NURSERY MANUAL

SITE SELECTION, LAYOUT, DEVELOPMENT PLANNING, PRODUCTION AND MANAGEMENT

PROJECT MANAGEMENT UNIT

WEST BENGAL FOREST & BIODIVERSITY CONSERVATION SOCIETY

Foreword

The present volume on Nursery Selections, Layout Development, Planning, Production and Management techniques is an attempt to standardize the Central Nurseries Management and tree planting efforts within the State.

The West Bengal Forest Department (WBFD) has decades of experience on the subject, both empirical and through research findings and is very advanced in know-how. This manual intends to standardize procedures for production of Quality Planting Material (QPM) in the State.

This manual has been prepared by the Project Management Consultant in consultation with the Project Management Unit of JICA assisted West Bengal Forest and Biodiversity Conservation Project. A high level Technical Committee constituted by the Principal Chief Conservator of Forests, and Head of Forest Forcehas edited & approved the Manual.

The technologies recommended have been decided upon during a series of meetings with the Principal Secretary Forest Department, Government of West Bengal, the Principal Chief Conservator of Forests and Head of Forest Force, West Bengal, the Principal Chief Conservator of Forests Research, Monitoring and Development, West Bengal and a number of senior and field officers of the Directorate of Forests.

Recommendations regarding materials and techniques have been liberally taken from past research records of the Research wing of the Forest Directorate and other sources and adapted for present use.

(S.Barari)
Chief Project Director
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14th July,2016

Acknowledgements and thanks

The consultant would like to use this place to express his thanks and appreciation for the cordial reception, patience and efforts made by Dr. Subesh Kumar Das, ex-Addl. Chief Secretary Forest Department, Govt. of West Bengal, Shri C. Sinha, Principal Secretary, Deptt. Of Forests, Govt. of West Bengal, Shri P. Shukla, Principal Chief Conservator of Forests and Head of Forest Force, West Bengal, Shri S.B. Mondal, ex-Principal Chief Conservator of Forests and Head of Forest Force, West Bengal, Shri N.C. Bahuguna, ex-Principal Chief Conservator of Forests and Head of Forest Force, West Bengal, Sri P. Vyas, Principal Chief Conservator of Forests, Wildlife & CWLW, West Bengal, Sri N.K. Pandey, Principal Chief Conservator of Forests, General, West Bengal, Sri R.R. Pandey, Ex-Principal Chief Conservator of Forests Research, Monitoring and Development, West Bengal, Sri S. Dhaundyal, Managing Director, WBFDC Ltd., Sri R. K. Mahtolia, Principal Chief Conservator of Forests Research, Monitoring and Development, West Bengal, Sri S. Barari, Chief Project Director, WBFBC Project, Dr. P. T. Bhutia, Addl Principal Conservator of Forests, North, Sri V.K. Yadav Member Secretary, W.B. Zoo Authority, Sri S. Chaudhuri, Project Director, M&E, WBFBC Project and the forest officers of the districts of Bankura, Burdwan, Purulia, Birbhum, Paschim Medinipur, Darjeeling and Jalpaiguri. Together they succeeded in providing the needed insights and directives for the production of this volume making this exercise well organized, efficient, pleasant and enlightening.

Thank you again for your hospitality, patience and support.

J.P. van Kooijk,
Team Leader and
Forestry Specialist PMC
14th July, 2016

WBFBCP

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Site Selections, Layout and Development.

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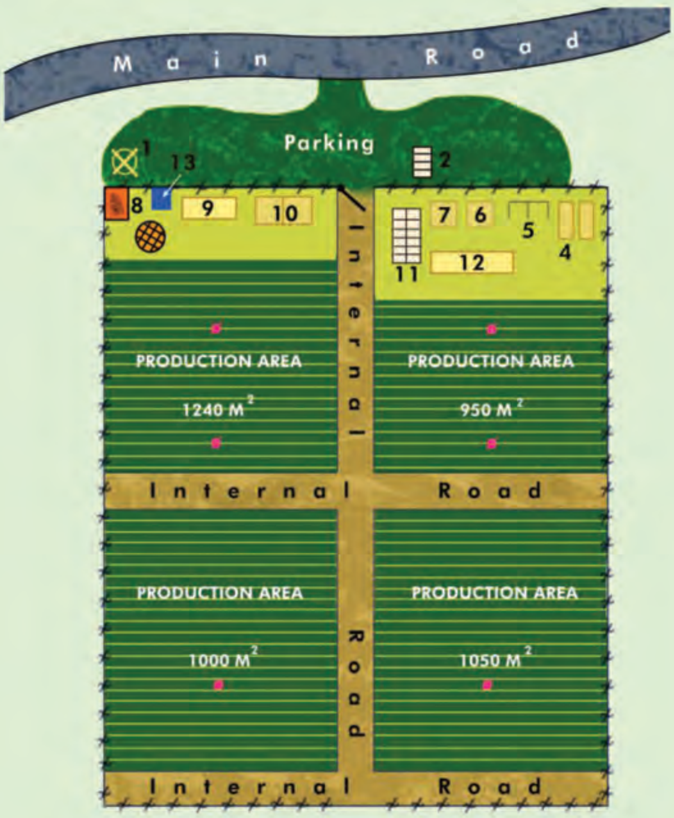


Project Management Unit

West Bengal Forest and Biodiversity Conservation Project

2.1 Introduction

In the following chapters, criteria and prescriptions have been given for site selection, layout and development for the new Central Nurseries for the state of West Bengal. Most of these recommendations can also be followed for the planned increase of existing nurseries' production capacity and their improvement.

Since most of the potential nursery sites are not ideal, site selection inevitably requires suitable adjustments. Since the Quality Planting Material (QPM) will be grown in containers in the Central Nurseries, local soil characteristics are less relevant and the following selection criteria may be adhered to:-

1) Proximity of the potential site to Range office, Beat office, Forest Rest House or any other forest establishment.

2) Proximity to (center of) future out-planting areas.

3) Accessibility.

4) Proximity to services.

5) Good water supply (both quantity and of reasonable quality).

6) Reasonably flat topography providing natural drainage.

7) No flooding risk.

8) No erosion risk (protect with grassed waterways up-slope or build terraces in hill areas).

9) Space for future expansion.

Potential sites should be visited and evaluated and the best site chosen. A development team should then lay out the nursery, formulate an action plan, and document current development and possible future expansion in a comprehensive master plan. Careful site selection and planning plus proper management are essential to the economical production of high quality nursery stock.

Ideally several member strong team should be designated to select a nursery site.

- The team should develop site-selection criteria and establish priorities, then visit and evaluate possible sites on the basis of the chosen criteria, and finally select the best site.
- A development team should lay out the nursery, formulate an action plan, and then document nursery-site development in a flexible but clearly defined master plan.
- Possible future expansion of facilities and staff must always be considered.

- A perfect nursery site does not exist; tradeoffs are inevitable, but nursery efficiency and quality of seedlings produced should not be compromised.
- Wise planning and thoughtful decision-making, plus proper management, are essential for the economical production of high-quality nursery stock for reforestation.

2.2 Site selection

The basic objective of any nursery operation is to modify the natural environment so that plants can be produced quickly, efficiently, and economically. Container nurseries offer the potential for considerable environmental modification, but both development and operating costs increase with the degree of modification. A successful container nursery must therefore be carefully matched to the environmental conditions on the site; a nursery designed for one site will not necessarily be best for another. As the nurseries will be Target oriented (out-planting survival rate and post planting tree development) nursery developers must analyze the climatic environment at each potential site by critically evaluating both short-term and long- term weather records as well as through direct observation and compare these with climate data of future planting sites. Nursery developers should be prepared to devote a substantial amount of time to site selection because many biological and operational problems that develop later in nurseries can be traced back to problems with the selected site. Nursery sites that are selected mainly for economic or political reasons frequently fail to meet some of the more critical criteria, and these deficiencies limit the success of the nursery. Biological site selection criteria should always be paramount, but potential nursery developers must also consider out-planting realities. The things to look for in a potential container nursery site can be divided into critical factors and desirable factors (table 1).Critical site selection criteria are those factors that are essential to a successful nursery operation. Desirable attributes include those site factors that are not absolutely necessary but will increase the economy and efficiency of the nursery operation.

Table 1Site selection criteria for container tree nurseries

Critical factors	Secondary factors
Close to forest establishments	Protected microclimate
Solar access	Gentle topography
Good water supply	Seasonal labor supply
Reliable energy	Accessibility
Adequate land area	Distance to out-plant area

2.2.1 Critical Site Selection Criteria

2.2.1.1 Climate

Climate should be the same as the Target Area for out planting.

2.2.1.1.1 Precipitation

High rainfall areas are best avoided and if this proves impossible should be taken into account during the nursery design phase regarding roads, foot paths, nursery platforms and drainage lay out. However, the season in which the precipitation occurs is important. Heavy spring rains can delay spring operations such as adding soil amendments or sowing tree seed. Summer rains tend to be a problem only when they occur as cloudbursts and result in flooding, erosion, or seedling wash-out. Frequent summer rains may be detrimental, because rains may disrupt stock hardening processes already induced by withholding irrigation. Areas with heavy winter rains will result in saturated nursery soil to the point of hindering movement of materials, lifting, movement of personnel and causing flooding and erosion.

2.2.1.1.2 Wind

Areas with frequent, long-lasting, high-velocity winds, particularly where humidity is low should be avoided. Winds will affect irrigation application and uniformity and may result in soil movement. High winds can desiccate seedlings, and soil carried by winds can blast stems and foliage. Wind can restrict spraying of pesticides, cause tree-seed cover to be blown away, and displace or scatter seedbed mulches. In sites with a risk of high wind velocities, double semi-permeable wind breaks should be planted along the nursery's entire length (or all around the nursery) outside the nursery grounds and perpendicular to the predominant high velocity wind direction.

2.2.1.1.3 Unobstructed solar access

It cannot be stressed enough that nursery sites must be selected in areas with the same climate as the targeted out-plant areas. Similarly it should go without saying; container tree nurseries must be located on sites with good solar access, both throughout the day and during the growing season. It is usually considered uneconomical to supply enough light energy for photosynthesis, and so container nurseries must be located where they receive full sunlight for almost all of the solar day. Any amount of shading will decrease productivity and increase costs and, if or when necessary, can be easily supplied with agro-netting during the short periods of plant development before the hardening off. This is most critical in perennially cloudy climates of our hill divisions but also applies to tropical sunnier locations; because it is relatively easy to provide the shading if it is required. Growing areas must not be affected by shade from surrounding trees or buildings. If crops are to be grown year-round, the solar angle should be determined for all seasons to ensure that the growing area will always receive full sunlight. To this end it is recommended that, as a general rule, nurseries should be located at a distance that is at least 2.5 times the height of any object to the east, west, or south. Shelterbelts on the north side can be relatively close as long as falling leaves and litter are not a problem.

2.2.1.2 Soil

Soil characteristics or quality are not a critical site selection criterion as long as it is firm or can be made firm after removing the topsoil and compacting. Containers are typically filled with a growth medium consisting of a mix of sand, vermiculite or perlite and organic materials such as compost, composted coir, dry cow dung etc. and not grown in the ground as is the case with bare root production. (*Potting media has been dealt with in Central Nursery Manual- Planting, Production and Management.*

2.2.1.3 Supply of water

Next to sunlight, a reliable supply of quality irrigation water is the most important site selection factor. Relatively large amounts of water are needed by the seedlings themselves and also for regulating the temperature of the growing environment. Container seedlings have very low moisture reserves, which are limited by the volume of the container and the moisture holding properties of the growing medium, so seedlings must be irrigated frequently. In hot climates, water is also essential for evaporative cooling. In cooler climates, growers may need to use irrigation water during the early spring or late fall for frost protection of seedlings in open growing compounds.

2.2.1.3.1 Water quality

For nursery site evaluation purposes, irrigation water quality is determined by two factors: suspended particles (sediments or pests) and dissolved salts.

2.2.1.3.1.1 Suspended sediments

Inorganic materials such as clay, silt and even very fine sand particles are small enough to remain suspended and must be mechanically filtered or removed by chemical treatments. Suspended sediments are abrasive and can quickly wear out water pumps, fertilizer injectors, and sprinklers.

2.2.1.3.1.2 Pests

Water from surface sources, especially ponds in agricultural areas can contain propagules of potential nursery pests, which may include weed seeds and spores of fungi, algae, mosses and liverworts. Specially designed filters can remove the larger pests, including weed seeds, algae, and some fungal spores, but the cost of the filters increases as the minimum pore size decreases.

2.2.1.3.1.3 Dissolved salts

Many different mineral ions can be dissolved in potential irrigation water, and even perfectly clear water can contain harmful salts. In coastal areas, potential nursery sites can have its groundwater contaminated by saltwater intrusion during water extraction from tube wells. In such areas adequate supply of sweet water has to be ensured.

2.2.1.3.1.4 Testing water quality

On-site observations Although a complete water-quality analysis is always necessary, some basic observations will give the nursery developer some important clues to irrigation water quality. Water containing high levels of salts often tastes heavy and flat; if it tastes salty, chloride is probably greater than 250 ppm. Whitish crusts or scale deposits on faucets indicate high concentrations of calcium and magnesium bicarbonates in the water supply. Note the effort and amount of soap required to work up a lather; if little soap or effort is required and the soap is difficult to rinse off, the water is relatively "soft" and the water contains a high concentration of sodium compared to calcium or magnesium. Brown or orange-brown staining indicates high iron concentrations.

Heavy metals Contamination of irrigation water with elements known as heavy metals(such as lead, chromium, cadmium, and mercury) can also be a problem because even low concentrations can be toxic to plants. Sites having known history of heavy metal contamination should be avoided.

Specific ions Measures the concentration of the three directly toxic ions (sodium, chloride, and boron), as well as the other accessory ions that can indirectly affect water quality (table 2).

2.2.1.3.1.5 Estimating amount of water use

Once the quality of the irrigation source is verified, both the total amount of water per season and the rate at which the water can be supplied must be evaluated. Estimates of total annual water use and peak water use rate must be determined for assessing the irrigation pump capacity and the need for water storage ponds or tanks.

In addition to current water requirements, projected nursery expansion must also be considered when estimating total annual water demand. If the primary water source is unreliable, it may be wise to evaluate a potential backup source of irrigation water.

