hardwood or impregnated with a preservative. It is desirable to have at least one large gate sufficiently wide to admit a 5 ton capacity truck and the gate should be kept closed after working hours. In large nurseries it is usual to maintain an open strip of land about 5 metres wide encircling the inside perimeter of the fence to serve as a roadway and buffer zone between the neighbouring land and the nursery. This area should be kept weed free, or at the very least, weed species should be cut or mowed and not allowed to flower and produce seed for obvious reasons.
Notes
CHAPTER 4: DESIGN AND LAYOUT OF NURSERY

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

ADMINISTRATION AREA

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

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

OPERATIONS AREA

Adequate space should be provided to accommodate the following operations:

- Extracting, drying and processing of seed: The surface of this area should have a concrete floor close to covered facilities and could have multiple functions as it is usually suitable for other operations
- Preparing germination trays and potting mixtures
- Screening compost and soil
- Filling pots
Figure 2: Example of a layout for a permanent nursery

1. Administration office
2. Canteen
3. Changing room, showers, etc.
4. Operations area
5. Storage
6. Production areas
7. Bare root production area
8. Reserved for expansion
9. Potting soil storage
10. Compost area
11. Boundary fence
12. Weed free buffer strip
13. Parking
14. Entrance gate
- Soil shed with compartments for screened soil, sand and compost: The soil shed should allow for soil mixing and the filling of containers to be carried out under shelter throughout the year.
- Composting area: Compost production should be considered mandatory in all nurseries, and a place provided for this purpose.

Production Areas

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

Germination Section

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

Transplanting Area

The nursery beds for growing bare rooted plants or for standing containers occupies the greater part of the nursery area and it is here that the transplanted or direct sown seedlings are grown until they are ready for planting in the field. Normal bed width is 1 to 1.2 metres to facilitate hand tending. Length is also important and beds should not be longer than 20 metres in order to facilitate moving from one bed to the next. Bare root production beds should be located where the soil has the best chemical and physical properties.
The only fixture in the transplant area is the watering system if one has been installed. However, in very hot and dry locations, and with certain species, better results may be obtained by transplanting and raising seedlings under a roof used to control the light intensity. The building need not be elaborate but it should be high enough for workers to stand underneath. Pickets of wood or bamboo slats are commonly used and preservative treatment will extend their useful life. Imported polypropylene shade cloth is available in different light intensities offering a longer lasting, tidy and more efficient material. Polypropylene shade cloth comes in standard widths of approximately 2, 3 and 4 metres (6, 10 and 12 feet) that provide different intensities of shade, eg, 47, 55, 63, 73 or 80 percent.

**Other Production Areas**

If nursery production includes rooted cuttings, grafting and budding, space will be required to include glass frame bins or a mist propagation unit as installed at the Hope Gardens Nursery.
CHAPTER 5: PRODUCING PLANTS FROM SEED

The following are the most common methods of raising tree seedlings from seed and there are many variations in these methods:

- In an open bed from which seedling plants are lifted and planted with roots bare of soil
- In containers, either singly or in multi-cavity trays which are taken to the planting site and the seedlings planted with a ball or plug of soil around the roots
- Transplanting natural regeneration seedlings often found under mature trees into containers

Initially, the local practice followed that of temperate countries by raising seedlings in open beds and planting them in the field. The survival rate was often low due to unpredictable weather, dry conditions and seedling stress due to high temperatures in the field. The Forestry Department found that survival increased considerably when seedlings were taken from the nursery to the planting site with roots growing in soil. Originally the containers used were made of fibre from banana stems and from woven split bamboo produced in large quantities at prisoner rehabilitation centres. The advent in the 1960s of cheap polyethylene tubes or bags led to the almost total use of this material for container grown seedlings in the country.

Although many different types of containers are now available with obvious advantages, the following three disadvantages are worth mentioning:

- High quality seed is required to obtain acceptable results
- Obtaining and preparing suitable growing media and filling process is proving expensive
- Plants are bulky when compared with bare root seedlings and therefore costly to handle and transport

With improved seedling conditioning, and to effect cost savings, consideration should be given to reverting to bare root production particularly for sites with adequate rainfall.
The sequence of operations for the bare root method is shown in Figure 3 below and that for containers in Figure 4.

**Figure 3:** Bare root cultivation.

1. Cultivate and raise bed in nursery
2. Sow seeds in drills
3. Care and tend seedlings over whole bed

**Figure 4:** Sequence of operations for container growing.

A. **Sowing in Trays**
   1. Sow in tray
   2. Prick out
   3. Care and tend
      - Remove container just prior to planting

B. **Direct Sowing**
   1. Obtain soil
   2. Fill containers
   3. Place in bed
   4. Care and tend
      - Pack in cartons, crates or boxes for transport
The production of seedlings in the nursery is best described under the following stages of development and growth:

Stage 1: Seed Handling
Stage 2: The Germination Process
Stage 3: Transplanting the Young Seedlings
Stage 4: Tending the Seedlings

**Stage 1: Seed Handling**

**Seed Procurement and Storage**

Which species and provenance to use is pre-determined by Head Office who also have the responsibility for collecting or purchasing national or local seed requirements. When the seed arrives it is therefore normally ready for sowing. It may be necessary however to store the seed for short periods. Use rodent and insect proof containers which should be airtight if possible. Avoid extremes of temperature and humidity and fluctuating temperatures. Keep the seed in a refrigerator if one is available, placing the seed in a cloth bag and then placing the cloth bag in a plastic or glass container. The cloth bag will absorb the condensation inside the container during periods when the electricity supply is disrupted. Do not store seed in a freezing compartment. Keep the seed at a uniform temperature in the refrigerator above 5° C. Since fluctuations in temperature can be harmful, divide the seed lot on arrival into manageable units and remove from storage only the amount required to be sown on the appointed day. Apply seed fungicide and insecticide on arrival of seed at the nursery if this was not previously done. Some seeds cannot be stored for long periods, eg, neem, Spanish elm, mahogany. When these seeds arrive at the nursery they should be given priority for immediate sowing.

**Seed Dormancy and Pre-Treatment**

Seed dormancy refers to a state in which viable seeds fail to germinate when provided with conditions normally favourable to germination, ie, adequate moisture, appropriate temperature and light. Dormancy in seeds may be advantageous or problematic during seed handling. The advantage is that it prevents seeds from germinating during storage and normal handling. On the other hand, where dormancy is complex and seeds need a specific pre-treatment,
failure to overcome these problems may result in poor germination. Some pre-treatment procedures are not directly related to seed dormancy but are carried out in order to speed up the germination process.

It is important to maximise germination of all seed sown and the following are the main pre-treatment or pre-germination treatments that may be necessary.

**Separation of empty seed.** This usually applies to small seed and may be effected by soaking the seed in water overnight and discarding those that float as this often indicates emptiness. If the seed is extremely valuable or of uncertain viability, those that float can be broadcast sown to gain experience and confirm results. Soaking for one or two days is also used to encourage early, even germination.

**Pre-treatment to weaken seed coat or break dormancy.** Aside from emptiness, many seeds exhibit dormant characteristics. For example, the hard seed coat of many legume species prevent the uptake of moisture. Some seeds contain chemical germination inhibitors which must first be broken down whilst others have partially developed embryos which need to mature. The techniques used to counter this problem vary with the particular species and include the following measures:

- Many woody plant species require a cool temperature and moist media treatment for seed germination to occur. Cool-moist treatment of seed to promote germination is called a **stratification** treatment. In most cases seeds with a stratification requirement, such as teak, need a minimum of a 6 to 12 week treatment in a moist, aerated environment followed by a warm, moist environment for seed germination to occur. Seed must be maintained cool and moist since either warm temperatures alone or dry media during the stratification process will inhibit germination. Burying the seed between layers of wet, sifted sand is a form of stratification that facilitates germination of teak seed.
- The **scarification method** facilitates germination by physically removing enough of the seed coat by nicking, piercing, chipping, filing, or drilling with the aid of a knife or needle or by burning. Although effective with tough seed coat species, this method is rarely used because it is time consuming and impractical where large seed quantities are involved.
- **Hot water** overcomes dormancy in Leguminoseae by creating tension which causes cracking or weakening of the seed coat. The method is most effective
when seeds are submerged into the hot water and not heated together with the water. A quick dip is also better to avoid heat damage to the embryo. For most hard-coated Acacia species, it is enough to bring the water to the boil and place the seed in the water after removing the flame. The seed can be planted as soon as the water cools or kept in storage for short periods.