The total amount of water that a container tree nursery will require depends on many factors, including climate, type of nursery and irrigation system, container volume, and the water use patterns of the species. Total water demand can be given in many different units, but volume of water that must be supplied over some time interval per unit area of growing space or per thousand seedlings is most useful for planning purposes as is shown for example in table 3. Water may also be required for purposes other than seedling production, such as domestic uses, and estimates of these requirements can be developed with normal engineering calculations.

A nursery consisting of a 500m²semi controlled shade area and a 3,500m² open area would require about 9,000,000liter of water per year on an average (table 3) including other nursery and domestic uses, or 6 mm per day per unit area (i.e. 6 mm X 4000 m²).

Since the Central Nurseries will be irrigated by hand watering with knapsack, peak water demand becomes less important except for emergency water storage capacity.

Water Storage, water point, raised beds with knapsack sprayer.

Table 3 Total irrigation water demand for container tree nurseries. *

Nursery type	Container volume	Irrigation demand per Growing area	Irrigation demand per 1,000 seedlings**
Fully shaded enclosed raised beds	75 cm^3	—	130 l/wk
Fully shade controlled raised beds	150cm^3	—	180 – 350 l/wk
Fully shade controlled raised beds	300 cm^3	—	380– 650 l/wk
Open raised beds	150 - 300 cm^3	1800– 2450 $l/m^2/yr$	570-780 l/wk

** Calculate 60 - 100 seedlings in root trainers per m^2

2.2.1.4 Availability of energy source

All container nurseries require electricity to operate irrigation pumps and other nursery equipment. Although the type of electrical service will vary with nursery design, three-phase 240-V service is most efficient for large motors and so is preferred if available. To determine the electrical demand, the number and size of electrical motors, lights, environmental control equipment, and other users of electricity must be estimated. Remember to allow for future expansion. If the proper type of service is not available at the potential site, then the cost of bringing in a new electrical line must be included in the site development cost estimate. All container nurseries should have a backup generator in case of short-term power failure; chronic problems with reliability of electrical power are unacceptable.

2.2.1.5 Adequate land area

The amount of land selected for a container tree nursery must be large enough for the production areas and support buildings, and also allow for efficient movement of equipment and materials. The shape of the parcel may be more important than the actual area because production ranges tend to be elongated areas. In addition to immediate needs, the nursery developer should evaluate potential nursery sites on the basis of their space for possible expansion. In fact, it is to be recommended looking for a site that has at least twice the planned growing area. Sketching potential expansion areas on the existing site plans along with access roads and support buildings is strongly recommended. It is much easier to give it for a different use at some future date than to acquire some much-needed space for expansion or try to operate at two separated locations.

2.2.2 Secondary Site Selection Criteria

Although not as important as the criteria discussed in the previous section, the following factors should be considered during site evaluation. They can greatly increase the efficiency of a nursery operation and reduce operating costs.

2.2.2.1 Protected microclimate

In addition to having unobstructed solar aspect, a potential nursery site should be located in a protected area with the most equitable climate in the local region. Within any geographic area, nurseries should be located in areas that are not subject to extremes in temperature or damaging winds. On the other hand, a moderate degree of air movement is necessary for ventilation during warm weather. As long as they do not shade the growing area, trees on the windward edge of the nursery site can act as a natural windbreak and protect against damaging winds. However, trees or other obstructions on the lower edge of the site can serve as barriers to cold air drainage, and valley bottoms or other low sites that collect cold air should be avoided. Obviously, potential nursery sites near industries or utilities that could generate possible pollutants should never be considered. Even in rural West Bengal air pollution can present problems in certain areas.

2.2.2.2 Gentle topography

The general topography of a potential nursery site is important for both biological and economical reason A relatively level site reduces the cost of land leveling during construction and increases the ease of moving equipment, supplies, and vehicles after the site is developed.

2.2.2.3 Dry land free of flooding or erosion risks

In all cases potential nursery sites should be risk free where flooding or erosion is concerned. Sites should be dry all year round and if necessary the nursery platform heightened to prevent even accidental flooding. If a remote chance exits the site might become damaged by erosion run off from higher up the slope (in Northern Hill Divisions) grassed waterways should be constructed up hill to deviate eventual run off deposits away from the nursery site. This will obviously greatly increase the nursery establishment costs.

2.2.2.4 Seasonal labour supply

The success of a container tree nursery depends on the quality of the available work force. In addition to a small permanent professional staff, a container tree nursery requires a reliable source of semiskilled labour for several peak work periods during the year, when tasks such as sowing or grading must be completed in a short time. During the site evaluation process this has to be taken into account. The number of employees required depends on the size and complexity of the operation. At least one technical supervisor for each central nursery may be engaged as a rule of thumb.

2.2.2.5 Accessibility

A good nursery site must be accessible for regular delivery of nursery supplies and nursery stock. Most supplies are delivered by truck, making good all-weather roads and accessibility to regular routes important. Access roads should not have any steep slopes or sharp turns that would prohibit safe operation of delivery trucks. Essential supply and maintenance services should be available nearby. Remote locations may increase the cost of supplies, particularly in locations where fuel oil must be delivered regularly. Nurseries must also be easily accessible to workers, especially the key personnel who respond to emergencies. Regardless of how well a nursery is designed for reliable operation, there will be times when key nursery workers must be able to respond within an hour or less. If accessibility is a potential problem, then it may be necessary to provide a dwelling on the site, and this cost must be considered during site evaluation.

2.2.2.6 Distance to out-planting areas

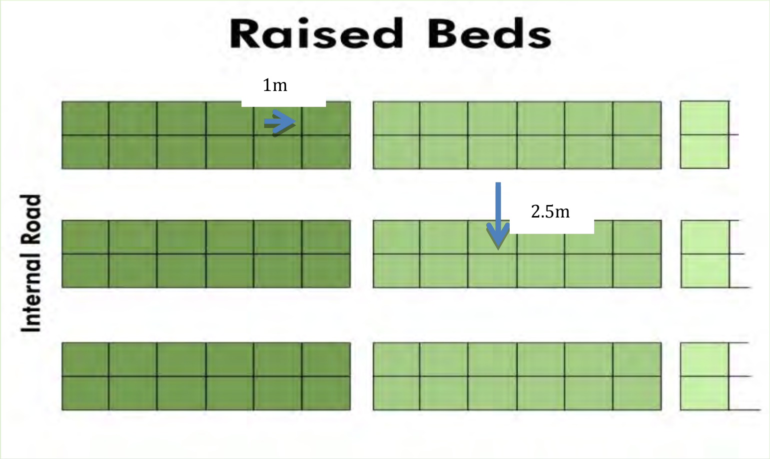
The distance from the potential nursery site to the delivery point must also be considered during the site evaluation process. The nursery site should be chosen at a central location to the main out-planting areas for years to come and delivery needs to be taken into account.

2.2.2.7 Site production potential

To help determine the acreage needed for the seedling growing area, the required production capacity for seedlings by species is of course basic. The need for a particular container size for a specific species is described in details in Volume II. Considering the production with a species distribution according to needs for container sizes of 150 cc (50%) and for container sizes of 300 cc (50%), the following calculation can be made:

Each raised stand holds about 150 nos. containers of 150 cc size per $m^2$and about 100 nos. containers of 300 cc size per m^2. The raised stands are built in segments of about 1 m^2 each. If 6 nos. stands are placed in double rows with a gap of 1 m for easy passage between double rows of stands, about 1150 m^2 space will be required for the 100,000 seedlings in 150 cc container and 1,750 m^2 for 100,000 seedlings in 300 cc containers, or a total of about 3,000 m^2 production area will be required to produce 2,00,000 seedlings with raised containers.

Banks (groups) of raised bed elements as nursery beds perpendicular to internal nursery road



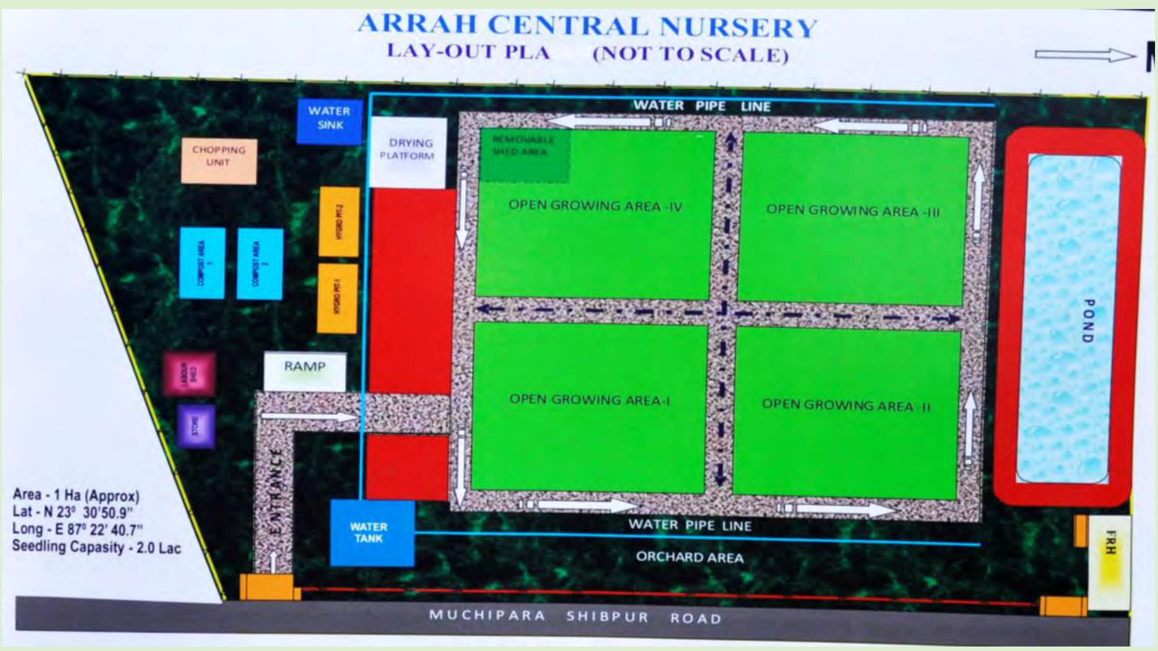
Central Nursery Raised Beds

2.2.3 Layout and Development

2.2.3.1 Access and traffic flow

The nursery should be as compact as possible, nearly square or regular in shape, to minimize the length of the boundary fence and reduce the time loss in moving from one part of the nursery to another. Roads provide access to the site and to growing fields. When the site is developed, all access roads should be paved if possible; they must be capable of taking heavy "semi" truck and tractor traffic in all kinds of weather. Parking areas must be evaluated and particular attention given to the placing of a "loading ramp" to facilitate the loading of seedlings in vehicles outside the nursery. Connecting points (entries and exits) to existing road systems should be taken into account.

Central Nursery Layout Plan



2.2.3.2 Administrative site

The administrative site could include administrative offices although in most cases the FD office space will be used, but certainly will need a storage area for equipment, seed, pesticides, other chemicals, and fuels; a water pump housing and seedling-processing facilities. The type, number, and location of required buildings must also be determined regarding production technologies used. Other than for administrative uses, the site development will include holding areas for irrigation water and a composting area, a protected divided shed for compost, sand and other potting media ingredients, root trainer cleaning and storage areas, a culled-seedling disposal area (compost heap), an area for holding scrap material and used equipment. In case where a clonal nursery has to be developed, an adjacent Clonal Multiplication Area (CMA) has to be established. Although possible future expansion must always be kept in mind, the administrative complex must optimize the use of space to avoid being spread out.

2.2.3.3 The master plan

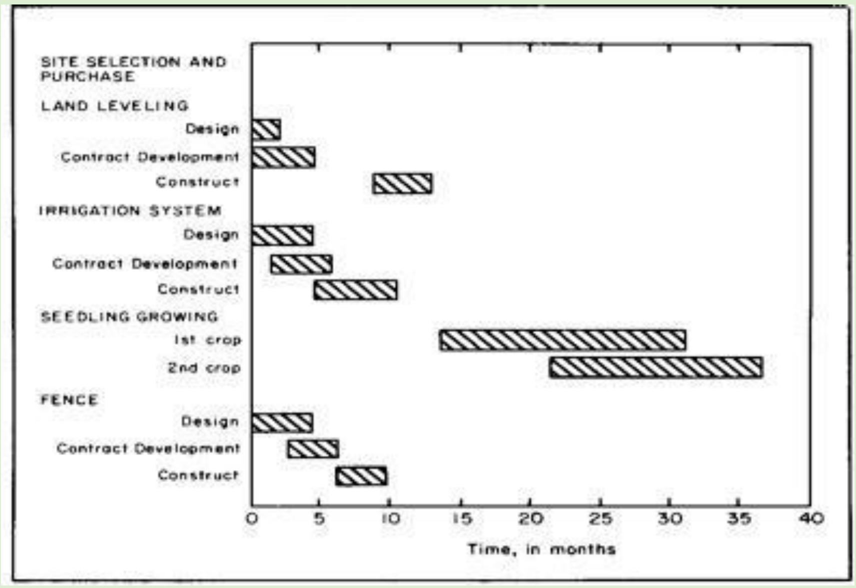
Once agreement has been reached on placement of all structures and development begins, a master plan—a dynamic tool—must be made to document the team decision. Once the selection process and the nursery design has been completed, this plan will stand as an illustrated document of site layout, indicating growing areas, roads, buildings, outdoor storage areas, reservoirs, streams, fences, neighbors, possible expansion areas for buildings, and other site development. The master plan is not cast in concrete, and can and must be up-dated as management needs change.

Example of a Nursery Master Plan

2.2.3.4 Development program

To properly develop a site, an action plan must be prepared. One approach is to construct a critical-path chart that shows events and operations on a timeline. Seedling production scheduling must be coordinated with site development. Structures that are needed first must be built first. For example, Figure3 shows a partial nursery action plan, developed as a timeline. Throughout nursery development, the action plan is continuously reviewed and revised, as needed. Critical factors that may have been overlooked initially are identified and incorporated. It is important for everything to be viewed objectively and in a proper perspective.

Example of an Action Plan for a Nursery



2.2.3.5 Budgeting and accountability

Budgeting is critical and must have highest priority in the development process. Budgets should be planned well in advance to ensure that funding, people, and facilities will be available when needed. The budget and the action plan must be developed together. If shortages of funds or people are anticipated, construction may have to be delayed or other alternatives sought.