- Soaking hard-coated seed in sulphuric acid for periods varying from 5 to 60 minutes, depending on the concentration of the sulphuric acid, can improve germination but care and experience is necessary as results vary considerably between species and seed lots. The duration of acid treatment should aim at reaching a balance in which the seed coat is sufficiently ruptured to permit the seed to imbibe water but without the acid itself reaching the embryo. The acid may be re-used several times although its strength will gradually decline. After soaking, the seed is removed from the acid and rinsed under running water for at least 10 minutes.
- Pre-treatment with fungicides or insect repellent is useful if there is a risk of insect or damping-off fungal attack. The method is to dust the seed with an appropriate fungicide/insecticide prior to sowing. Special pre-treatment against rats, mice, birds or small insects may be necessary in which case Head Office should be consulted to help obtain a suitable repellent.

**Stage 2: The Germination Process**

This stage begins with the absorption of water and ends with the elongation of the radicle (root) and involves the following steps:

1. Seed coat imbibes/absorbs water
2. Water moves into the inner membrane
3. Stored food reserves (protein and starch) activated
4. Cells multiply and elongation begins
5. Seed coat cracks
6. Radicle emerges and seed has germinated

**Time of Sowing**

Time of sowing is important since seedlings must be of the right size and quality by the start of either the short rains which normally peaks in May or the start of the longer rains in September/October. If it takes 3 months from sowing to be ready for planting, then seed should be sown this amount of time in advance of plants being needed. Since all the plants will not be needed at the
same time, a certain amount of staggering may be necessary, based on the demand which should have been planned or estimated in advance of sowing.

**Method of Sowing**

The two basic methods of sowing seed for container or bare root production are broadcast and direct sowing. The choice of method will depend on the local conditions and experience. It should be noted that:

- The yield of plantable seedlings from a given seed lot is usually much greater with broadcast sowing
- Development of transplants are sometimes slow compared with undisturbed direct sown seedlings
- There is a risk of root distortion during transplanting with broadcast sowing

When seed is plentiful, of good quality and its cost is only a small proportion of total nursery costs, direct sowing is sometimes preferred. Direct sowing is also easier if the seed is large enough in size to be handled individually and the risk of root distortion is reduced with this method.

**Broadcast Sowing**

This is usually done in specially constructed beds containing sand or sandy loam or pre-mixed sterile sowing medium in a wood or concrete block frame or metal tray (see Figure 5). Clay or heavy soil must not be used as it is essential to have free drainage in the beds. Make the surface smooth, level and firm but not compact. The seed should not be broadcast too thickly over the bed surface to avoid overcrowding and to allow each seedling to have sufficient growing space. A ‘roll on’ cover may be necessary to protect the seed from birds and to provide shade.

**Broadcast Methods**

For tiny seeds such as Eucalyptus species, the practice is to mix the seed intimately with an equal part of fine, dry sand of a similar size and spread the mixture evenly with the fingers. An alternative method is to make a 20 by 20 cm tray using strong mosquito or similar wire netting. The tray is then covered with fine sand particles just large enough that they will not penetrate the netting. On top of this the seed is added, usually sufficient to sow 1 square metre of the germinating seed bed. After shaking the tray, the small seed will find the openings and be deposited on the bed evenly and in the quantity desired. If the seed is
mixed with sand of a similar size, it will be sown more evenly and uniformly. The work can be simplified if seedbeds are divided into 1 metre quadrants so that the recommended amount of seed to be sown per square metre can be premeasured.

**Direct Sowing**

The advantages of direct sowing are lower cost and the avoidance of damage to seedlings through careless transplanting. Although only one seed is necessary if the germination rate is high, the aim is to sow an average of two to three seeds per container. With small seed, special methods need to be used to regulate the amount to be sown. In some overseas nurseries, a shaker is used, made from a small bottle with graduated holes in the lid set to allow a given number of seeds to drop per shake. Good results have been obtained from direct sowing *Acacia auriculiformis*, *A. mangium* and *Azadiracta indica* in pre-filled polythene bags. The use of cell packs that resemble egg boxes is also popular since the germinated seedling can be lifted with a plug of potting medium thus avoiding shock on transplanting.
Depth of Sowing

A general rule is to cover the seed to a depth equal to twice the seed diameter and not deeper than 1 cm in the case of *A. mangium* and similar small seed sizes. The recommended practice is to apply the lightest cover which is capable of withstanding routine watering. The tendency in some nurseries has been to sow the seed much deeper than necessary to avoid the washing out or uncovering after heavy watering. In such cases it is the water that should be regulated, using nozzles and pressure that will reduce the force of the water.

Care of Seedbed and Direct Sown Container

After sowing, cover the seed with a layer of fine sand or sifted nursery soil or potting mix to the desired thickness and water the bed or container lightly. Do not press the seed into the seedbed or container. Shade the seedbed from direct sunlight immediately after sowing with jute bags, newspaper, bamboo or any suitable available cover. This may be placed directly on the seedbed at first as a source of protection and to maintain humidity and an even damp moisture condition that favours germination. The cover must be lifted to about 30 cm or higher at the first sign of germination and removed completely as soon as possible afterwards to avoid weak, pale looking seedlings. Watering must be done gently with a fine spray and in large nurseries where piped water is available, mist nozzles are recommended for watering seedlings, using a filter to avoid sediment from clogging the small openings of the mist nozzle.

Stage 3: Transplanting the Young Seedlings

Depending on the species, seedlings are normally ready for transplanting from 3 to 5 weeks after germination when 2 or 3 pairs of leaves have formed. With *Pinus caribaea*, transplanting is best done at the ‘match-stick’ stage whilst the seed coat is still attached to the young stem and when lateral roots have not yet started to show. With *A cacaia* spp, when the first pair of leaves show, the seedlings are ready for transplanting into the polythene bag. Some selection may be necessary at this stage since all the seeds do not germinate at the same time. The important points to remember when transplanting are:

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

- In lifting the seedlings take care not to damage the roots or the stem. Do not pull them individually. Lift the seedlings by raising a whole block of soil using a thin piece of wood and free a bunch of seedlings together. Afterwards, the soil should fall away easily as there should be few lateral roots at that stage to retain it.

- Hold the seedlings only by the leaves or by the ‘match head’ or needles in the case of the Caribbean pine. If the stem or root is held, the plant is more susceptible to damping off fungi from bruising, crushing or infection by the fingers.

- The roots must not be exposed to air or sunlight for longer than a few seconds. As soon as the seedlings are lifted, place the roots in water in a shallow container to avoid drying out before transplanting.

- Plant the seedlings at the same depth as they were in the seedbed or perhaps a little lower but never higher.

- Fill the container and prepare the transplanting space using a broad flat stick or your fingers rather than the customary pointed stick that makes a narrow conical shaped hole that encourages abnormal root development.

- Cut off the tip of the root if it is too long using a sharp knife, making a clean cut, leaving about 5 cm of root.

- Firm the soil gently around the root. Do this carefully to avoid air pockets at the bottom or side of the slot. Do not use force as this could bruise the seedling and reduce the porosity of the soil medium by compaction.

- Plant the seedling in a straight, upright position in the centre of the container. The roots should not be allowed to bend or curl in the planting space (see Figure 6).

- After transplanting a batch of seedlings, water them again immediately with a fine sprinkle and place them under shade if the days are particularly hot. This should not be necessary if the transplants were sufficiently ‘hardened off’ or grown in full sunlight.
Experienced nursery workers will gradually reduce the frequency and amount of water during the last 10 days before transplanting in order to harden the seedlings, particularly if they are more than 4 to 5 weeks old. The above principles apply equally to the transplanting of seedlings from seed beds or from pots in which more than one ‘direct sown’ seed has germinated.

**Light and Shade**

Light affects all the different stages of growth of container tree seedlings and should be managed by the grower to increase photosynthesis which takes place in the foliage. With photosynthesis, the plant is able to produce the basic building blocks of its life such as carbohydrates, amino acids and fats and also generate oxygen which is essential for the respiration of all organisms. Water is absorbed in the roots and transported to the leaves where it is combined with carbon dioxide in the presence of light to produce sugar. The products of photosynthesis are transported throughout the plant and are used in respiration to release the energy required for a wide variety of growth and maintenance functions.

For the above reason, seedlings will do best under high light intensities and the goal should be to grow seedlings in the open wherever possible. Trees high
enough to provide ample walking space for adults may be necessary to provide
shade for nursery workers during the transplanting operation. In contrast, low
shade spread on supports of 30 to 50 cm above the ground is sometimes
necessary to provide temporary shade for seed beds and transplant bags in
periods of intense heat or heavy rainfall. It is a mistake to use shade once the
seedlings are over the shock of transplanting although nursery staff will be
tempted to keep them under shade to reduce the amount of watering needed
and to mask the effect of bad transplanting. Plants that have been transplanted
will require shade for only up to 3 days if the job has been satisfactorily done.