2.2.4 Generic Central Nursery layout and brief infrastructure description

With the selection criteria as described in the previous paragraphs, a general recommendation for layout and infrastructure needs can be given for new Central Nurseries. Each new nursery will require adaptation to specific site characteristics regarding overall shape, internal roads, paths, length and compass direction of nursery beds. Ideally the site will be on gentle sloping land (slope less than 2%) to facilitate drainage without erosion risks, with beds along contour lines if necessary but preferably perpendicular to the central internal road. Most of the infrastructure described can be found on existing nurseries and most of the recommendations given can be used for the expansion of existing nurseries too. Sufficient and easily accessible water is a must and therefore where possible a water harvesting structure must be constructed outside the fence but at lowest foot of nursery area for eventualities.

2.2.4.1 Total approximate surface area needs

The initial production capacity target for the new nurseries will be 200,000 seedlings/yr. As mentioned above under 2.2.7, “Site production potential”, approximately 3,000 m^2 area will be needed. While developing the central nursery additional areas as given below should also be taken in account:

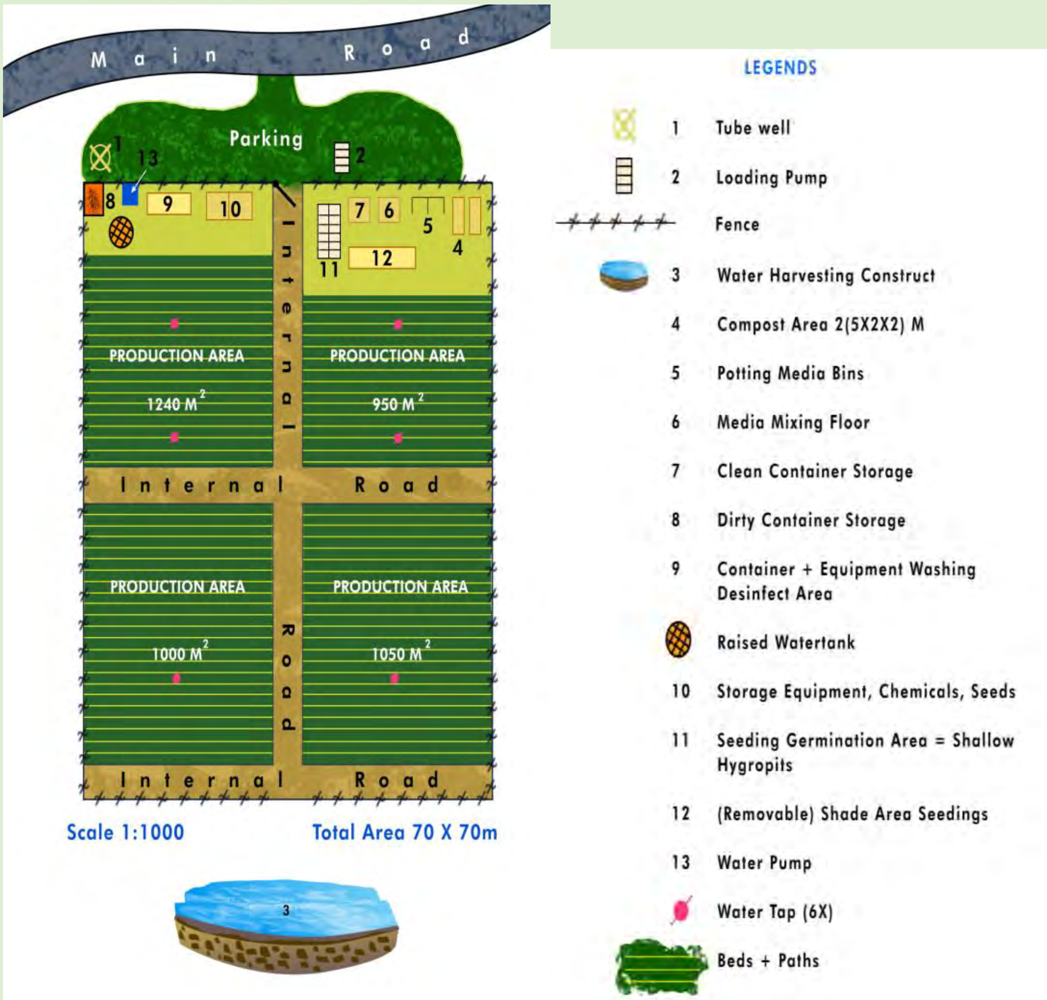
i. About 1500 m^2 (50% of the area) for future expansion.
ii. About 500 m^2 (20% of the area) for all non-productive areas such as roads, administrative site, storage buildings, sand/compost bins and any area where seedlings will not be grown.
iii. About 3000 m^2 for spacing out the seedlings and accommodating the 2nd batch of seedlings prior to dispatching out to planting sites.

Thus the total nursery area will be 8000 m^2 or around 1.0 ha. Many nursery sites have been selected and developed with little or no allowance made for future further expansion. Regardless of how remote it may seem, expansion should be considered.

2.2.4.2 Master Plan for Seed Origin Central Nursery

A diagram representing a general Master Plan for a “seed origin nursery” for one of the new Central Nurseries is given below. Different aspects of the infra-structure and production areas are explained in subsequent paragraphs.

Master Plan for new "Seed Origin" Central Nursery



2.2.4.3 Master Plan Clonal Origin Central Nursery

A diagram representing a general Master Plan for a "Clonal origin nursery" for one of the new Central Nurseries is given below. Pure Clonal Nurseries can be much smaller and only a few will be needed. Those already in existence can be put up to standard with little costs. Differences between pure Clonal Origin Nurseries and Seed Origin Nurseries are mainly found in

(i) adjacent Clonal Multiplication Area (needs a lot of water),

(ii) size of nursery (smaller),

(iii) no compost needed,

(iv) potting media bin can be smaller and will only hold coarse sand

(v) Hygro-pits have to be larger and deeper.

Different aspects of the infrastructure and production areas are explained in subsequent paragraphs

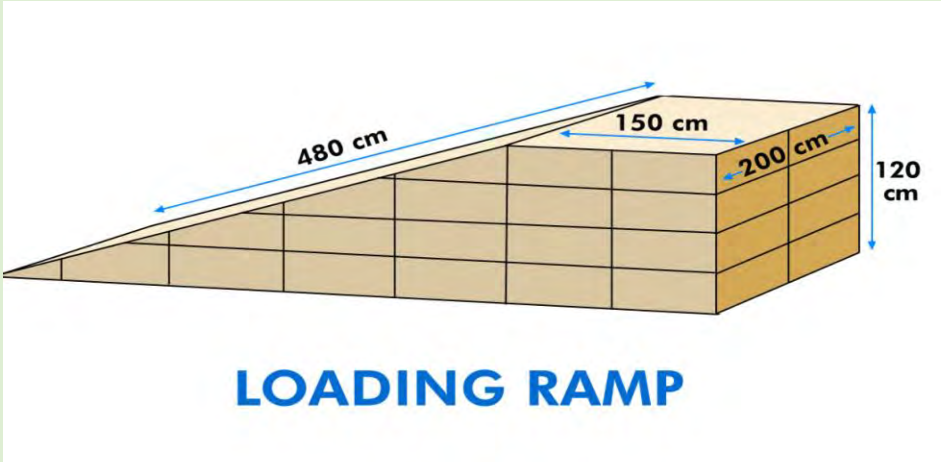
2.2.4.4 Initial development

Before anything else the total nursery area will have to be graded in order to give it a smooth topography without depressions where water might accumulate. Construction areas and internal roadbeds will have to be scraped to remove organic topsoil and compacted.

2.2.4.5 Lay out of roads and paths

Internal central roads should be about 2.5 m wide and slightly higher then the surrounding areas with a shallow drain on each side. However, the internal arterial roads should not be more than 1 m width. Material freed from leveling the area and excavating the foundations for the buildings can be used for filling up the roadbed, after which preferably a layer of gravel or morrum or "bajri" may be applied. In the new Central Nurseries the parking area will be provided with a ramp 120 cm high x 200 cm wide with a 150 cm x 200 cm platform and a sloping 480 cm long x 200 cm wide walkway to facilitate loading of trucks.

Diagram of loading ramp and platform for easy loading of seedling



2.2.4.6 Layout and type of beds

The beds are comprised of raised bed elements 85 cm x 85 cm x 60 cm, which can be stacked on top of each other for efficient transport of seedlings during out planting season

They are put together in repeating groups of 2 elements wide and 6 elements long, running perpendicular to the central internal nursery road with 1 m wide alleys (paths) in between. These alleys are needed for working the beds, but also provide easy access and drainage.

Raised bed elements 85x 85 x 60 cm and stacked for easy transport.

Pure Clonal Origin Nurseries in container size of 60-75 cc will require much less production space. A clonal nursery with a production capacity of 200,000 ramets/year will require about 0.25 ha of nursery area to cover production area, administrative area and area for future expansion.

2.2.4.7 Layout for watering system

Since an irrigation system is costly, the nurseries, although labour intensive, will rely on watering with watering cans or knapsack sprayers. **Watering with hoses should never be done**. To facilitate the filling up of the watering cans or knapsack sprayers, adequate number of taps will be placed as recharging points at equidistance distributed over whole area connected with waterlines starting at raised water tank. Hydraulic pressure from raised water tank will be used to provide water throughout the nursery while a pump will recharge the water tank.

2.2.4.8 Tube well or other water supply

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 species, container size, rooting media, the number of seedlings and the watering method employed. More frequent watering is needed for containers with sandy media, which have a low water holding capacity. In central nurseries with 200,000 seedlings production capacity using knapsack sprayers or watering cans an estimated amount of 24,000 liters of water per day will be the peak requirement during the dry season. This is equivalent to approx. 2.4liters per second of water uptake for a three-hour effective water pumping.

2.2.4.9 Fence

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 concrete, durable hardwood or wood impregnated with a preservative. At the entrance the fence should have a sufficiently wide gate to facilitate easy movement of labour and material. It is advisable to maintain an open strip of land about 5 meters wide around the fenced perimeter, to serve as a roadway and buffer zone between the neighboring 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.

2.2.4.10 Office/Administration building

It is not foreseen that a separate office/administration building is needed as all paper work will be done at the nearest forest establishment.

2.2.4.11 Washroom

Separate washrooms of reasonable size for male and female laborers are required. The nursery water supply can be used for washroom cleanup.

2.2.4.12 Tools and chemicals shed

Tools, equipment, chemicals, seeds etc should be stored in a simple shed of around 5 x 3 x 2.2 meter with separate lockable closets for chemicals and expensive equipment. Seeds can be stored for a short time in sealed well labeled containers on shelves.

2.2.4.13 Generator and pump

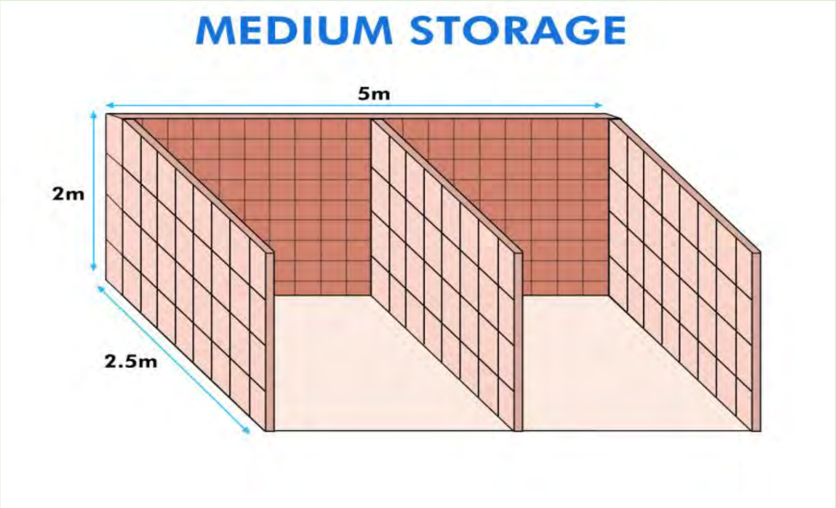
Although the nursery should have access to 2 or3-phase electricity, a back-up generator will be advisable to prevent damage to seedlings during prolonged periods of power cuts. A 2 Generator will be sufficient in most cases, unless water is drawn from bore wells more than 20 m deep. Likewise a3-5 HP submersible pump will be sufficient to raise water through a 5 cm diameter pipes to the overhead water tank (7-8 m height) from bore wells of depth upto 50meters.

2.2.4.14 Raised water tank

The height and capacity needs for the overhead water tank depend on the nursery topography, nursery water needs and watering system. With a watering system as recommended, gravity water pressure can be used if at least ¾" diameter water lines are used. To this end the tank has to be placed on the highest area of the nursery closest to the water source (well head) and raised to at least 7-8meters above this point. With an estimated water need of 24,000 liters/day (peak requirement) the overhead tank should have a capacity of at least 8,000 liters. The overhead tank (PVC tanks) should be hoisted on a concrete platform of suitable thickness having area of 3 m (l) x 2.5 m (w) erected on pillars (7 m high). The space in between the pillars should be used to house pumps, generators and tools.

2.2.4.15 Potting media storage can be kept simple and inexpensive with a two chamber bin covered construction. Each bin of size 2.5 (l) x 3.0 (w)x 2.0 (h) meter, one for compost and one for coarse sand, will have a storage capacity of approximately11 m^3 and is made of a concrete floor and cemented brick walls. Protective cover against rain and sun can be provided with a

3.0 m high roof (CGI sheets) supported on G.I. pipe structure.



2.2.4.16 Medium mixing area and Drying Platform

It should be a clean area of 6 x 6meters next to the potting medium storage and consists of cement concrete floor on single brick flat soling. The cement concrete floor should have a brick edging all around. No cover is needed. Sterilized sand and compost out of the storage bins, or burnt rice husk, or leaf mould compost, or vermin compost will be mixed in a **cement mixer** at a standard ratio as described in volume III of Nursery Manual. The cement mixer should be installed adjacent to the Drying Platform.