**Transplanting Natural Regeneration Seedlings**

Natural regeneration, sometimes called wildlings, refers to seedlings that have
germinated below parent trees either individually or under forest cover. In recent
years, there has been an increased demand and use of seedlings from this source
due to:

- Shortage of planting stock
- Inadequate seed supply
- Seed germination failure
- Higher demand at short notice

In the absence of proper care and attention to detail, the survival of newly
transplanted wildlings in the nursery and in the field is often sporadic. Good
results can be obtained if the following practices are followed:

1. Select younger seedlings before tap roots have developed and penetrated
deep into the soil.
2. Arrive on the site with the necessary tools and equipment consisting of:
   - fork or pick-axe to loosen the earth
   - burlap or plastic for packaging
   - coir dust or compost material to reduce moisture loss from roots and
     stem
   - sharp knife or secateur for root pruning
   - container with supply of water to keep package damp and reduce shock
3. Do not wrench seedlings which are firmly rooted in the soil.
4. Place lifted seedlings in water; root prune if necessary.
5. Package seedlings in bundles of 20 or less packing damp coir dust or compost around the roots.
6. Transplant seedlings in containers at the nursery with minimum delay.
7. Temporary shade may be required until roots recover and start absorbing moisture.

**STAGE 4: TENDING THE SEEDLINGS**

**Watering**

*Germination Beds and Transplants*

The single most important factor in germination and seedling production is water but too much water can be just as harmful as too little water. With seeds and tiny seedlings, it is not necessary to provide heavy doses of water as this not only leaches out the soil nutrients but can expose seed or wash out seed before germination begins. The answer to this problem is not to plant the seed any deeper, as is sometimes done, but to adjust the hose nozzles to allow a finer spray or cover the seed temporarily until they germinate. Water the containers before sowing and immediately after covering the seed with the sowing medium or sifted sand. The sowing medium should not be allowed to get dry. Several light applications of water at this stage is far better than one or two heavy applications. Keep the soil moist but never sodden, watering preferably in the mornings and avoiding the mid-day period when the sun will cause excessive evaporation. Water deposited on the surface of leaves heats up readily in the overhead sunlight, causing the tender leaves to scorch.

*Over Watering*

Excess water is nearly always damaging since the water tends to replace the air in the soil and cause compaction, which in turn restricts the respiration process of the plant. Further, excess water promotes development of fungal diseases like damping off. The visible symptoms of over watering are slight to severe yellowing and stunted growth. This usually occurs near spray lines and at drip points where the sprinkler is attached to upright pipes. It is also common in areas where, due to depressions on the nursery bed, water is allowed to stand in pools. Over watering tends to occur in nurseries with heavy soils. Sometimes large groups of seedlings exhibit ‘wave’ formations where the watering system is not supplying water uniformly to all the plants. This condition should not be confused with blocks of plants with stunted growth which is normally caused by a deficiency of nutrients.
**Under Watering**

Wilting is one of the early signs of under watering. In sandy or heavy soils, there is a tendency to apply insufficient water, wetting only the superficial layer of the container. For this reason, it is often necessary to sample some bags, particularly those at the edge of beds to see if they have in fact received an adequate supply. Any signs of wilting should be immediately tended to by the addition of water so as to prevent permanent damage.

**Watering Methods**

Watering may be either by hand or by irrigation. Hand watering with cans fitted with a rose spray or knapsack mist nozzles are the obvious methods for small nurseries. With these methods an adequate number of filling points must be provided. Hand watering with a plastic or rubber hose fitted with a rose spray is also popular in small nurseries where water pressure can be provided. This method can of course work with large nurseries but it suffers from the same disadvantages as the other hand methods in that uniformity of coverage is difficult to achieve.

Surface irrigation was used effectively at the former Twickenham Park Nursery but the method is no longer widely used. Great skill is required in laying out such a system which is also not an efficient method since it wastes water that is often in short supply.

The ideal system for large nurseries is overhead sprinkler irrigation as it is easily controlled and provides the most uniform method for the application of water. A large number of systems are available and the heavy drops from some systems have been known to cause nursery workers to direct sow seeds much deeper than normal resulting in large-scale germination failures. On the other hand, some rotary systems can be so efficient that the need for shading transplants is often unnecessary. Whenever a sprinkler system is being installed in a new nursery, it is advisable to obtain expert advice before a final decision is made.

**Weed Control**

Weeds compete with the seedlings for nutrients, water and light. If they are not removed in time, this competition will suppress the young plants because the weeds are usually more vigorous and grow at a faster rate. The most troublesome are grasses or dicotyledonous plants that grow from a root stock. If such a
weed is cut off at the ground level, it will sprout again and continue to grow from the carbohydrates stored in its root tissue hence the need to remove the whole plant.

As much as possible one should prevent the presence and dispersal of weed seeds in the nursery. Most weeds produce large quantities of seed which are easily transported by water, wind and also brought in by introduced top soil, chicken litter and farm yard manure. No weeds should therefore be allowed to flower and fruit along paths and roadways or unused land in the nursery. Grassy areas should be regularly cut and trimmed. A thick hedge around the nursery helps keep out weed seeds that are otherwise brought in by wind. Since it is more difficult to eradicate weeds after they have invaded seedlings growing in containers and in transplant beds, both the potting soil and the pre-filled containers may be watered in advance so that the germinated weeds can be removed in advance of transplanting. For this purpose, containers should be filled up to 4 weeks in advance of transplanting or direct sowing operations if weed free potting soil is not available.

Pruning

Ideally, the roots of most high quality tree seedlings should be straight, carrot like or compact with many healthy succulent fibrous roots and root hairs. The corresponding stems should also be straight and sturdy with a symmetrical dense crown demonstrating a good balance between shoot and root. Because of the many variables involved, achieving this goal is not an easy task and one of the main limitations is the small size of the container or the comparatively unlimited space in the case of bare root production. Some time after transplanting, the roots of most seedlings will tend to exit the pot through the drainage holes at the bottom or sides of the container into the soil if there are no ground cover barriers. If they fail to penetrate the container a vigorous root will develop other abnormalities by having to run circles inside the pot. In situations where the root exits the pot, root pruning will be necessary.

Some growers overlook this routine operation and wait until just before the plants are about to be lifted and sent to the field. Although giving the appearance of a healthy seedling in the nursery bed, the wrenched plant with obvious unbalanced root to shoot ratio becomes the first casualty in the field. This is because the vigorous shoot loses water through its leaves and soon wilts as the
incapacitated root is unable to perform its function of replacing the loss by absorbing water from the soil. The condition of the root system and in particular that of its absorbing surface, the hair rootlets through which water and nutrients are taken up, determines to a large extent whether a seedling will survive field planting or not. Pruning stimulates root growth and causes the roots to become compact and fibrous rather than long and thin.

As a general rule, carry out the first root pruning as soon as the roots appear through the bag and enter the ground. Repeat the pruning every two weeks or as necessary. Do not wait for the last moment. Carry out the operation at least three weeks before the plants leave the nursery for the field. This is to allow sufficient time for the plant to replace its loss of roots by developing new laterals under the more favourable nursery conditions.

Since root pruning reduces the water absorbing surface of the root system, it is best carried out on a cloudy day when transpiration is low. If there are signs of wilting, then the plants should be watered.

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

**Root Pruning by Lifting**

In this method (see Figure 7), the first row of plants are carefully removed to provide operational space and each plant in the second row is lifted and placed in the vacant row after the roots growing out of the container have been cut with pruning scissors or a sharp knife. Do not shock the plants by lifting them forcibly as this damages the roots which do not heal easily or properly and the laterals tend to develop slowly. Using force can also destroy the intimate relationship between the roots and the soil in the bag and the benefits of growing the seedling in a container will have been lost.
Root Pruning in Bare Root Transplant Beds

While the seedlings are in the transplant beds, the roots are cut underground with a sharpened spade. The pruning level should not be too deep nor too shallow ranging from 10 to 30 cm below the soil surface depending on the species and the size of the seedling. Using a well sharpened spade, vertical cuts are made between the seedlings to shorten long lateral roots (see Figure 8). Then the spade is again forced into the soil, this time between the row of seedlings at an angle of about 45 degrees starting as far away from the seedling as the intended pruning depth.
Cutting Back Transplants
If necessary, most oversized seedlings can be cut back to a convenient height of 5 to 15 cm and allowed to recover in the nursery before planting in the field. Cut back plants tend to be bushy for the first few months after planting in the field but a leading shoot usually comes away and well formed trees are later produced. Where possible, a second pruning of unwanted shoots can be done as soon as they appear to facilitate the growth of a single stem. This method of cutting back stems is particularly useful if plants reach the desired size sooner than required and the need exists to hold them back for two to three months. On the other hand, it is normally undesirable to cut back plants and hold them for the next planting season as, by then, the plant would have used up all the fertility in the small bags. It would also most certainly have developed abnormal roots which would, in all likelihood reduce its chances of survival in the field.