2.2.4.17 Composting area

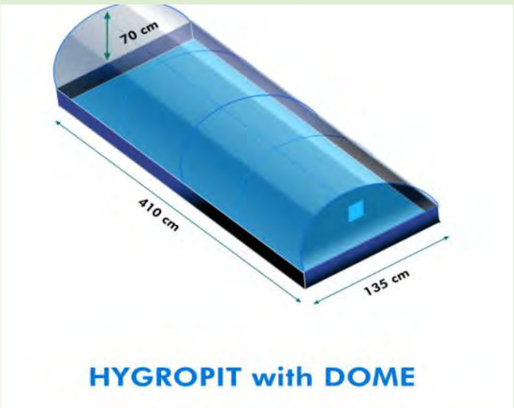
Total compost needs for standard central nursery will be about 32 m^3/yr, production of which (with the Berkeley method) will require 2 compost heaps of 5 x 2 x 2 meters each. In between (next) to these, at least an equal area is needed for turning the heaps with 1 meter extra each side for easy access and movement, giving a need for a total surface area of 5 x 11 meters. No extra provisions are needed as the soil underneath the compost heaps has to be loosened before starting and heaps can be protected against heavy rains with weighted heavy gauge agricultural plastic sheets. Weighting of plastic sheet covering against "blow off "can be achieved by e.g. tying a heavy stone as anchor at each corner with a rope. The heaps may be supported on all sides with split bamboo mats.

Chopping machine should be installed adjacent to the composting area

2.2.4.18 Germination hygro-pits

The tree species having large seeds will be dibbled directly in their end use containers. Small seeds will be germinated first in coarse sterilized sand filled hygro-pits covered with domed heavy (200 micron) gauge plastic. These pits will be 100 cm wide x 400 cm long and 10 cm deep, lined first with agricultural plastic and then filled with sterilized coarse sand. Hygro-pits will be covered with domes having dimensions of 410 x 135 x 70 cm made of PVC pipes and covered with 200 micron plastic with a 15 x 15 cm ventilation hole cut at top of each face. The germination hygro-pits will be situated at the edge of the removable shade area. After germination the plantlets will be pricked in 150 cc/300 cc root trainer containers filled with a rooting medium (potting mixture) as prescribed in volume III of the Nursery Manual. The containers with seedlings will be placed in raised beds either under shade in a removable shade area or directly in the open field.

Hygro germination pit, lined with plastic, filled with course sand and either covered with thatch mulch or with a plastic dome

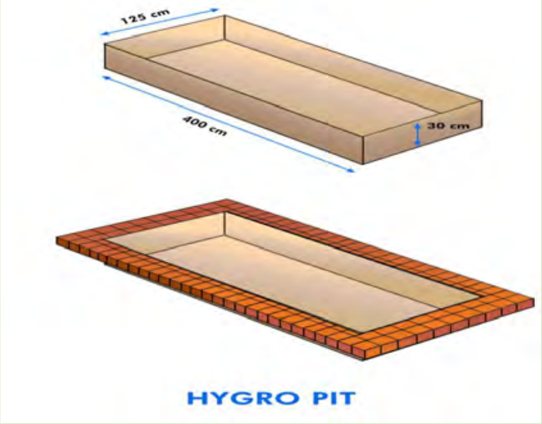


2.2.4.19 Hygro-pits for rooting of clonal cuttings.

For clonal reproduction, cuttings dipped in a growth hormone in powder medium and directly placed in 60 -75 cc root trainer containers filled with sterilized course sand, or vermiculite should be placed in trays in coarse sterilized sand filled hygro-pits

Hygro-pit for root cuttings

Trays for holding containers



These pits will be 125 cm wide x 400 cm long and 30 cm deep, lined first with agricultural plastic and then filled with sterilized coarse sand. Each pit is surrounded by a double line of bricks to better support to the dome and will be covered after placement of trays with domes (similar to the germination hygro-pits) with dimensions 410 x 135 x 70 cms made of PVC pipes and covered with 200 micron plastic with a 15 x 15 cms ventilation hole cut at top of each face. After about 3 weeks the rooted cuttings will be placed directly with their 60 ml root trainer containers in raised beds after which the hygro-pits will become available for the next batch of cuttings. As is the case in the other nurseries with the germination hygro-pits, the rooting hygro-pits will be situated at the edge of the removable shade area. The containers with rooted cuttings in their raised beds can either be placed directly in the open growing area or preferably, first placed in a removable shade area (50% agro net shade).

2.2.4.20 Removable shade area

After the first culling, germinated seedlings or rooted cuttings, can either be placed directly with their raised beds in the open growing area or, preferably placed under light shade in the "Removable Shade Area" before being moved after about 3 weeks out to the open growing area. The removable shade area can be a simple structure of agro netting threaded over wires tensed between uprights either made of galvanized steel / M.S angle/G.I pipe. The actual structure can be simple and inexpensive but must be sturdy enough to withstand heavy rains and winds. The required size of the area depends of course on the number of seedlings and cuttings being raised. Uprights can be placed East-West as 12 x 12 m grid as wide and long as needed and will accommodate raised beds in pairs between uprights in any direction desired. Agro netting with metal ring reinforced 3/4" perforated holes each meter can be threaded over galvanized steel wire or cable tensed between the uprights, which will permit netting to be spread out over area or recovered to provide direct sunlight.

Removable shade area with galvanized steel uprights

2.2.4.21 Storage for clean root trainers

Should be a simple traditional roofing to provide shade and rain protection over a compacted earthen floor. To prevent containers from tumbling out of the storage area if not properly stacked it would be advisable to surround the area with a 1 m high wall made of either bricks, wood or even hurricane fencing material.

2.2.4.22 Storage for dirty root trainers

Should be a simple traditional roofing to provide shade and rain protection over a compacted earthen floor. To prevent containers from tumbling out of the storage area (if not properly stacked) it would be advisable to surround the area with a 1 m high wall made of either bricks, wood or even hurricane fencing material.

2.2.4.23 Washing, disinfecting trough for root trainers

Two basic brick or concrete troughs adjacent to each other, with inner dimensions of 2.0 x 1.80 x 0.75 (depth) meter seach will be able to hold enough water and containers at a time to permit efficient washing and soaking by several people at once. The troughs must have wide drains on each side to permit efficient draining and cleaning.

2.2.4.24 Resting and Training area

A temporary structure 4 m x 3 m open on all sides should be set up at a convenient place within the nursery to be used by laborers for resting and also for training of small groups visiting the nursery. The area should be covered with G.I sheets on G.I pipe truss.

West Bengal Forestry and Biodiversity Conservation Project

Planning, Production and Management.

Container Nursery Techniques for Improved Tree Seedling Production

3.1 Introduction

In the following paragraphs, criteria and prescriptions have been detailed for Planning, Production and Management of the new Central Nurseries within the State. The recommendations can also be followed for the planned increase of existing nurseries' production capacity and their improvement management.

The final phase of nursery development begins when the construction is complete and it's time to plan for the first production. To start production in a new container nursery many aspects have to be taken into account, which might prove quite a challenge for a new manager, and so the purpose of this volume is to outline the various aspects of nursery management. The key aspects of every successful nursery are solid organization, professional personnel, a system of data collection and analysis, and an established system for solving problems.

3.2 Organization

"A tree nursery is like a ship, it cannot be managed by consensus. Somebody has to decide what the ultimate goal is and which direction to sail in order to arrive safely. The captain has to take the responsibility of when and how to get to the destination."

If it is to succeed, the management of a nursery must have a structured organization that ensures that responsibilities are assigned and jobs get done. The responsibilities for a container nursery can be divided into four general categories:

I. **Production**: performing the day today cultural operations of growing and maintaining the QPM stock.

II. **Engineering**: maintaining the physical production infrastructure and custom-building any special equipment.

III. **Shipping**: receiving indents, supplying the QPMs,and providing other related assistance.

IV. **Administrative**: keeping records, accounting costs, labour management, bills, purchases, and payrolls.

Regardless of the organizational structure, any successful nursery must have one characteristic: **unity of command.** Nursery managers must establish a clear assignment of responsibilities, together with the authority to carry them out. Raising QPMs in containers is not a simple procedure. In nurseries where there has not been a clear assignment of responsibility, trouble eventually develops.

3.3 Personnel and Supervision

3.3.1 Attributes of container nursery managers

One of the most important decisions is appointing the nursery manager.

Nursery managers have to be knowledgeable, good organizers, planners, diplomatic in personnel management and problem solvers. The nursery manager must see that overall management is coordinated.

3.3.2 Professional attitudes

Managing a container nursery facility is more than just growing QPMs. Successful nursery managers must possess certain key professional attitudes that guide their daily work and provide an example for their co-workers.

3.3.3 Technical competence

Traditionally, forest nursery managers have come from the ranks of the forestry profession. Regardless of their backgrounder training, the key factor is that managers understand the daily operations of a container nursery and are able to grow tree seedlings.

3.3.4 Clear managerial goals

Nursery managers too often, are buried by administrative details or the need to attend other activities. This is a waste of resources. Adequate support staff must be provided to allow nursery managers to do the real job they were assigned to do. The mission of the nursery must be kept foremost in the minds of managers and their staffs, and it is helpful to state that mission in terms of a concrete goal. For example, agoal might be "to grow high-quality seedlings at area sonable cost in a timely manner."

3.3.5 Understanding the needs of the seedlings

Nursery managers should view nursery activity priorities from the standpoint of the biological requirements of the seedlings. The goal at the nursery usually is to grow good quality seedlings on an economical basis. It would be useful to give a basic training to the nursery workers. This training should not only give meaning to the work they do, but an appreciation of the effect of their activities on the plants being grown. Such education will often prevent disastrous errors on the part of container nursery workers who, for instance, might not understand the implications of removing the plastic domed structure from the clonal rooting hygro-pits because "it is too hot inside."

3.3.6 Commitment to the nursery

A container nursery can not be run by “committee." Instead, one person always has to accept primary responsibility for the production at any particular time. Problems always develop when there is no one person who conscientiously looks after the crop and the functioning of the nursery all the time. The key to rapid seedling growth in container nurseries is knowledge and constant vigilance.

3.3.7 Cleanliness

The cheapest insurance against disease, insect, mechanical, or seedling physiological problems in a container nursery is to keep everything clean and in good working order. The emphasis on cleanliness, neatness, and maintenance also affects the nursery workers.

3.3.8 Supervision

Successful supervision ensures work environment and quality of the seedlings. Regular visits to the nursery sites are a must and the notes of inspection should be recorded in the Inspection Register of the nursery. As per the saying in the department, there is no better fertilizer for the seedlings than the sweat of a forester.

3.3.9 Safety programs

The greatest hazard created by wetness is the danger of electrical shock. All wiring should be in waterproof conduit. All outlets should be properly earthed and equipped with ground fault interrupters. Power must be shut off first when electrical equipment is being repaired or adjusted.

Pesticide storage areas must be properly designed, and all employees (not just applicators) must be given regular training on pesticide use in enclosed areas.

Tools and other equipment should never be left lying around, and hoses or cords should be coiled and placed out of traffic areas. Propagation areas are often humid, which makes floors slippery and storage areas of e.g. containers are ideal nesting places for snakes.

Safety meetings should be held at the start of each major work period and procedures explained including use of first aid kit and anti-venom use.

3.3.10 Operational planning

Operational planning is the advance work that brings all the non-structural requirements of nursery production (labor, supplies, equipment, etc.) together at key times of the production process. For planning purposes, a container nursery can be visualized as a system that consists of a series of sequential processes (filling and sowing the containers), operations (placing germinated seeds or clonal cuttings in containers), and the requirements (propagation structure, equipment, labor, and supplies) to complete each process.

3.4. Data Collection and Analysis

Another important aspect of nursery management is the collection and analysis of information. The types of records and the methods of information collection and storage will vary considerably with the type, size, and complexity of the nursery.

Nursery records provide particular kinds of information for the nurseryman, the forester, the silviculturalist and the economist. The records provide the basis for reviewing the success or otherwise of the nursery methods employed.

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. The purpose of this section isto introduce the terms and concepts necessary to start managing a nursery and to impress on new nursery managers the importance of keeping good records right from the start. The types of records kept at a container nursery fall into two general categories:

- Financial and production records, and
- Cultural records.

3.4.1 Financial and production records

Financial records are kept to meet governmental and project requirements. A financial record keeping system should be designed/adapted to document three general classes of information:

(1)Expense data,

(2) Production data

(3) Unit-costdata.

Such financial data are used to calculate unit output costs (INR's. per thousand seedlings). This latter information is essential for setting accurate prices and estimating future production costs.

3.4.2 Cultural records

Cultural records are maintained to provide a plan for duplicating successful crops and give an accounting that can be used in (a) determining the cause of failures in the culture of the crop, (b) deciding on action to be taken on the current crop, and (c) making plans to avoid problems with future crops.

Cultural records fall into three categories:

- Growing schedule for QPM.
- Environmental conditions in the propagation area.
- Crop development records

3.4.2.1 Growing schedules (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 out-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 off and as different species grow and mature at different rates or will be out-planted at an older age like Sal, this will influence timing of production for scheduled delivery.

These written plans of crop timing are essential to successful nursery management and are developed prior to sowing based on the best information and experience available. Growing schedules come in various degrees of sophistication and refinement. They may be only rough outlines of dates for key cultural processes, such as sowing, culling/thinning, and harvesting, or they can provide considerable detail on each step of the process together with a record of actual accomplishment. The best growing schedules include a variety of operational considerations related to crop timing, culture, and growing space utilization. They should include:

a. Target specifications for the crop and the time of delivery,

b. Adequate allowance of time for seed stratification, if needed, prior to sowing and for a proper hardening period prior to out planting,

c. Placing species or container types with similar growth regimes in the same propagation environment,

d. Planning efficient use of space in the propagation environment to allow large blocks of similar species to be sown at the same time and kept in the same area, if possible, placing seedlings to be removed first near the pathways for ease of handling.

Growing schedules should serve as a daily reminder to the nursery manager about the operations to be done and should, in aggregate for the various crops being grown, serve as the basis for work force and materials planning on a week- to-week basis (See example in annexure I).

It is useful to prepare a second type of calendar to show, on a monthly basis, the more important nursery activities such as dates for start of compost production, preparation of potting media, preparation of hygro-pits, filling of root trainers, sowing in hygro-pits/dibbling in root trainers, weeding and repairs to nursery (See example in annexure I).