Production of Stumps
Stumps are bare rooted seedlings with most of the shoot and more or less all lateral roots pruned so that only a short piece is left. Seedlings intended for stumps are raised in beds at wide spacing with or without transplanting to attain a diameter at the root collar of 1 to 2 cm. The stem is cut back to between 5 and 10 cm above the root collar, leaving one or two pairs of buds for sprouting and developing into a new plant. If a longer part of the shoot is left, the stump may produce several sprouts. Lifting of nursery seedlings can be done by hand (digging and pulling) or by machine. In Thailand, about 800 to 1000 teak seedlings can be lifted by hand per day. After lifting, the seedlings are transported to a stumping shed. The lateral roots are trimmed off (for teak, close to the tap root). The tap root is also cut to a length of about 15 cm (see Figure 9). At low rainfall locations, planting of stumps should commence soon after the rains begin. The seedlings in the nursery should therefore be prepared into stumps before the growth flush period, to obtain a higher growth potential when planted. Therefore, stump preparation should start just before the rainy season. In Thailand, teak roots are graded according to size and the small stumps planted soon after preparation. Larger stumps can be stored up to 4 months in so called pit stores at temperatures between 25 to 30°C.

Seedlings known to have the capacity to be grown as stumps include teak, neem, Honduras mahogany, Cassia siamea, G melina arborea, G liriodida, Spathodea, and bamboo and growers may have experience of several others.
Figure 9: Pruning bare root seedlings after lifting

Hardening Off

This refers to the progressive withdrawal of the favourable conditions in which the seedling has developed in the nursery with the objective of conditioning the plant for survival in the harsher environment in the field. This ‘rougner’ treatment should begin not later than halfway through the life of the seedling in the nursery. The main treatment involves the reduction of water and full exposure to sunlight. Reduce the amount and frequency of watering gradually to two or three applications per week depending on the species, the potting medium and the local climatic conditions. Hardened seedlings have the following characteristics:

- Firm, lignified stems, often brown in colour
- Sturdy, well-developed crowns with leaves extending over three quarters the length of the stem
- Vigorous, healthy, leathery leaves, compact rather than oversized and weak

Nursery workers often leave the practice of hardening off to the last week or two when already the first rains have started. As a consequence, the plants are never really in a hardened condition and often suffer a setback being unable to withstand a dry spell after planting. For this reason it is advisable to extend the growing time by sowing seeds two or three weeks ahead of time and slowing down the rate of growth by reducing water during the dry spell.
During the hardening off period, the reaction of the plants must be observed closely with a kind of intuition or instinct since the progress cannot be measured and the changes in the plant do not take place abruptly but gradually. Immediately before the plants leave the nursery they should be given a good final watering. Do not lift the seedlings by the stem at this or any stage. In summary, the following treatment can be applied to facilitate the hardening off process:

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

**Grading of Plants**

The production of seedlings of low quality and poor condition are some of the main causes of low field survival and these should not be taken to the field for planting. Also the few survivors grow slowly and must be tended for longer periods than good quality, faster growing seedlings. Losses have to be replaced incurring additional cost and also represent a waste of time, effort and money. The following points should be considered in judging whether a plant should be sent from the nursery or destroyed.

**Health**

Plants should be free of disease and insect attack. Discolouration of leaves and weak crowns indicate improper nursery treatment or abnormal roots.

**Injuries**

The plant should be free from mechanical injuries although some damages can be rectified by pruning.

**Stems**

Stems should be straight but not etiolated and should be able to stand firm without support. Curved stems usually signal abnormal rooting.
Sizes
Generally, each planting unit should receive plants of the same size and therefore plants of different sizes should not be mixed. Some plants like *Acacia mangium* retain its juvenile leaves when quite mature and this should not prevent them from being selected for planting in the field.

For most species, 25 to 35 cm plus the container is considered to be the best height for mature seedlings and should be ideal in terms of vigour and hardiness if the hardening process is followed. Some growers favour taller plants but they tend to lose the lower leaves and are inclined to bend over when planted. They have more difficulty in maintaining their water balance and tend to wilt much sooner under dry conditions. Also taller plants are usually older than normal and such plants find it difficult to start growing again in the time available in the first short growing season or after late planting in the field.

Fungi and Insect Control

In general, ‘damping off’ is the most likely fungal disease problem. The symptom 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.

**Control of Damping Off**
Heavy watering, particularly in the afternoon and evening hours encourages the disease so that as a first step, watering should be reduced to a minimum and only in the mornings. As a preventive measure, the seedbed should be watered once a week during pre- and post-germination with a solution of a copper based fungicide. To control attacks of the fungus, the fungicide should be applied every three days until brought under control or as directed by the particular supplier. In soluble form it is best applied with a knapsack sprayer.

**Control of Insect Pests**
Protection against grasshoppers, slugs and other leaf eating insects will sometimes be necessary. A number of formulations are available on the market, and distributors should be consulted on the most suitable chemical for the particular problem. A list of chemicals available locally and sources is provided at Appendix 4. Remember that temporary control can be effected by isolating the plant(s) until spraying is done.
Transport of Plants

This is the final responsibility of the nursery supervisor before the plants leave his or her care. About 4 months of hard work and skill can come to nothing if the plants are not properly prepared and given the necessary care for the journey to the planting site. The main problems are damage at the root collar, bad lifting, vibration on the way from the nursery, wind damage, drying out and sun scorch, and bad storage and holding facilities.

Seedlings should be handled as little as possible to minimise physical damage therefore avoid transporting seedlings to a temporary holding site to eliminate the need for additional handling.

The seedlings should not at any stage be lifted by holding their stem. Care must be taken with handling of seedlings at every step of the transporting process:

- From the transplant beds to a waiting area in the nursery
- From the waiting area to the trailer/truck
- From the truck to the temporary nursery site (when necessary)
- From the temporary nursery site to another truck
- From the truck to the plantation site
- From the plantation site to the planting hole

Given all these steps, without due care in handling seedlings, their survival in the field can be less than 40 percent although good quality plants were produced in the nursery and the planting in the field took place under favourable conditions.

The container grown plants should be packed and moved at each stage in open-top boxes until they arrive at the planting hole. It is important to pack the boxes tightly so they cannot move about in the truck.
Vegetative reproduction is the method of producing plants without the use of seed. Otherwise called asexual reproduction, the methods most often used to produce trees are cuttings, air layering, grafting and micropropagation.

**Cuttings**

What are the conditions needed for good results from cuttings?

- High humidity
- Full light intensity
- Protection from pests and diseases
- Absence of water logging
- Absence of windy conditions
- Appropriate rooting medium

Maintaining high air humidity is perhaps the most important because cuttings lose water rapidly especially through the cut ends which have as yet no roots to take up water to replace water loss. Any water logging around the cut portion will inhibit or delay the development of roots. Death due to dessication before rooting is the major cause of the lack of success in propagation by cuttings. High humidity can be maintained by frequent manual spraying or through the use of mist propagation systems.

**Mist Propagation**

Mist propagation is a mechanical way of spraying water on to the cutting:

- To maintain high humidity
- To reduce moisture loss by evaporation and transpiration
- To keep the cutting alive until enough roots are formed to support itself

Advantages of mist propagation include:

- Less disease and insect problems
- Reduced respiration and transpiration
- Maximum use of light intensities
• Increase of carbohydrate reserves  
• Improved root quality  
• Increased percentage of cuttings that root

It is possible to use a continuous system for rooting small quantities but intermittent systems give best results. Growers should at least have a clock to turn the system on in the mornings and off in the evenings and an intermittent cycle timer connected to a solenoid valve to control the frequency of the mist. Other devices that are available for misting systems include:

• Photo cells that activate the system when the light reaches certain levels  
• An electronic leaf to maintain a uniform level of humidity on the leaf surface

Mist beds may be on the ground or raised, preferably exposed to full sunlight and fenced to avoid the action of wind blowing away the fine spray of water.

**AIR LAYERING**

Air layering or marcotting has several advantages in that large plants can be produced quickly by relatively unskilled workers and with fewer operations than are required for budding or grafting. Also they can be brought into fruit production much quicker than budded or grafted trees or plants produced from seed.  

In air layering (see Figure 10), the branch to be propagated is girdled by removal of a ring of bark 25 to 38 mm in width. It is advisable to scrape the surface of the wood in the girdled area to remove the cambium, otherwise the area can heal over quickly and fail to make roots. The girdled area is then covered with a ball of sphagnum or coir dust which has been soaked in water and squeezed by hand. The wet sphagnum or coir dust is covered with a sheet of plastic tied at each end with twine or with a sheet of aluminium foil tightly twisted closed at both ends.