3.4.2.2 Environmental conditions in the propagation area.

This set of culture-related records contains such things as temperatures inside and outside the propagation structure (hygro-pits), precipitation, evapotranspiration, wind speeds, growing medium analysis, occurrence of insect pests and disease, and other general observations. These records not only show the crop environment maintained but also will indicate various equipment failures and any involuntary deviations from the growing schedule. Abnormal crop development discovered later can often be related back to failures to respond timely to variations in Environmental conditions indicated in the environmental records. Daily or weekly records of environmental conditions and seedling growth can be charted by hand on clipboards mounted near the work area. This system has the advantage of being readily accessible and simple.

Hygro-thermographs or Hygro-thermologgers are handy ways to permanently record temperature and humidity. This weather information is constantly stored and can be used to plot and analyze trends, which can help nursery managers spot problems quickly and take corrective action before serious growth loss occurs. Ambient weather conditions should also be collected in a standard weather station, preferably to be set up at the nursery site, including daily temperature highs and lows, humidity, precipitation, and wind speed. Weather records are very valuable data that can tell the nursery manager how to design and operate propagation structures and how to acclimatize crops, as well as provide a way of evaluating the risk of potentially damaging weather occurrences.

3.4.2.3 Seedling development Records

All nurseries should keep some form of permanent records that monitor the growth and development of their crops over the growing season. Nursery managers should monitor significant events such as time, period and percentage of germination and also take periodic measurements of growth parameters including shoot height and stem diameter (with calipers). Root growth is more difficult to monitor because small seedlings are damaged when removed from the container. Although it requires destructive sampling, seedling oven dry weight is a useful index of crop development and is necessary for the calculation of root -to-shoot (R : S) ratios. It is suggested that few samples should be taken (about 10 per 10,000 production) to collect the R: S ratios of different species. The Root: Shoot ratio may be estimated every September and March. It is best to appoint one person responsible for taking all seedling development and inventory measurements. This ensures that the measurements are taken the same way each time. Seedling height can easily be taken with a ruler and stem diameter with calipers, and the data recorded on prepared data forms as prescribed in Annexure I.

3.4.2.4 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 each provenance (Division/Range/Beat) separately. For example, the first batch to arrive in 2014 would be No. 1/14, the second lot No. 2/14 and so on. The first lot in year 2015 would be No. 1/15. These numbers in conjunction with the species name and provenance (Division/Range/Beat) are sufficient to identify any particular batch of seed or plants in the nursery. It is expected that each lot is marked with date of collection of the seeds 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 4.Further details can be written on the reverse side or on additional lines showing, for example, the treatments as pre germination treatment, type of fungicide used and the dates of application.

It is important to record the exact location in the field to which seedlings grown out of each and every seed lot have been sent. This is important because the genetically aspect of seed sources is recognized 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.

In addition nursery managers need to maintain a **Nursery Stock Register**. This helps in keeping account of nursery stock - Seedlings and /or Ramets (Clone). Stock register should be updated on a regular basis, preferably weekly, to reflect the current status of nursery stock. The suggested format Nursery Stock Register, keeping stock species wise and total nursery stock, is given in Annexure I

3.5 Nursery Problems

One of the most important aspects of nursery management is solving the day-to-day problems that come up. Although previous experience is the best weapon, even novice nursery managers can become proficient problem solvers by visiting other nurseries, attending workshops and training sessions, and keeping up with the latest published literature.

Any nursery facility has certain standard operating procedures that represent the best information available. Therefore, changes in cultural procedures, equipment +settings, or timing should be made with caution. A record of the change should be noted. A stock of spare parts should be kept of those items whose function is critical, that need regular replacement, are hard to find, or take a long time to get.

An indicative chart listing a few common nursery problems, their visible symptoms, analyses of causes and probable solutions is given in Annexure III.

3.6 Production of Seedlings

Production of seedlings in the WBFBCP Central Nurseries will differ species wise from nursery to nursery according project preferences, needs and ecological niches to be occupied, and will be mostly geared towards raising seedlings from (whenever possible) locally acquired seed, with clonal eucalyptus seedling production in some of them. The objective of the present manual is to standardize nursery seedling production in order to achieve a uniform degree of high quality planting material in all projects nurseries and furnish the necessary elements to enable nursery managers and DFO's alike to work towards continuous improvements in productivity of the forests/plantations.

3.6.1 Infrastructure

Productive infrastructure is described in detail in "Central Nursery Manual Volume II, Site Selections, Layout and Development" and has been kept as basic as possible to achieve a standardized consistent production of high quality planting material in all central nurseries within the budget constraints, using simple, easy to implement technology without creating dependency on high tech inputs.

3.6.2 Growth media

3.6.2.1 Growth Media for Germination Beds

The physical structure of the medium in which seeds are germinated is crucial both for germination. 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.

3. Large spaces between the medium particles should be avoided.

4. Little physical resistance so that the emergence of the seedling is not restricted and root penetration is fairly easy.

5. Infiltration capacity that permits easy watering and avoids crusting on the surface as often occurs with fine sand and silt.

6. Absence of fungi, bacteria, nematodes and weeds.

7. Chemically neutral.

The sterilized coarse sand provides all above characteristics and therefore is recommended as the growing media for Germination Beds.

3.6.2.2 Growth Media for Container Seedlings

A key production component is the growth media, standardization of which is, together with the use of root trainer containers, perhaps the most important aspect of our nursery techniques. At least 8 properties are important when considering growth media mixtures for plant production:

- Particle size
- Organic matter content
- Porosity
- Moisture content (water holding capacity)
- pH
- Electrical Conductivity (salinity-alkalinity)
- Presence of pests and disease pathogens
- Presence of weed seeds

Although each can be evaluated separately, they are all interrelated. The presence of organic matter is the most obvious ingredient and is essential for maintaining a satisfactory moisture balance necessary for plant growth. Soil that is not porous encourages water-logging, hence oxygen, which is essential for root development and respiration, becomes unavailable to the plant. Since the growth medium relates to every cultural practice in the production of nursery seedlings 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 of the properties from batch to batch.

In general a porous well-draining growth media with a moderate to slightly acidic reaction (pH 5.5 to 7.0) represents the most favourable condition for forestry and agro forestry nursery stock, although slight variations may be necessary for certain species. Pinus spp, for example, grow 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 media, certain plant nutrients are either leached or become insoluble and therefore unavailable. Acid media 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.

Experiments with several growth media for root trainers, like compost mixed with coarse sand, locally available moss, composted leaf mould and burnt rice husk have been carried out in the

State. Nurseries have also been using mixes of local soil, sand and cow dung manure in different ratios. Based on the previous experiences and the availability of the components in different areas, the growth media to be used in the central nurseries have to be either :-

I. 1 part compost : 1 part coarse sand.

II. 1 part compost : 1 part washed burned rice husk : 1 part coarse sand.

III. 1 part cow dung manure : 1 part washed burned rice husk : 1 part coarse sand.

[Note: All nursery managers should ensure that under no circumstances the potting mixture should be 1 part cow dung manure: 1 part coarse sand as this may pose danger of burning the rootlets]

In case of non-availability of vermiculite, 60 -75 cc containers for the clonal Eucalyptus root cuttings should have the bottom 1/2filled with a 1:1 coarse sand: compost mixture and the remaining top 1/2with coarse sand only.

[Note: It is of the utmost importance that when filling the containers they are filled through and through without tampering down the mixture with force.]

It is always advisable to know the basic chemical characteristics of the growth media being used for germination and transplanting.

3.6.2.3 Coarse Sand

Coarse sand has a particle size distribution between 2000 micron and 200 micron and although this does not have to be rigorously applied it should at least be between 2000 and 300 micron to guarantee well drained media with good aeration, permitting rootlets to penetrate easily. The best sources (with least fine sand, silt and clay particles) will be found on the outer levees of river bends and in sand banks (sandbars) with gravel present.

As the coarse sand component is an important part of our growth media it is essential that it is indeed coarse sand and not a mixture with finer particles.

Sand has to be collected, dried if wet, and thrown through, or shaken through, a 2000 micron (2 mm) sieve first to separate out large particles, stones, roots, etc. . Material which does not pass through the 2000 micron (2 mm) sieve has to be discarded because it is too coarse (large). All sand that passed through the first coarse sieve of 2000 micron (2 mm) is a combination of coarse and fine sand (plus the even finer silt and clay) and has to be sieved again through a fine 300 - 400 micron (0.3 mm or 0.4 mm) sieve to separate the smaller particles (fine sand, silt and clay). All material passing through the second fine (300 -400 micron or 0.3 -0.4 mm) sieve has to be discarded because it is too fine (small). Only the material which did not pass through this last fine sieve is the coarse sand to be used as potting media ingredient. This can be done with sieves attached to sturdy wooden or metal frames of approx. 120 cm x 120 cm reinforcing the back parts of the sieves with heavy gauge galvanized steel wire in a 1' wide grid, especially the 300 – 400 micron sieve. See fig 1 and 2 below as examples.

Fig 1 Throwing sand through a propped up sieve

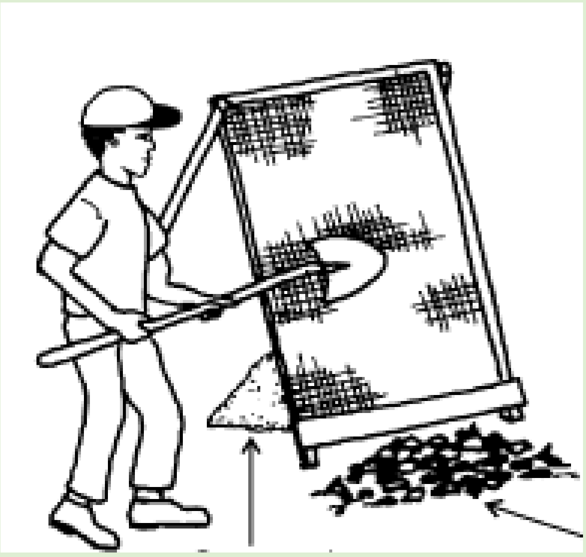


Fig 2 Sieving sand through a hanging frame

There are many adequate commercial materials for sale in India with the required mesh widths, of which galvanized steel industrial sieve materials are the most durable. See examples below in fig 3 and 4.

Fig 3 Commercial 2000 micron mesh sieve

Fig 4 Commercial 200 micron mesh sieve

3.6.2.3.1 Sterilizing coarse sand

After having separated the gravel, grit, roots, etc., from the bulk and sieved the fine sand out, the coarse sand fraction left over will have to be washed to remove dust, harmful dissolved substances and weed seeds and sterilized.

The coarse sand can be sterilized on any clean flat surface reserved for the media preparation (Central Nursery Manual Volume I, Site Selections, Layout and Development) by spreading the wet coarse sand in a 5 -10 cm thick layer on a large black plastic tarp in the sun, covered with a transparent plastic 200 micron sheet (as used for the hygro-pit domes) and leaving it to pasteurize for 4-5 hours or longer, taking care to turn the layer at least 2 times. After the covered pasteurization treatment, the sand can be further disinfected and dried by removing the top transparent sheet and exposing it to the sun, turning the layer now and then. The dried sterilized coarse sand can then be used immediately for the germination beds, root trainers for clonal propagation and for preparation of the growth medium by mixing with compost and other components or stored in the appropriate reserved covere

Fig 5 Coarse sand

3.6.2.4 Organic Material

The following range of organic material are being used irregularly in mixture with soil or sand to produce the growing media for containers at present forest nurseries: animal manures, bagasse, chicken litter, coir dust and 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 view of data available that confirm the most suitable organic materials, below are some points that should be borne in mind in developing Departmental capability:

- Material should have a high fiber content to provide internal water holding capacity (small pores) and yet allow for drainage between particles (large pores)
- If the material appears oily when wet or is slick rather than fibrous when rubbed between fingers, it is unsuitable for container grown plants
- Sufficient pore space within which air can be trapped as roots need oxygen for development and growth
- Ability to mix intimately with soil
- Ability to bind or hold applied substances such as fertilizers

- Should not be a source of fungi, insect pests or weed seeds
- Should be sufficiently decomposed as otherwise there may be ammonia damage to roots and foliage or an initially high demand for nitrogen by micro-organisms which will induce a nitrogen deficiency in plants growing in comparatively fresh material

Compost. With sufficient organic raw material available, compost with the above characteristics can be produced at the nursery site. For this reason and in view of its important role in container seedling production, it is mandatory for each nursery to cover its own compost needs on a continuing basis. In the subsequent paragraphs, the recommended Berkeley Process for compost making is explained. A central shredder close to a source of fiber from which sustained amounts could be transported to nurseries would facilitate this activity.

The following raw materials are suitable for making compost and should be more easily available on a sustained, self-reliant basis:

Cattle dung

Elephant dung from the pilkhanas

Chicken litter

Sludge mostly in the form of compost or partially composted material, and commercial organic matter ('Bioganic').

Weed growth and culled plants at the nursery

Thinnings and coppice regrowth from woodlots

Foliage and branches from trees felled.

Grass and other road side shrubs and vines

Bark residue and sawdust

Straw

Water hyacinth (duly chopped)

[Note: *Whatever mixtures of easily available raw materials are decided upon for composting, they should be continuously used each year once the resulting quality has been verified and found optimal. It is important to maintain constant quality for nursery growth media mixtures, thus compost making has to be standardized in each nursery]*

3.6.2.5 Producing Compost

There are two methods of making compost —Aerobic or "Hot" and Anaerobic or "Cold". In central nurseries it is preferable to use the Aerobic or "Hot" composting since it is faster and economical. Hot process, usually called Berkeley Method of composting takes about 18-21 days where as the Cold composting method takes about 6 months. The reduction of volume is dependent on the type of the raw material used and can be upto one-third.

Each nursery site can have unique materials for composting because all that is needed is a very large supply of low cost vegetative material (green matter shrinks to only a fifth of its original volume during the composting process). For compost production the only machine needed is a straw cutter to chop the vegetative material to fairly small sizes.

Good compost requires careful management of the micro-organisms of which two types are present in the compost-making process:

(1) the normal' type, which occurs in abundance during normal decomposition;

(2) 'thermophilic' (temperature loving) micro-organisms.

The normal microorganisms quickly raise the temperature of the heap to 40°C. At this temperature they die, leaving the thermophilic micro-organisms to continue digestion. These heat-loving organisms operate very quickly, raising the temperature considerably and using up oxygen rapidly. They die if the temperature exceeds 65°C, the oxygen supply fails or the heap becomes either too dry or too wet. Thus the art of making good compost quickly lies with the care of the thermophilic micro-organisms.

Nursery managers must monitor the C:N ratio, chop up vegetable matter into small pieces of similar sizes, ensuring adequate but not excessive moisture, supply enough oxygen and ensure that the temperature does not exceed 60°C. Temperature and oxygen control are linked because, by lifting and turning the heap, temperature is reduced and oxygen is supplied.

Composting Materials and the Carbon-Nitrogen Balance

Many ingredients used for composting do not have the ideal ratio of 25-30:1. When using aerobic composting methods, an assessment of how quickly materials decompose, should be made and then a blend of things that rot quickly and things that rot slowly should be used.

- Composting materials with a very low C:N ratio of 7:1 would rot very quickly, because they are high in nitrogen, e.g. fish, this decomposes very quickly
- Composting materials with a very high C:N ratio of 500:1 would take a long time to decompose, because they are low in nitrogen, and need to be broken up, e.g. tree branches

For example, if the C:N ratio is too high, it can be lowered by adding manure or grass clippings. If the C:N ratio is too low, it can be raised by adding cardboard, dry leaves or wood chips.

- The materials containing high amounts of carbon, but low in nitrogen are considered "browns"
- The materials containing higher amounts of nitrogen are considered "greens."

The average C:N ratios for some common organic materials used for composting are given in table 5 below:.

Table 5 **Some C : N ratios of common composting materials:**

Browns = High Carbon	**C : N**
Wood chips	400:1
Cardboard, shredded	350:1
Sawdust	325:1
Newspaper, shredded	175:1
Pine needles	80:1
Corn stalks*	75:1
Straw*	75:1
Leaves*	60:1
Fruit waste	35:1
Peanut shells	35:1
Ashes, wood	25:1
Greens = High Nitrogen	**C : N**
Garden waste	30:1
Weeds	30:1
Green Wood**	25:1
Vegetable scraps**	25:1
Grass clippings	20:1
Seaweed	19:1
Horse Manure	18:1
Cow Manure	16:1

* *With ratios between 75:1- 60:1 or above, Urea needs to be added to reduce C:N ratio to about 25-30*

** *25:1 is balance C:N for start up*

In the aerobic composting method, the ratio of carbon to nitrogen in the compost materials needs to be between 25 to 30 parts carbon to one-part nitrogen by weight. This is because the bacteria responsible for the composting process require these two elements, in these proportions, as nutrients to construct their bodies as they reproduce and multiply.

*Materials that are high in carbon are typically dry, "brown" materials, such as sawdust, cardboard, dried leaves, straw, branches and other woody or fibrous materials that rot down very **slowly.***

*Materials that are high in nitrogen are typically moist, "green" materials, such as lawn/grass clippings, fruit and vegetable scraps, animal manure and green leafy materials that rot down very **quickly***

Berkeley Method Composting Step by Step

The hot composting method, the ***Berkeley method***, developed by the University of California, Berkley, is a fast, efficient, high-temperature, composting technique which will produce high quality compost in 18-21 days. The requirements for hot composting using the Berkley method are as follows:

- Compost temperature is maintained between 55-65 degrees Celsius
- The C:N (carbon: nitrogen) balance in the composting materials is approximately 25-30:1
- The compost heap needs to be 1.5 – 2 m high
- If composting material is high in carbon, such as tree branches, they need to be broken up, such as with a mulcher
- Compost is turned from outside to inside and vice versa to mix it thoroughly

With the 18 day Berkley method, the procedure is quite straightforward:

1. Build compost heap
2. 4 days – no turning
3. Then turn every 2nd day upto 18-21 day

Start preparing the bases for the compost heaps in the assigned areas of the nursery by measuring out (for each of the 2 heaps) **2** areas of 2 x 5 m. One will be the area on which the compost heap will be started, the adjacent area (base) will be where the material will be deposited when turning the heap. The soil of each 2 x 5 m area will have to be loosened to a depth of at least 20cm with a spade or pick ax, then loosely covered with branches of 3 – 5 cm diameter and twigs, layered cross wise up to 40cms high. The compost heap can be built up on top of these beds of branches layer by layer till the required height of roughly 2 m.

Day 1 Mix together shredded ingredients by laying them in alternating layers of "greens" and "browns". Add an activator by thinly sprinkling either old compost or some top soil over each 20 – 30 cm layer, then wet the layer spraying water over whole surface before adding mixed shredded ingredients for the next 20 – 30 cm layer. Keep adding layer by layer sprinkling activator and wetting each till the desired height of approx.2 m has been build up.

A heavy gauge black plastic tarp can be thrown over the compost heap, weighted down at the corners (and center if felt necessary) with stones tied to sturdy ropes attached to the tarp corners in case of prolonged heavy rainfall.

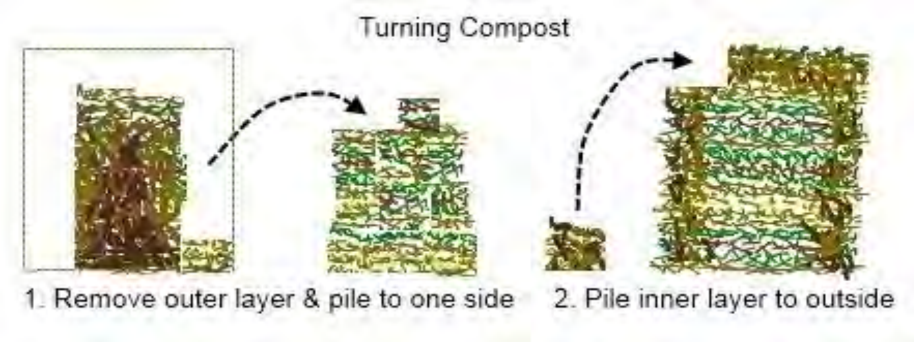
Day 4 Turn the compost heap over, outside turned inside, inside turned outside on the marked off and prepared base next to the heap. When turning the compost, move the outside of the pile to a spot next to it, and keep moving material from the outside to the new pile. When done, all the material that was inside will be outside and vice versa.

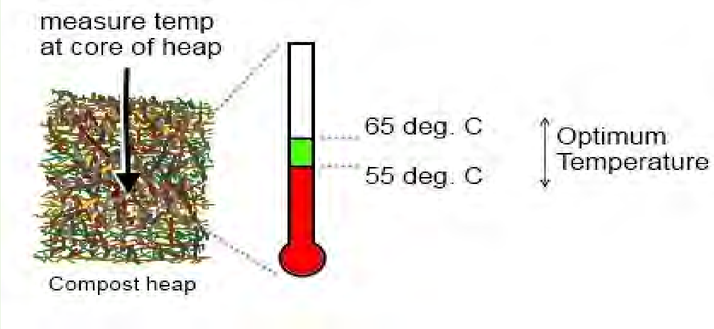
[Note: *Ensure that moisture stays constant. Squeeze a handful of the compost materials, this should only release one drop of water, or almost drips a drop].*

Day 6 & Day 8 The compost heap should reach its maximum temperature on these days. As a simple guideline, if the arm can be put into the compost heap up to the elbow without experiencing discomfort, then it is not at 50 degrees Celsius, and is not hot enough. It is suggested to use a compost thermometer or a cake thermometer. The optimum temperature is 55-65 degrees Celsius. At temperatures over 65 degrees Celsius a white "mould" spreads through the compost, which is actually "fire blight", an anaerobic bacteria. Temperature peaks at 6-8 days and gradually cools down by day 18.

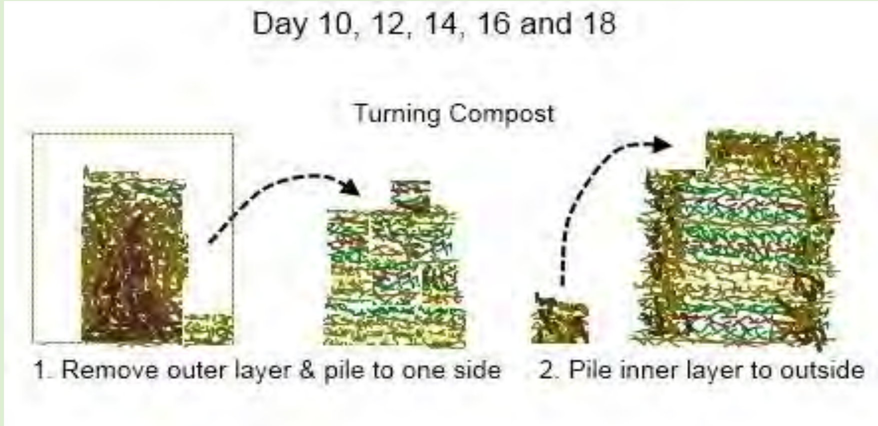
Turn the compost heap over every second day (on day 6 and again on day 8).

- *If the compost pile starts coming down in size quickly, there is too much nitrogen in the compost.*
- *To heat up the compost faster, adding handful of chicken manure per pitchfork or urea at the rate of 10.0 gm. per m*^{3} *of heap size when turning speeds it up.*
- *If it gets too hot and smelly and goes down in size, it has too much nitrogen, need to slow it down, throw in a handful of brown material per pitchfork when turning.*
- *Using the Berkley method, methane is released from the compost.*





Day 10 to day 18 Continue to turn the compost every second day.



Day 18

The compost is ready when it looks brown - it should have the consistency of coarsely ground coffee. Whether the compost is ready or not, can be determined by placing two handfuls of the material into a plastic bag and leave the bag sealed for 24 hours in a dark place. If there is no odour on opening the bag or heat is noticeable, the compost is ready. The ready compost can then be removed from the bed and stored. A plastic sheet with fine holes placed over the heap will allow the compost to breath but will prevent weed seeds from entering.

Compost, pasteurized by the "hot" Berkeley Composting process, should be sieved through the coarse 2000 micron sieve after sun drying before use. Dried sieved compost can be stored for a long period if it is bagged and stored in a cool and dry storage shed.

3.6.2.6 Mixing the Growing Media

The nursery operator must take steps to ensure that quality of the growing medium ismaintained.Some hints for maintaining quality media are:

Proper mixing and handling procedures:

1. The aim is to have a homogeneous mixture with the same measured inputs for each batch.
2. Variability between growing medium batches can result in undesirable differences in plant growth and quality.
3. Mixing should be done with a clean cement mixer.
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 growth media should be available when needed, it is important to make plans well in advance of the production cycle.

Mixing growing media components:

Mixing the growth media thoroughly is very important. Therefore a clean cement mixer should be used, adding prescribed proportions of all dry ingredients each time.






3.6.3 Root trainer – containers

For many years in both temperate and tropical forest regions, root trainers have been used to successfully grow high quality trees. They come in many shapes and sizes, but all have two characteristics in common:

- Vertical ribs
- Athumb size hole at the bottom.

Root trainers are made with black HDPE material of the following dimensions:

150 cc capacity: Inner diameter 51mm, outer diameter 55mm, wall thickness 2mm, length 101 mm, inner ridges 05 nos., inner ridge height 2mm, outer ring 1.5 mm from top, ring thickness 2mm.

300 cc capacity: Inner diameter 71mm, outer diameter 75mm, wall thickness 2mm, length 129 mm, inner ridges 05 nos., inner ridge height 2mm, outer ring 1.5 mm from top, ring thickness 2mm.

The vertical inner ribs direct the roots straight down as they grow, thus avoiding the root deformities caused by smooth plastic bags. The containers are suspended in suitable stands above the ground, so that air circulates around the bottom hole. The stands should be at least 1 m off the ground to allow for air pruning. This height also provides working comfort and efficiency. Root trainers can be made to suspend from the gap between parallel metal bars in specially constructed raised iron beds as is the case for the central nurseries of the WBFBCP, or can be made from chicken wire and placed on bricks with wooden supports. Roots are air-pruned as they emerge from the container. This natural pruning of the main roots encourages growth of secondary roots so that eventually the volume of the root trainer is filled with a 'plug' of fibrous roots, as shown below.

When the seedling (QPM) is planted in the field, the pruned roots continue to grow again. The right size of the container depends mostly upon seed size and some testing may be necessary for each species. Since the volume of root trainers, 60–300 ml, is usually much smaller than that of plastic bags (bags are usually 1/2–3 liters), only a rich organic substrate such as the coarse sand and compost as recommended in this manual can be used. The media mixture must be well packed in each container, but not too tightly, and well-watered before inserting the seed or cutting, or pricked out seedling. Another great advantage of root trainers is that they are easy to fill, which improves labour productivity.

Root trainers are more expensive, but can be reused for many years, if properly maintained. Root trainers are not simply a different container. They require a big change in nursery management. Different substrates are used, different support systems are needed and watering regimes may increase. Their main advantage is in producing plants that are free of root deformities, with extremely fibrous root systems and a balanced root to shoot ratio. They are also easy to transport to the field without damaging the root system.

3.6.3.1 Storage of used Containers

Used containers (Root Trainers) should be emptied of remaining growth media and stored out of the sun in a protected place far removed from the raised beds and especially from the germination and root cutting beds (hygro-pits) as they can easily contain harmful pathogens and infect the young seedlings being produced. To this end each nursery has a designated place close to the raised water tank and the container washing and disinfection tank. To leave them in a heap in the sun as in the picture below, is not only unwise from a plant health point of view, it will also greatly diminish their useful life time.

How NOT to store containers.