Callus and roots will form at the upper end of the girdled area in six to eight weeks. When the roots are well formed, the marcots are cut from the tree and either planted direct in the field or first planted in containers of soil and later set in the field.
The scion is the upper portion of the new plant and the lower portion is called the root stock.

**Grafting and Budding**

Grafting is the joining of parts of plants together in such a way that they unite and continue to grow as a single plant. The part of the plant that becomes the upper portion or top of the new plant is called the scion and the part which becomes the lower portion that includes the root is called the stock or root stock.

All methods of joining plants are called grafting but when the scion is a small piece of bark or wood containing a single bud, this form of grafting is called budding. Many different types of grafts are possible including veneer, cleft, arching, bottle, tongue, whip, and root grafting but only the veneer and cleft grafts are described, as well as the shield or inverted T-budding method.

Grafting requires experience and practice and the following six requirements to improve the performance of growers are recommended by the University of Florida Cooperative Extension Service:

1. The stock and scion must be compatible or they will not unite. Graft only closely related species or plant families such as Julie mango on Number 11 mango, and Jamaica mahogany on Honduras mahogany and not on teak or mahoe.
2. Cambial regions of scions and stock must be in intimate contact (see Figure 11). Cut surfaces should be held tightly for proper healing and flow of water and nutrients.

3. Grafting can be done at any time of the year but March through August is considered ideal if the stock and scion are at the right size and growth stage. Some months like May and October are however too wet and the scions show a tendency to rot unless special precautions are taken.

4. After grafting, all cut surfaces must be protected from dessication or drying out. This can be done by covering the graft area with wax or tape or some moist material like sphagnum moss.

5. Proper care must be given to the graft until it unites. Shoots from the stock must be removed as they can choke out the scion. Shoots from the scion can grow so vigorously that they break the scion off unless staked or tied.

6. The grafting knife should always be kept razor sharp during grafting operations.

Figure 11: Cambial regions of scion and stock must be in intimate contact.

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**Veneer Grafting**

For the veneer graft, the root stock should be in an actively growing condition and scions should be clean and free of disease and insects. Scions in which the terminal bud is just beginning to swell will give best results. Root stocks 6 to 12 months old with stem diameters of 6 to 25 mm (1/4 to 1 inch) are used in commercial nurseries for side veneer grafting mangoes.

Select a site for the graft where the root stock is straight and 30 cm (12 inches) or less from ground level (see Figure 12). The cut is made tangentially into and through the bark and just into the wood for a length of 5 to 8 cm (2 to 3
inches) cutting down in one motion parallel to the wood. A notch is formed with a separate horizontal cut at the lower end of the first cut in which the base of the scion will be placed. A slanting cut on one side of the scion is made, starting just below the terminal bud and continuing all the way to the base in one downward motion. A small wedge is made at the base on the opposite side of the scion to fit into the notch of the stock.

The scion is then placed in position so that the cambium of each piece joins as much as possible. A thick vinyl budding strip is securely wrapped around the stock and scion, starting from the bottom and working upwards over the terminal with enough overlap in each turn to keep out rain. The wrap is fastened by firmly looping the free end under the last turn. If the graft union is successful, new growth on the scion will begin in 2 or 3 weeks. The wrapping should be removed from the terminal as soon as growth starts and refastened just below the terminal. The vinyl strip may be removed after the first flush of growth has occurred and the rootstock partially cut back. The root stock may be cut off completely after the second flush. It should be trimmed in such a way as to leave no part of the rootstock above the union and buds and new growth on the rootstock should be removed as they appear.

**Cleft or V Grafting**

In Cleft or V grafting (See Figure 13) the top of the root stock is cut off square and a vertical cut made in the centre using a heavy knife or special grafting tool. The scion is made by cutting a long, gradually tapering wedge. Holding the split open with a screw driver or similar tool, one or two scions are inserted into the split so that the cambial layers are lined up with each other at least on one side or both sides in the case of small plants of equal size. Wrapping and subsequent care is the same as for veneer graft but the root stock does not require cutting back and hence wound healing is faster. Make sure the scion and buds are not upside down.
Shield or Inverted T-budding

Budding differs from grafting in that only a single lateral bud is used instead of a portion of a stem with several lateral buds as well as a terminal bud. The principal advantage in budding is that one terminal scion will furnish five or more buds for as many trees.

The shield or inverted T-budding method involves the use of a bud that is shield shaped and an inverted T-cut into the stock with the following steps (see Figure 14):

1. A vertical cut 4 to 8 cm (1-1/2 to 3 inches) long is made on the stock and a second horizontal cut is made at the bottom of the vertical cut.
2. The bud is prepared by cutting into the scion 13 mm (1/2 inch) or more above the bud and cutting downward, going under the bud and coming out well below it, leaving a long handle on the lower part which is cut off after the bud is inserted.
3. The shield can be 6 to 13 mm (1/4 to 1/2 inches) or more wide and 4 to 8 cm (1-1/2 to 3 inches) long with the bud being located in the centre.
4. The bark of the inverted T-cut is raised at the corners and along the vertical split to admit the shield.
5. The bud is forced into the cut and under the edges of the bark, being careful not to split the bark.

6. After insertion, the protruding handle of the shield is cut off with a horizontal cut at the bottom so that the shield can fit and slide completely into the cut made into the stock.

7. Buds are wrapped in 13 mm wide vinyl strips covering the bud completely.

8. Examine buds in two or three weeks and rewrap leaving the bud exposed if considered necessary.

9. Cut back top of root-stock gradually when bud begins to grow as well as any new growth below the graft.

Hints in collecting Budwood

- The best budwood comes from the second flush of growth from end of branch
- Budwood should be rounded with plump gray-green buds; trim leaves to very small stubs as budwood is cut from tree
- Some buds can be difficult to grow, and girdling the particular branch and removing all but three or four leaves two to three weeks before the buds are needed can help pre-condition the bud and hasten growth
MICROPROPAGATION

Sometimes referred to as tissue culture, micropropagation is a specialised method of mass production of seedlings in which very small pieces of plant tissue are regenerated in an artificial medium. Originally developed for ornamental plants, the technology has been extended to include forestry and fruit trees. Because of the high initial capital investment cost in laboratory and equipment and high salary and management costs, it is more economic to purchase such seedlings than to produce them.

The starting point for all tissue cultures is plant tissue or explant. This can be initiated from any part of a plant - root, stem, petiole, leaf or flower although the success of any one of these varies between species.

Pieces of plant tissue will slowly divide and grow into a colourless mass of cells if they are kept under special conditions which include:

1. The presence of a high concentration of auxin and other growth regulators in the growth media.
2. A growth medium containing organic and inorganic compounds designed to both sustain the plant cells, encourage cell division and control the development of either pale brown lumps called callus or as individual or small clusters of cells in a liquid medium called a suspension culture. These cells can be maintained indefinitely provided they are sub-cultured regularly into fresh growth medium.

For tissue culture to be successful, the parent must be healthy and free from obvious signs of decay or disease. The plants themselves must be actively growing and not about to enter a period of dormancy. It is essential the surface of the explant is sterilised to remove all forms of contamination. Since cell division is slow compared with the growth of bacteria and fungi, even minor contaminants will easily overgrow and destroy the plant tissue culture.

The exact conditions required to initiate and sustain plant cells in culture, or to regenerate plants from cultured cells, are different for each plant species. Each variety of a species will often have a particular set of cultural requirements. Despite all the knowledge that has been obtained about plant tissue culture, these conditions have to be identified for each variety through experimentation.


Chapter 7: Growing Media

Since the growth medium relates to every cultural practice in the production of nursery crops in containers, the selection and preparation of the medium is extremely important and will pay great dividends in terms of plant growth and quality. Several combinations of media with desirable physical, chemical and biological properties can be used but the goal should be consistency from batch to batch. The best soil to use will depend on the species and what is available. In general a sandy loam texture and moderate to slightly acidic reaction (pH 5.5 to 7.0) represents the most favourable condition for forestry and agroforestry nursery stock although slight variations may be necessary for certain species. The Caribbean pine, for example, grows best in acidic soils ranging from pH 4.5 to 6.0 whilst hardwood species prefer pH between 5.5 and 7.0. In very acidic or alkaline soils certain plant nutrients are either leached or become insoluble and therefore unavailable. Acid soils below a pH of 4.5 are low in exchangeable calcium and magnesium and lack most of the important plant nutrients like nitrogen, phosphorous, potassium, sulphur and some trace elements (copper, zinc and boron) with only iron and manganese being available. Bauxite soils at Williamsfield and Moneague fall into this group, necessitating the addition of large quantities of organic matter.