3.6.3.2 Disinfecting and storing clean Containers

When the time approaches for the soiled containers to be reused, or in days when no urgent work is to be done, soiled containers can be washed first in the special washing tank near the soiled container storage area and the raised water tank. After washing, draining the soiled water and cleaning the tank, the washing tank should be refilled with the usual form of chlorine in household Bleaching Powder or Potassium Permanganate. To use these as a sterilant, make a 10% solution (1 part bleaching powder or potassium permanganate to 9 parts water) and soak containers in it for at least 30 minutes. The use of a few drops of dish washing liquid helps prevent air bubbles rising to the surface. Chlorine is deactivated by dirt particles. Therefore clean all material to be sterilized thoroughly before putting it into the solution. Make a fresh solution each time you need it, and replace when dirty. The sterilized containers can then be stored in the “clean container storage” space close to the media mixing area and hygro-pits for immediate or later use. Annexure III

3.6.3.3 Filling containers

Containers will be filled by hand with the prescribed media mixture. Although filling containers might sound as a straight forward and simple procedure, this is a laborious process and care must be taken that the containers will indeed be filled completely while neither compacting the substrate too much by tamping down on the media with force, nor packing them too loosely leaving large open air pockets. Rigorous training of staff and close supervision is mandatory for this activity as all future results depend on it. The prepared mixture should be made humid (not wet) before using it to fill the root trainers, this is to prevent further compaction by expansion of dry potting mixture when watered the first times

3.6.3.4 Media compaction in containers

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 often results in seedlings growing in half or partially filled containers.
The large gaps in the potting media may induce deformity of roots at an early stage.

Over compaction can have several effects on the physical, chemical and biological properties of a growing medium. 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 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. Once the roots experience prolonged water logging resulting in lack of aeration and other adverse effects of over compaction make them prone to fungus infection, root rot and insect damage as demonstrated in fig 5 below.

Fig 5

Root trainer with bottom 2/3 filled with over compacted organic material (top soil or compost) and top 1/3 with fine (not coarse) sand demonstrates both the dangers of over compaction and the use of fine instead of coarse sand.

Note lack of rootlets in top 1/3 and insect larva just under sand layer. The arrow points to grub.

3.6.3.5 Checking Growth Media with "Pour Through" Method

Before filling up the containers the growth media should be tested for the availability of nutrients, pH and EC.

The availability of nutrients can be estimated by measuring how well the leachate (the solution that drains from containers) conducts electricity. Pure water does not conduct electricity. Electrical conductivity increases proportionally, however, with the dissolved salts (nutrients from fertilizers) present in the solution. Therefore, measuring electrical conductivity (EC) indicates the nutrient concentrations available to container-grown plants.

By measuring the electrical conductivity (EC) and pH of growing media and irrigation water, nursery managers can monitor nutrient availability and scout for problems. This is not time consuming, complicated, difficult to learn nor is it expensive. The present section intends to explain how to use the Pour Through extraction procedure and its interpretation as part of the nursery quality control program.

Pour-through Extraction Procedure : For testing the potting mixture, at least 10 root trainers should be filled up with the potting mixture. The root trainers are then saturated with irrigation water. 30 minutes to two hours after saturation, approximately 1/8 cup (30 milliliters) of water should be poured over the surface of a 150 ml container or 1/2 cup (120 milliliters) over a 300 ml container. To obtain about 25-30 ml of leachate more water may be required to be poured, if the container mix contains organic substrate amendments.

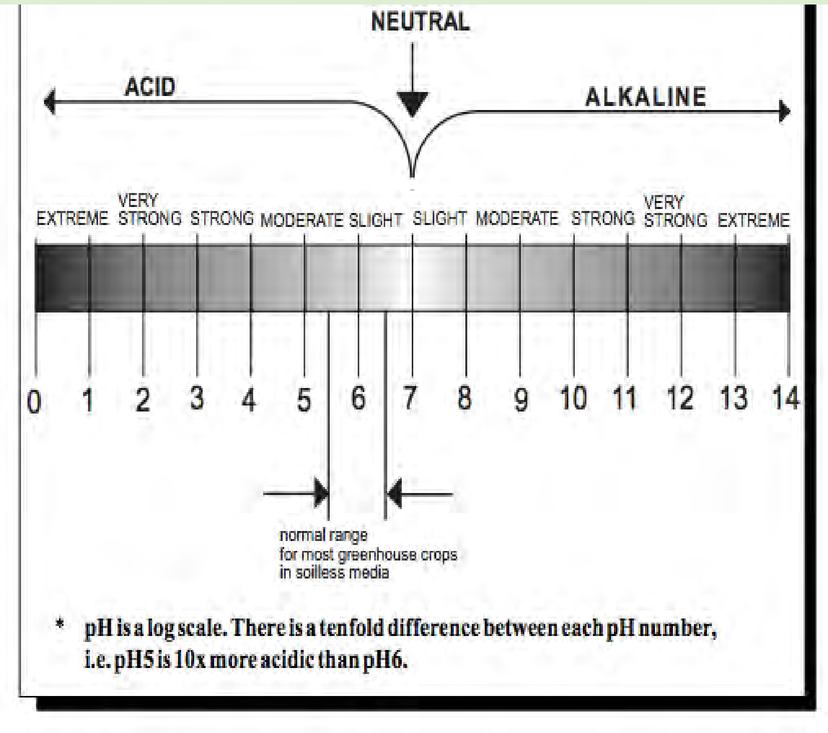
It is important to remember that the Pour Through extraction procedure provides an average of EC and pH concentrations in the container. Conductivity and pH equipment should be readily available to nursery managers and they should be trained to use and calibrate the equipment using clean, fresh standards. Calibrating both pH and EC equipment should be done before use or each time before testing a group of solutions, and between samples.

Equipment: A variety of equipment can be used to monitor pH and EC. Equipment usually can be purchased as a pen or a meter. Many horticulture or nursery supply companies carry pH and EC testing equipment and standards. Most pens and meters are temperature compensating, however read the information that comes with the equipment to determine if any adjustments are necessary related to environmental conditions. With purchase of a pH meter or pen, a pint of pH 4 or 7 buffer (standardizing) solution should also be procured. A standard solution should also be purchased with EC pens and meters to assure that the equipment can be calibrated to work properly. Glass pH electrodes are usually necessary for dependable pH readings, although they do not last forever. When a pH pen or meter will no longer standardize using the pH 4 or 7 buffer, it's time to replace the pen or the electrode. They last longer if they are left in pH buffer (4 or 7) and not left dry when stored. A normal life for a pH electrode may be 2 years, but it's a good investment if it is used during its' life and not set on a shelf and left to dry out. An electronic pH meter provides the most accurate and practical means of on-site testing.

Interpretation of results—pH :

pH : The pH of the growing medium and the irrigation source can affect the availability of nutrients in solution, and the health of root systems. Most plants have a relatively narrow range of preferred pH levels. The pH scale and the preferred range is 5.5 - 6.5 as shown in fig. 6 for most broadleaf tropical tree crops grown in organic substrates. Acid tolerant seedlings (trees), such as *Pinus spp* and to a lesser extent *Eucalyptus spp*, are usually grown at pH 5.0 - 5.5.

Fig 7 Preferred pH ranges for broad leaf tropical tree crops



Potting mixture leachate should give results in the range of 5.5 - 6.5 to prevent growth problems later on during the production phase.

pH deviations, possible causes and amendments			
pH	**Possible reason**	**amendment**	
Too high > 7 Check water*	Coarse sand is not sand at all but consists of calcium carbonate or dolomite (calcium magnesium carbonate), both of which are white in color.	**Do not use,** and acquire sand from alternative source. Check color, anything from black to golden brown will be good except white sand.	
	Burned rice chaff has not been washed properly (unwashed burned rice chaff will give pH 8.5 or higher measured on its own)	Wash the burned rice chaff thoroughly and test again (burned rice chaff only) it should be close to pH 5.4	
Too low < 5 Check water*	Compost is probably acid due to wet cold composting	Liming of potting mixture with 1.5 Kg of $CaCO_3$ per M^3 will raise pH 1 point (i.e. from 4.5 – 5.5) or add 820 g wood ash per M^3 to the same effect. If the pH has to be raised more than 1 point add a mixture of both in same quantities to raise pH 2 points (i.e. from 4 – 6) *	

Potting mixtures with a pH substantially lower or higher than the indicated range of pH 5.5 – pH 6.5 should not be used. Each component (coarse sand, compost, burned rice chaff) of the mixture should be tested separately to find out the cause of this deviation and appropriate measures should be taken. This means that if say the coarse sand fraction has on its own a very high pH of 8 or higher it should not be used, but another source should be found as the present source consists not of sand (which is mostly quartz particles) but of calcium carbonate or dolomite ($Ca.Mg\ (CO_3)_2$ = Calcium Magnesium Carbonate). Although the pH of both the compost and the burned rice chaff fractions should be well within the required range they also have to be tested and pH amended if necessary

* Before anything else, if PH deviates from desired range, check pH of irrigation water used for testing to make sure it is not contaminated and has a very high or very low pH itself. pH irrigation water should be around 7.

* *The quantities above are to be used as a "rule of thumb" because the exact quantities for pH amendment depend on the CEC (Cation Exchange Capacity) of the mixture. Therefore a CEC analysis may to be done first. If the CEC is very low (less than 30 meq/100g), only 1/3 of the recommended quantities can be used to achieve the same result.

Electrical Conductivity or EC : Fertilizers and other dissolved salts change the ability of a solution to conduct electricity. Pure water is nota particularly good conductor, but as the salinity level increases, its conductance also increases. Saltmeters (conductivity meters) are used to measure the electrical conductivity of solutions. This providesa rough idea of the fertilizer content of the irrigation water and the media solution. One factor that must be kept in mind is that not all salts are fertilizers. Some water sources are high in non-fertilizer minerals that tend to increase the overall conductivity. So while EC measurements are a good indicator of relative fertility levels, particularly if measured regularly and tracked over time, it is important to establish the non-nutritional background content of irrigation sources and to have an occasional complete mineral analysis performed by a testing laboratory to determine the balance of nutrients in the media.

Interpretation of results—EC

Table 1. Interpreting potting media leachate testing results*

EC reading in mS (or mmhos)

1:5	1:2	SME	Pour-Through*	Indication
0 to 0.12	0 to 0.25	0 to 0.75	0 to 0.9	Very low. Nutrient levels may not be sufficient to sustain rapid growth.
0.12 to 0.35	0.26 to 0.75	0.76 to 2.0	1 to 2.6	Low. Suitable for seedlings, bedding plants and salt sensitive plants.
0.36 to 0.65	0.76 to 1.25	2.0 to 3.5	2.7 to 4.6	Normal. Standard root zone range for most established plants. Upper range for salt sensitive plants.
0.66 to 0.89	1.26 to 1.75	3.5 to 5.0	4.7 to 6.5	High. Reduced vigor and growth may result, particularly during hot weather.
0.90 to 1.10	1.76 to 2.25	5.0 to 6.0	6.6 to 7.8	Very high. May result in salt injury due to reduced water update. Reduced growth rates likely. Symptoms include marginal leaf burn and wilting.
> 1.1	> 2.25	> 6.0	> 7.8	Extreme. Most crops will suffer salt injury at these levels. Immediate leaching required.

The preferred range of EC for broad-leaved tropical species in the Pour Through method is 2.7 to 4.6 mmhos/cm or microS/cm

Potting mixtures with an EC substantially lower or higher than the indicated range of EC 2.7 – EC 4.6 should not me used. Each component (coarse sand, compost, burned rice chaff) of the mixture should be tested separately to find out the cause of this deviation and appropriate measures should be taken. **If found deviating the most like source is the irrigation water**

EC deviations, possible causes and amendments		
EC	**Possible reason**	**Amendment suggested**
Too high > 5 Check water*	Contamination of one of the ingredients	**Do not use,** check each ingredient first and thoroughly wash with clean water before testing again. Find alternative non-contaminated source for affected potting media ingredient.
	Course sand fraction might be salty unwashed sand from beach?	Wash coarse sand thoroughly and test again. It should be close to EC 2 or lower.
	Compost raw materials where contaminated through industrial waste (water hyacinths from contaminated canals might be the cause)	Use compost made from different raw materials in the future. Try washing contaminant out and test again
Too low < 1	Very unlikely. Will only occur if all potting media ingredients have been washed too much or if Pour Through has been done with too much very clean water.	Add small amounts of wood ash to mixture. If pH is low also, amend pH first and test again. If pH is in reasonable range add 100 g of wood ash per M^3

* Before anything else, if EC deviates from desired range, check EC of irrigation water used for testing to make sure it is not contaminated and has a very high or very low EC itself. EC irrigation water should be below 2.5

* *The quantities above are to be used as a "rule of thumb" because the exact quantities for pH amendment depend on the CEC (Cation Exchange Capacity) of the mixture. Therefore a CEC analysis may to be done first. If the CEC is very low (less than 30 meq/100g), only 1/3 of the recommended quantities can be used to achieve the same result.

Media Testing Record Keeping : Growing media should be tested for salts and pH for each batch of potting mix. It's important to keep records so that pH and EC levels can be shown on chart against the raw materials used for potting media. It will enable to make informed decisions about the raw material used for making potting mixture.

3.6.4 Raised beds

All containers, independently of the species of tree seedling or size of root trainer will be placed in raised beds. The clonal *Eucalyptus* root cuttings will be placed first in hygro-pits to induce root formation. These will also be placed in raised beds once rootlets have formed. All raised beds are frames equipped with parallel interior metal bars separated according the different container diameter sizes to be used, with about 60 cm high legs.

Note: *Parallel holding bars to accommodate the containers are chosen instead of a metal grid, because the bars permit to move the containers apart so they can be separated from each other on development to prevent crowding, light competition and thus excessive growth in height of the seedlings*.

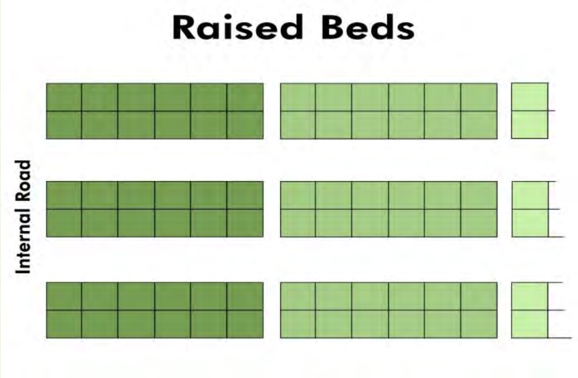
Each upper corner of the beds is fitted with a welded support angle to hold the legs of another raised bed frame so they can be stacked one on top of the other to facilitate efficient transport for out-planting. (See Fig 10)

Fig 8 prototype raised bed

Fig 10raised beds stacked for transport

Each raised stand holds about 150 nos. containers of 150 cc size per m^2 and about 100 nos. containers of 300 cc size per m^2. The raised stands are built in segments of about 1 m^2 each. If 6 nos. stands are placed in double rows with a gap of 1 m for easy passage between double rows of stands (Figure 11) , about 1150 m^2 space will be required for the 100,000 seedlings in 150 cc container and 1,750 m^2 for 100,000 seedlings in 300 cc containers, or a total of about 3,000 m^2 production area will be required to produce 2,00,000 seedlings with raised containers.