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

Raising and lowering the pH value. The pH value of soils can be raised by adding lime or a fertiliser that reduces acidity such as sodium nitrate or calcium nitrate. An alkaline or neutral soil can be changed by the application of acid forming fertilisers such as ammonium nitrate and urea. Care must be taken with these fertilisers not to over fertilise the seedlings.
GROWING MEDIA FOR PROPAGATION AND GERMINATION BEDS

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

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

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

GROWING MEDIA FOR TRANSPLANT BEDS

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

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

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

Figure 15: Two simple methods of screening soil.

**Growing Media for Container Seedlings**

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

The following range of organic material has been used irregularly in mixture with soil to produce the growing media for containers in forest nurseries: animal manures, bagasse, chicken litter, coffee waste, coir dust, saw dust, sludge mostly in the form of compost or partially composted material, and commercial organic matter (‘Bioganic’).

The use of one or more of the above has been influenced by cost and availability and over the years, results have been variable. Since future supplies of any of the above materials are likely to continue to be erratic, every effort should be made to develop self-reliance for this component in seedling production. In the absence of research data to confirm the most suitable organic material, below are some points that should be borne in mind in developing Departmental capability:

1. Material should have a high fibre content to provide internal water holding capacity (small pores) and yet allow for drainage between particles (large pores). Peat and sphagnum moss and sifted compost are good examples.
2. If the material appears oily when wet or is slick rather than fibrous when rubbed between fingers, it is unsuitable for container grown plants.
3. Sufficient pore space within which air can be trapped as roots need oxygen for development and growth.
4. Ability to mix intimately with soil.
5. Ability to bind or hold applied substances such as fertilisers.
6. Should not be a source of fungi, insect pests or weed seeds.
7. Should be sufficiently decomposed as otherwise there may be ammonia damage to roots and foliage or an initially high demand for nitrogen by microorganisms which will induce a nitrogen deficiency in plants growing in comparatively fresh material.

Compost

If sufficient organic raw material is available, compost with the above characteristics can be produced at the nursery site or at a central location. For this reason and in view of its important role in container seedling production, it is mandatory for each nursery to produce at least some of its own compost needs on a continuing basis (See Appendix 2 for notes on How To Make...
Compost). A central shredder close to a source of fibre from which sustained amounts could be transported to nurseries would facilitate this activity. In addition to the organic materials already mentioned, the following raw materials are also suitable for making compost and should be more easily available on a sustained, self-reliant basis:

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

**Mixing the Growing Media**

With the availability and common usage of such a wide range of organic substances and soil types it is difficult to prescribe an ideal mixing formula. The proportion of soil to compost on a volume to volume basis can range from 1:1 to 3:1. The addition of sand should be unnecessary except with particularly heavy soil.

Assuming that the soil and organic material are on the site free of weeds, weed seed, fungi and insects and is sieved into a uniform and acceptable particle size distribution, the nursery operator must take steps to ensure that quality is maintained.

Some hints for maintaining quality media are:

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

To mix soil and compost:

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

**MEDIA COMPACTION IN POTS**

Filling the container with the growing media is an important process because poorly distributed media can negate the beneficial cultural practices of even the best growing media. Under compaction can cause problems but is often ignored. It results in seedlings growing in half or partially filled bags which are small enough as it is and with roots forced to exit containers or become deformed at an early stage.

Over compaction can have several effects on the physical, chemical and biological properties of a growing medium. Although total porosity is naturally less in compacted media, the more important effect is the reduction or elimination of the large pores that control aeration and drainage. Media compaction is difficult to assess because of the small container sizes used and there is no precise technique available for measuring it. Containers that are unusually heavy should be suspect. The medium in properly filled containers should still feel springy to the touch.

The symptoms of over compaction on tree seedling growth are often subtle and difficult to diagnose. They include foliar chlorosis, leaf drop, root browning and eventual death. Because it affects root function, the initial symptoms of root compaction can mimic drought stress, over watering or even mineral nutrient deficiency since roots may malfunction.
Multiplying

Mulching means covering the soil surface in bare root beds or individual seedlings with a 5 to 10 mm layer of organic matter. Mulching can provide protection from heavy rain and water splash and it reduces evaporation of soil moisture. In dry localities, the presence of mulch on the surface of transplanted seedlings is a great help in reducing the amount of water required and reduces the tendency for the surface to become muddy or compacted. Like a sponge, a mulch can quickly absorb plenty of water which then passes slowly into the soil. In very wet situations, it can be harmful by reducing aeration and increasing the risk of damping off, insect damage and over watering.

Mycorrhiza

The potted media needs to be inoculated with symbiotic fungi to provide mycorrhiza which is essential in the production of healthy Pinus caribaea seedlings and for their subsequent growth in the field. In the absence of mycorrhiza, pine seedlings exhibit slow, irregular growth and obvious signs of chlorosis.

The easiest method is to obtain soil and humus containing the inoculant from under stands of pine in plantation forests. If large annual amounts are required, the nearby forest soon takes on the appearance of a mini mined out area. One alternative is to establish what has been described as a mycorrhiza bank or bed at a convenient location at the nursery site. The process involves:

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

6. The size of the bed or beds will vary with demand and can be based on a ratio of one tablespoon of infected soil to three standard size bags of potting soil and added to the growing medium when it is being mixed with the organic matter.
Chapter 8: Nursery Records

Nursery records are valuable documents which should be compiled with due care and attention. They provide particular kinds of information for the nurseryman, the forester, the silviculturist and the economist. The details required vary according to the size of the nursery, but whether the nursery is small or large, good records provide the information necessary for task allocation and for monitoring the efficiency of the day to day operations. The long-term records provide the basis for reviewing the success or otherwise of the nursery methods employed.

The efficiency of a nursery can be judged by its productivity and its costs of production. The nurseryman is required to produce the required number of healthy, vigorous seedlings at the correct time and at reasonable cost. Neither of these can be achieved unless plans are made well in advance and these can only be done effectively by reaching back into the past records to study and compare what has gone on before. It will not be possible to calculate the unit cost of individual operations until the input of labour and materials and the output of work and products are quantified. The cost of plant production is based solely on recurrent labour and materials and need not include capital costs of establishment nor allowance for depreciation of buildings and equipment. These refinements can be developed at Head Office.

Types of Records

The following are the most important records that should be kept to ensure the efficient management of a permanent nursery.

Nursery Calendar: Nursery calendars are helpful tools in scheduling necessary activities such as sowing dates and the purchase of supplies and materials. The date for sowing seeds, for example, can be calculated by counting backwards from the anticipated date of planting, taking into consideration the number of days needed for germination and further seed development until the right stage for planting in the field (see example in Table 1). Seedlings for drier sites may need more time for hardening and customers may need to be reminded of this when placing orders. Also different species grow and mature at different rates and this will influence timing of delivery and expectations from the Head Office.
Some nurseries prepare a second type of calendar to show, on a monthly basis, the more important nursery activities such as dates for bed construction, preparation of potting soil, start of compost production, sowing, weeding, repairs to nursery and the timing of annual staff leave. Table 2 is an example of this type of calendar.

**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 store 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 2003 would be No. 1/03, the second lot No. 2/03 and so on. The first lot in year 2004 would be No. 1/04. These numbers in conjunction with the species name are sufficient to identify any particular batch of seed or plants in the nursery. When seed is received from Head Office, it already should have an identity number and this is retained for identification purposes as well. 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 Table 3.

Further details can be written on the reverse side or on additional lines showing, for example, the type of fertiliser and fungicide and the dates of application.
Table 2: Example of a Calendar of Nursery Activities on a monthly basis

<table>
<thead>
<tr>
<th>Month</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>Clean nursery</td>
</tr>
<tr>
<td></td>
<td>Repair/construct seed beds, buildings</td>
</tr>
<tr>
<td></td>
<td>Clean and repair water supply</td>
</tr>
<tr>
<td></td>
<td>Repair plant trays</td>
</tr>
<tr>
<td></td>
<td>Review production programme</td>
</tr>
<tr>
<td></td>
<td>Seed supplies: check if supplies have arrived</td>
</tr>
<tr>
<td></td>
<td>Plastic bags: check on stock</td>
</tr>
<tr>
<td></td>
<td>Work force required: plan labour requirements by operation</td>
</tr>
<tr>
<td></td>
<td>Holiday period for workers</td>
</tr>
<tr>
<td>February</td>
<td>Continue work from January</td>
</tr>
<tr>
<td></td>
<td>Start making compost</td>
</tr>
<tr>
<td></td>
<td>Holiday period for workers</td>
</tr>
<tr>
<td>March</td>
<td>Prepare potting soil</td>
</tr>
<tr>
<td></td>
<td>Prepare sowing soil</td>
</tr>
<tr>
<td></td>
<td>Obtain poles for shade cloth</td>
</tr>
<tr>
<td></td>
<td>Level areas for transplant beds</td>
</tr>
<tr>
<td></td>
<td>Monitor compost production</td>
</tr>
<tr>
<td>April</td>
<td>Prepare seed bed and transplant covers</td>
</tr>
<tr>
<td></td>
<td>Start pre-germination tests</td>
</tr>
<tr>
<td></td>
<td>Prepare transplant sites</td>
</tr>
<tr>
<td></td>
<td>Sieve compost if ready</td>
</tr>
<tr>
<td></td>
<td>Prepare potting medium</td>
</tr>
<tr>
<td></td>
<td>Start filling plastic bags</td>
</tr>
<tr>
<td>May and June</td>
<td>Start sowing seed (over 4 week period)</td>
</tr>
<tr>
<td></td>
<td>Check germination (week 2) and revise seed estimates to achieve planting goal</td>
</tr>
<tr>
<td></td>
<td>Transplanting begins</td>
</tr>
<tr>
<td>July</td>
<td>Transplanting completed (2nd week)</td>
</tr>
<tr>
<td></td>
<td>Weeding commences</td>
</tr>
<tr>
<td></td>
<td>Check plants for vertical position</td>
</tr>
<tr>
<td>August</td>
<td>Reduction of watering commences (mid-August)</td>
</tr>
<tr>
<td></td>
<td>Root pruning commences</td>
</tr>
<tr>
<td></td>
<td>Last month to order supplies for next year's campaign: seeds; plastic bags; replacement tools; fertilisers; chemicals</td>
</tr>
<tr>
<td>September</td>
<td>Check transport boxes</td>
</tr>
<tr>
<td></td>
<td>Hardening off process continues</td>
</tr>
<tr>
<td></td>
<td>Root pruning continues</td>
</tr>
<tr>
<td></td>
<td>Repair access roads to nursery</td>
</tr>
<tr>
<td></td>
<td>Selection/grading process starts</td>
</tr>
<tr>
<td>October</td>
<td>Removal of plants begins</td>
</tr>
<tr>
<td></td>
<td>Hardening off continues</td>
</tr>
<tr>
<td>November and December</td>
<td>Removal of plants begins</td>
</tr>
<tr>
<td></td>
<td>Hardening off continues</td>
</tr>
<tr>
<td></td>
<td>Reduce watering to minimum</td>
</tr>
<tr>
<td></td>
<td>Last month for removal of plants (November)</td>
</tr>
<tr>
<td></td>
<td>Finalise annual report</td>
</tr>
<tr>
<td></td>
<td>Clean up of nursery commences</td>
</tr>
</tbody>
</table>
It is also important to record the exact location in the field to which each and every seed lot has been sent. This is important because the genetical aspect of seed sources is recognised as an important matter and identity should follow seed lots through the nursery into compartment registers in other locations in order to facilitate future improvement.

**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 Head Office in good

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**Table 3: Example of a Seed and Plant Identification Record**

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mahoe</td>
</tr>
<tr>
<td>Identification number</td>
<td>2/02</td>
</tr>
<tr>
<td>Date sown</td>
<td>1. 14/2</td>
</tr>
<tr>
<td></td>
<td>2. 4/3</td>
</tr>
<tr>
<td>Quantity sown</td>
<td>1. 1 kg</td>
</tr>
<tr>
<td></td>
<td>2. 550 g</td>
</tr>
<tr>
<td>Method of sowing</td>
<td>broadcast</td>
</tr>
<tr>
<td>Date of first germination</td>
<td>7/3/02</td>
</tr>
<tr>
<td>Date of last germination</td>
<td>21/3/02</td>
</tr>
<tr>
<td>Number germinated (%)</td>
<td>80</td>
</tr>
<tr>
<td>Date transplanted</td>
<td>10-16/4</td>
</tr>
<tr>
<td>Number transplanted</td>
<td>4,000</td>
</tr>
<tr>
<td>% dead after 2 months</td>
<td>8</td>
</tr>
<tr>
<td>Culls/rejects</td>
<td>160</td>
</tr>
<tr>
<td>Number distributed</td>
<td>1,800</td>
</tr>
<tr>
<td>Remarks</td>
<td></td>
</tr>
</tbody>
</table>
time if seedlings are under or over produced so that remedial action can be taken promptly. It should therefore be prepared in a tabular form, suitable for collection and analysis using the Department’s computer network. Table 4 shows an example of a Nursery Production Record.

Table 4: Example of a Fortnightly Nursery Production Record

<table>
<thead>
<tr>
<th>Fortnight Ending:</th>
<th>Nursery:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of plants for potting</th>
<th>No. of weeks before ready to plant out</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not ready</td>
<td>Ready</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td>------</td>
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<tr>
<td>---------</td>
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</tbody>
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**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 bits of tin or metal which are fixed to pieces of wood in each bed or batch of seedlings giving the nursery the semblance of an untidy cemetery. One alternative is to fold the identification by rolling it so that it can fit into the hollow joint of pencil size bamboo which can fit into another joint so that both ends are closed. The action is similar to that of replacing the cap of a ball point pen. The bamboo with the seed data is kept in the first row of a particular batch of seed or transplants so that it can easily be consulted on the spot when necessary. Labelling transplant beds in this way should not replace the nursery records kept in the office.
Appendix 1: Common Errors Found in Tree Nurseries

Containers not filled properly:
After a short period, the growing media settles leaving space at the top, exposing roots. The top of the bag folds inwards and consequently during irrigation, insufficient water reaches the seedling.

Cylindrical shape of container not maintained:
If the plastic bags take on different shapes in the transplant beds, each seedling will not receive the same optimum space for growth and light.

Container not in upright position:
Plastic bags not placed in an upright position is one of the causes of stem curvature.

Soil or sand used in germination beds not changed after each production cycle:
Using the same germination media each year increases the risk of attack from damping off fungi. Preventive methods are more effective than control.

Sowing seed too deep:
This is often done to avoid the washing out or displacement of seed by rain or heavy watering and results in unequal germination or low germination percent.

Lifting transplant seedlings individually and wrenching them:
Transplant seedlings should be lifted carefully in groups with the aid of a wooden knife to avoid destruction of the young tender roots and root hairs.

Exposure of seedlings to air after lifting:
Exposure to air for longer than ten seconds can cause unnecessary wilting and delay normal seedling growth.

Handling transplant seedlings by root or stem or at root collar:
Always hold seedlings by the foliage to avoid physical damage caused by abrasive dirty fingers to delicate roots and stems.

Bad transplanting:
If principal or secondary roots are bent upwards, intertwined or benched, a poor quality seedling will be produced with undesirable roots.
Leaving air space around the root of the young seedling after transplanting:
Roots lack contact with soil and are unable to fulfil function of water and nutrient uptake resulting in wilting, slow recovery and sometimes death.

Bad root pruning while transplanting:
Nursery workers use their fingers and fingernails to cut back long roots during transplanting. In doing so they squeeze the roots between their fingers, damaging them. Roots should be cut with a sharp knife.

Uneven transplant container beds:
Water collects in depressions causing chlorotic symptoms and stunted growth.

Same knapsack sprayer used to apply weedicides and fungicides:
Large quantities of seedlings have been killed by this practice even with thorough washing.

Inadequate attention paid to root pruning in transplanted containers before transporting to field:
Insufficient time available for the seedling to recover from shock and seedling will wilt at the planting site.

Hardening off process starting too late or neglected:
Do not wait until the last week or two to start this operation as seedlings will not have had sufficient time to adjust to the harsher environment in the field. The rains will also have started and controlling water reduction at this time will be difficult.

Dispatch and transport of plants not properly done:
Often plants are lifted by their stems when loading and unloading vehicles and when transporting to the planting site. Never lift plants by the stem. Boxes or crates should be provided for the purpose.

Too many trees in the nursery:
Tall trees give unnecessary shade, harbour insects and other pests and make it difficult to achieve a good hardening process.

Bad storage of plants near planting site:
Try to avoid leaving plants in the shade without water for long periods after they leave the nursery. Remember that bad handling and poor care after seedlings leave the nursery often destroys in a few days all the skill and care taken by nursery workers during the previous 3 to 4 months.
COMPOST IS A VERY VALUABLE ADDITION TO ANY SOIL AND IS PARTICULARLY USEFUL IN NURSERIES WHERE THE AVAILABLE SOILS ARE EITHER TOO SANDY OR TOO HEAVY AND OF LOW QUALITY. IT HELPS TO BUILD A GOOD SOIL STRUCTURE, IMPROVES WATER HOLDING CAPACITY OF THE SOIL AND PROVIDES NUTRIENTS FOR PLANTS. IT GREATLY REDUCES THE NEED FOR CHEMICAL FERTILISERS AND, WHEN MIXED WITH SMALL AMOUNTS, DILUTES THE FERTILISER, MAKING IT AVAILABLE IN MUCH LARGER USEFUL QUANTITIES. IT IS THEREFORE AN ECONOMIC WAY OF USING AVAILABLE CHEMICAL FERTILISERS AND IS ITSELF A NATURAL FERTILISER, VERY SIMILAR TO HUMUS.

COMPOSTING IS THE PHYSICAL AND CHEMICAL BREAKDOWN OF ORGANIC MATERIAL BY INSECTS, FUNGI, AND BACTERIA THAT DIGEST THE MATERIAL DURING THE DECOMPOSITION PROCESS. THE TWO BASIC WAYS IN WHICH THIS IS DONE ARE DESCRIBED AS **ANAEEROBIC** AND **AEROBIC**. ANAEROBIC METHODS SUPPLY MINIMUM OXYGEN TO THE MICRO ORGANISMS THAT DIGEST THE ORGANIC MATERIAL AND IS A MUCH SLOWER PROCESS, TAKING PERIODS OF UP TO 8 MONTHS OR LONGER. THIS IS BECAUSE THE SYSTEM UTILISES DEEP PITS FILLED WITH ORGANIC MATERIAL WHICH ARE USUALLY COVERED AND LEFT UNATTENDED. UNDER THESE CONDITIONS, IT IS NOT UNUSUAL FOR FOUL SMELLING GASES SUCH AS METHANE AND SULPHUR TO DEVELOP AND POLLUTE THE SURROUNDING AREA.

THE AEROBIC METHOD RELIES ON A SUPPLY OF OXYGEN AND CAN BE READY FOR USE IN TWO MONTHS ALTHOUGH A 4 MONTH PERIOD IS CONSIDERED AVERAGE. HANNAH JAENICKE IN HER BOOK, _PRACTICAL GUIDELINES FOR RESEARCH NURSERIES_, IDENTIFIES THREE PHASES BASED ON TEMPERATURE DURING AEROBIC COMPOSTING AND DESCRIBES THEM AS FOLLOWS:

"DURING THE FIRST 24 TO 48 HOURS, THE TEMPERATURE IN THE HEAP RISES TO 40 TO 50°C, DESTROYING SUGARS AND OTHER EASILY BIODEGRADABLE SUBSTANCES. DURING THE SECOND PHASE, AS THE TEMPERATURE RISES TO 55 TO 60°C, THE INITIAL MICRO ORGANISMS DIE AND OTHERS SPECIALY ADAPTED TO THE HEAT BEGIN TO BREAK DOWN THE MORE DIFFICULT MATERIAL LIKE CELLULOSE, A COMPONENT OF WOODY STEMS. THE TEMPERATURE SHOULD REACH A PEAK OF 70°C FOR THREE DAYS TO KILL ALL WEED SEEDS AND PLANT DISEASES. KEEPING THE TEMPERATURE BETWEEN 55 AND 65°C FOR AS LONG AS POSSIBLE IS THE FASTEST WAY TO PRODUCE COMPOST BECAUSE THIS IS THE PHASE WHEN THE MOST EFFICIENT MICRO ORGANISMS ARE BREAKING DOWN THE HARDEST TO DIGEST MATERIAL. TURNING THE PILE TO INCORPORATE OXYGEN AND TO ENSURE AN EVEN DISTRIBUTION OF THE MATERIALS AND MAINTAINING 40 TO 60 PERCENT MOISTURE ALLOWS FOR OPTIMAL COMPOSTING EFFICIENCY. THE FINAL STAGE IN WHICH THE TEMPERATURE REMAINS BELOW 40°C IS CALLED MATURING OR CURING BECAUSE THE BACTERIA AND FUNGI THAT HELP CONTROL PLANT DISEASES AS WELL AS THE LARGER ORGANISMS LIKE EARTHWORMS, MOVE IN."
The leaves of seedlings planted with unfinished compost usually turn yellow because the plant cannot acquire all the nutrients it needs whilst the immature compost continues to absorb what little nitrogen that might be available. To see whether compost is ready, place two moist handfuls in a plastic bag and seal it leaving it in a dark cool place. After 24 hours, open the bag. If no odour or heat is present, the compost is ready. The original material such as a leaf or orange peel should be unrecognisable with the consistency and colour of coarsely ground coffee. The compost can then be sifted and large particles returned to the next compost batch.

**Suitable Ingredients:** Compost can be made from most organic materials like grass, leaves, small branches, rice husks, coir dust, bagasse, pulped coffee residues and a mixture is best. One should avoid using woody branches, hard pods and any material that does not break down easily. Dead or rejected seedlings and weeded material from nurseries often make good compost if there is no danger from disease and insect pests. Adding fertiliser may speed up the process and improve its nutrient content but is not necessary and defeats the purpose of producing a cheap fertiliser substitute. The addition of thin layers of rich top soil and or farmyard manure to the first phase and earthworms in the last phase will also prove useful but is not essential.

A small wood lot planted close to the nursery with species that coppice readily such as *Gliricidia* (quickstick), *Erythrina* or *Acacia auriculiformis* can be established to provide a steady cheap supply of raw material as required.

**Compost Production System:** Several closely related methods and modifications have proved successful but the following ‘three bed system’ is recommended (see Figure A2):

1. Collect ingredients and store excess material in the open since dried material is better.

2. In a flat area, make three rectangular foundations (3 metres long x 1.5 metres wide or of convenient size) side by side using concrete blocks, bricks, or wooden beams. Allow 1 metre between the rectangles as a path for working.

3. On top of this foundation, construct a flat bed with bamboo, wood, metal poles or chicken wire. If coconut or thatch fronds are used, be sure to leave enough cracks and holes for air to pass through and circulate. Choose a material that will not rot too quickly. If discarded wooden pallets are available they can be used for this purpose or laid directly on the ground avoiding the need for the block or brick foundation.

4. Pile organic matter to about 1 metre high on the two outer beds leaving the middle bed empty. Keep the beds flat, not pointed like a pyramid. If top soil or farmyard manure is to be
added, it should be spread thinly on top of the pile and a second layer of organic matter placed above. With or without the added top soil, the pile should become warm in about 14 days.

5. After a month to 6 weeks, carefully move the material from the two piles to the empty centre bed starting from the outside of each pile. This mixes the pile, putting the material from the outside into the inside of the pile. After a week, the compost in the centre pile should become warm again.

6. The two outer beds are ready to be filled again with fresh material as soon as the piles have been moved to the central bed.

7. Always monitor the moisture status of the pile. Add water when dry or build a roof if there is too much rainwater. Keep the pile well aerated and moist at all times. Use a plastic sheet, coconut leaves or other covering over the pile to conserve water if the days are hot.

8. After 3 to 4 months the compost in the middle pile should be moved to a storage area. This allows it to mature and be available for use when required.

Figure A2: The ‘three bed system’ to make compost.
Notes
APPENDIX 3: USEFUL TOOLS AND EQUIPMENT

Axes
Balance (grams)
Balance (kg)
Bar, crow
Barrows, wheel
Benches, wood or metal (for sitting)
Boots (rubber)
Boxes, plant transport
Brooms
Buckets, plastic
Cans, watering
Containers, measuring
Containers, seed storage
Containers, for germination
Containers, for loading seedlings
Cutlasses
Cutters, wire
Drums, 10 litres
Files, sharpening
First aid kits
Forks, digging
Funnels, plastic
Ground cover, polypropylene
Hammer, nails
Hoes
Hoses
Irrigation system
Knives, hand pruning
Knives, budding
Labels, plastic
Lamps
Lens, hand
Levels, carpenter’s
Machine, calculating
Masks, respiratory
Mattocks
Nozzles, heavy and mist spray
Pencils, drawing
Pencils, marking
Pens
Pipe repair kit
Pliers, cutting
Rakes, garden
Refrigerator
Rose heads, watering cans
Rule, carpenter’s
Saw, bow
Saw, hack
Scissors
Screwdrivers
Secateurs
Shears, root pruning
Sharpeners, pencil
Shovels, shredder, biomass
Spanners, adjustable and fixed
Sprayers, knapsack
Sticks, height measuring
Sieve, 6 mm
Tables, potting
Tanks, water
Tape, 50 ft
Tape, budding, grafting
Notes
## Appendix 4: Sources of Nursery Supplies

The following is a list of local firms from which nursery supplies and irrigation equipment can be purchased.

<table>
<thead>
<tr>
<th>Name of Firm</th>
<th>Polyethylene Bags</th>
<th>Plastic Containers</th>
<th>Insecticides</th>
<th>Fungicides</th>
<th>Herbicides</th>
<th>Ground Cover</th>
<th>Shade Cloth</th>
<th>Growing Medium</th>
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Indicates item is stocked by supplier
References


McDonald, B. Practical Plant Propagation for Nursery Growers. 1986

Schmidt, L. Guide to Handling of Tropical and Subtropical Forest Seed. DANIDA Forest Seed Centre. 2000.