Fig 11 Banks (groups) **of** raised bed elements as nursery beds perpendicular to internal nursery road



3.6.5 Eucalyptus clonal propagation

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 asexually are cuttings, air layering, grafting and micro propagation. In the WBFBCP Central Nurseries, high yielding *Eucalyptus spp* clones will be produced through rooting of cuttings, a well proven method long in use with the WBFD, which has acquired the necessary knowledge through research and empirical experience to sustain yearly production of excellent seedlings.

3.6.5.1 Cuttings

The conditions needed for good results from cuttings are:

- High humidity

- Full light intensity
- Protection from pests and diseases
- Absence of water logging
- Absence of windy conditions
- Appropriate rooting medium
- Use of root promoting hormone

Maintaining high air humidity is perhaps the most important issue 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 desiccation before rooting is the major cause of the lack of success in propagation by cuttings. High humidity will be maintained in the "**Hygro-pits",** plastic lined 30 cm deep trenches filled with sterilized coarse sand and covered with a transparent plastic sheeted dome. Root trainers (filled with coarse sand and potting mixture as explained further down) with one cutting each are placed in trays, and trainers are inserted in the coarse sand medium which has been saturated with water to a level below the trainers tip. After insertion a transparent plastic sheet dome is placed over the pit to maintain constant humidity and protect the cuttings. Occasionally water can be sprayed over the cuttings but the humid micro-climate should sustain itself automatically.

3.6.5.1.1 Hygro-pits are dug outpits (Figure 11) with dimensions of 100 cm wide x 400 cm long and 10 cm deep and are lined first with agricultural plastic and then filled with sterilized coarse sand. These hygro-pits will be covered with domes of 410 x 135 x 70 cm made of PVC pipes, covered with 200 micron plastic with a 15 x 15 cm ventilation hole cut at top of each face. (Figure 14). The root cuttings hygro-pits as well as the germination hygro-pits will be situated at the edge of the removable shade area.

Fig 11 Hygro-pit , lined with plastic, filled with course sand and covered with a plastic dome

3.6.5.1.2. Hygro-pits for rooting of clonal cuttings

For clonal reproduction, cuttings dipped in a growth hormone in powder medium and directly placed in 60 -75 cc root trainer containers filled with sterilized course sand, or vermiculite should be placed in trays (Figure 12) in coarse sterilized sand filled hygro-pits (Figure 13).

Figure 12 Trays for holding containers

Figure 13 Hygro-pit for root cuttings

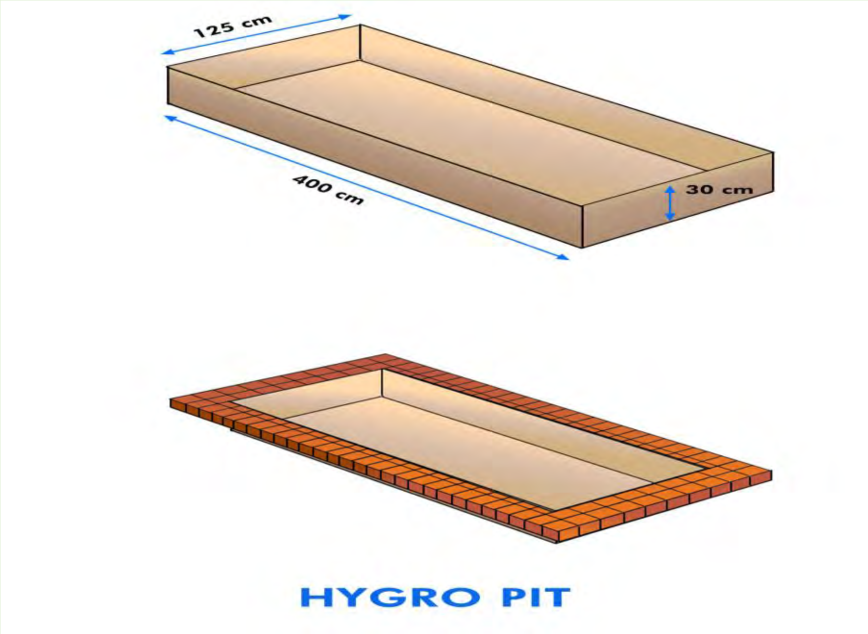


Fig 14 Domes over Hygro-pit

These pits (Figure 13) will be 125 cm wide x 400 cm long and 30 cm deep, lined first with agricultural plastic and then filled with sterilized coarse sand. Each pit is surrounded by a double line of bricks to better support to the dome and will be covered after placement of trays with domes (similar to the germination hygro-pits) with dimensions 410 x 135 x 70 cms made of PVC pipes and covered with 200 micron plastic with a 15 x 15 cms ventilation hole cut at top of each face. After about 3 weeks the rooted cuttings will be placed directly with their 60 ml root trainer containers in raised beds after which the hygro-pits will become available for the next batch of cuttings. As is the case in the other nurseries with the germination hygro-pits, the rooting hygro-pits will be situated at the edge of the removable shade area. The containers with rooted cuttings in their raised beds can either be placed directly in the open growing area or preferably, first placed in a removable shade area (50% agronet shade).

After every charge the sand used in the Hygro-pits should be replaced with sterilized coarse sand.

3.6.5.2 Hygro-pit Propagation

Hygro-pit propagation is a mechanical way of maintaining following ideal conditions, conducive to root formation for the clonal cuttings:

- high temperature and high humidity
- reductions in moisture loss by evaporation and transpiration

3.6.5.3 Production process

Cuttings (Ramets): Adjacent to the nursery an area depending upon the clonal production requirements, a Clonal Multiplication Area (CMA) will be established with required clones planted in 1 x 1 m square grid.

Note: *Development of these CMAs will require large amounts of irrigation water to guarantee timely production capacity and coppicing response. The CMAs have to be close to a good permanent water source with a water pump and at least primary irrigation lines for gravity irrigation.*

When stem diameters have reached approx. 12cm, 1/3rd area of the CMA can be coppiced for cutting production. The next 1/3rd area can be coppiced 20 days later and the last 1/3rd area after that to have a continuous supply of cuttings for reproduction. Cuttings should be harvested early morning 45 days after coppicing when they are pencil thick. It is important to prevent mother trees from weakening. The removal of cuttings should be made carefully and the number of coppice cycles restricted to 5 times a year in order to maintain the coppice vigour of the mother plants of the CMA. Replanting of the CMA with selected clones should be done preferably every 4th year.

Cropping of coppice shoots and Cutting preparation: The cropping of coppice shoots of mother trees is governed by a certain number of parameters which determine the rooting ability:

- The coppice shoots to be used for cutting preparation should be flexible (not too hard or soft) and perpendicular to the ground
- The minimal number of well coloured and developed leaves is fixed to four (without counting the bad coloured and young leaves).
- The rooting ability decreases quickly as soon as ramifications appear on the shoots: one must imperatively propagate by cuttings before this stage.
- The shoots are cut off just above the leaves of the lower part in order to initiate two new shoots at this level.
- *The cut coppice shoots are immediately placed in a water filled vessel to avoid their wilting.*
- The minimum size of the cuttings allowing its handling is about 5 cm
- The cutting should contain at least one node and the attached leaves should be clipped to at least 1/3rd the size to prevent loss of water by transpiration.

The morphology of the shoots moves according to the season:

- In the winter the internodes are short, the leaves small and well coloured.
- From spring to summer the internodes grow longer, the size of leaves increases and they take their coloration more slowly.

To avoid too much ramification of the mother plant (of CMA) which would lead to the production of shoots unsuited to rooting; the level of the cut on the mother plant (of CMA) is lowered from time to time.

Initiation of rooting in cuttings (ramets): The cuttings are dipped in a fungicide solution (six grams Benlate per ten liters water or 1% aqueous solution of Chlorpyriphos), then drained before hormonal treatment. This treatment is essential. After disinfection, the lower part (i.e; maintaining the polarity) of the cuttings are dipped in a Auxin-talcum powder mixture (usually

5500 to 6000 ppm of IAA). Excess hormone should be shaken off. Before inserting the cuttings in the potting mixture a hole (preferably in a conical shape) should be made with a *sterilized pointed stick* having a diameter bigger that the diameter of cutting, followed by placing the cutting in the hole. The hole is made to prevent wounding the herbaceous stem or scraping of the hormone.

Containers, media, insertion in Hygro-pits: The bottom 2/3rdpart of 60 ml root trainers are filled with a coarse sand: compost = 1:1 mixture, and the remaining top 1/3rd part filled with sterilized coarse sand only. Trays, with 70 holes each of the 60 ml container diameter, are placed on top of the coarse sand surface of thehygro-pits saturated with water. Holes are made on the impressions of the holes made on the sand surface. The root trainers placed in the trays are then inserted in the holes on the sand surface.

The Hygro-pit sand should be kept saturated with water by spraying water from time to time. Also suitable fungicide solution should be sprayed as a routine measure every10 days.

Placement of rooted cuttings in raised beds: About 2-3 weeks after insertion, the cuttings will have formed sufficient rootlets to be removed from the Hygro-pits. Containers with tray are carefully pulled out of the sand and then placed directly in the appropriate sizes of raised beds (container and all) in the removable shade area for 25 – 30 days and subsequently in the open growing area.

Nutrients: Regular watering with knapsack sprayers should be done. Oilcake solutions should not be used in nursery. As the root trainers are filled up with potting mixture upto 2/3rd volume no nutrient should be required. However, if the root trainers containing the ramets (cuttings) stay in the nursery longer than six months the growing media level would have gone down and containers can be topped off with the compost or potting mixture containing compost and coarse sand in 1:1 ratio. Nutrients should not be applied as foliar spray. Broad spectrum water soluble fungicide / insecticide may be applied as foliar spray as and when required.

Timing of production: The end of the hardening off generally takes place two months after the insertion of the cutting in the rooting medium. At the end of this period the rooted cuttings are developed enough to plant out. Estimated duration between the insertion of the cutting and the first crop on the new mother tree is 45 days after coppicing and the duration between the insertion of the cutting and its possible transportation for afforestation (15-20 centimeters high) is 75 days.

3.6.6 Seedlings production

3.6.6.1 Seed Stratification and Germination

Dormancy:

The duration of dormancy in seeds is species specific. It varies from a few months to many years.

The controlling factors that impose dormancy are many e.g., the strength or the susceptibility of seed coat, ability of the seed to absorb and utilize water or oxygen, presence of inhibitors and environmental factors like temperature, water, day length, etc.

Breaking of Dormancy:

There are many types of dormancy and each type can be interrupted in a specific manner. Considering the many species to be propagated for the project's afforestation program it is obvious that also many different **"Dormancy Interruption Methods"** have to be used. The WBFD has accumulated specific guidelines for each of the species to be used, based on research and empirical observations. In Table 6 recommendations for dormancy interruption of some of the species to be planted are listed:

3.6.6.2 Germination beds

Immediately after the dormancy interruption treatment has been completed, seeds will be either sown in the Germination Hygro-pits or in case of large seeds, dibbled directly into root trainers in raised beds. Germination hygro-pits are similar to the root cutting hygro-pits, they are also lined with plastic sheets, filled with sterilized coarse sand and covered with a removable plastic sheet dome, but need be less deep, 10 – 15 cm depth of coarse sand is sufficient for an adequate moisture regime. Seeds are spread over the surface of the wet coarse sand in the germination hygro-pits and covered with a layer of sterilized coarse sand, equivalent to the thickness of the seed, after which the surface will have to be thoroughly wetted with clean water and the pit covered with the dome. Occasional checking for wetness of surface and corrections when necessary is the only intervention necessary till germination commences.

Seeding time, Germination period and root trainer sizes for some of the species to be planted under the project are given in Annexure II table 7.

3.6.6.3 Post germination operations

Pricking out

Pricking of seedlings from hygropits should be started as soon as two leaves emerge and should be completed within 7 days. The rest of the seedlings should be discarded. While pricking, the seedling should not be plucked out forcibly, or else they may get damaged. The best practice would be to use a sterilized pointed stick or small fork shaped metal to loosen the growing medium without damaging the root and gently pull out the seedling holding the leaves. The collar zone should not be held while pulling out the seedling. After pricking out, the seedlings should be immediately planted in the root trainer packed with potting medium. Before planting in the root trainer, a hole should be made in the potting medium with a pointed stick, in which the seedling should be planted.

Culling

The culling operations of seedlings may take place 21 – 25 days after germination. The aim is to raise as even and uniform vigorous plants as possible in every root trainer. These operations should take place in the shade protected from wind and sun. Late germinators, diseased or drying seedlings should be culled every week or when observed keeping the beds healthy and hygienic.

Generally the best is to cull and grade the seedlings on the basis of plant form rather than height growth. The good seedling is balanced in height, has a thicker stem collar, rich branching and fresh leaves. Slender and tall seedlings without branches or with inadequate leaves along full stem should be culled out. Only good seedlings will be planted in the root containers. Overgrown plants with long stems have a low root : shoot ratio which means a larger stem mass has to be supported by the lower root mass on transplant, making field establishment difficult compared with seedlings with a high root : shoot ratio.

First culling: Seedlings planted in containers are generally culled out at the time of transfer of plants from the protected removable shade area to the hardening area. At this stage diseased and inferior seedlings are culled out.

Second culling: Unlike fast growing species (150 ml root trainers) culled after having been moved from the removable shade area into full sun as described above, seedlings of slow growing species (300 ml root trainers) like Sal will be culled 6 weeks after germination of seeds (first culling), while the second culling has to be done 5 months later. No grading (placing plants of similar sizes and shapes together) should be done at this stage.

Final culling: Sample measurements for height and collar diameter of plants ready for out planting should be carried out to enable grading.

- A random sample of 50 seedlings per lot is measured in height (from media surface up) and root collar measured at base. Calculate average (mean) of height and collar diameter and standard deviations of both the parameters.
- Eliminate seedlings with height and diameter lower than 1 standard deviation from the average (mean). Alternately, seedlings having height 20% above or below the average height /collar girth of the seedlings should be culled. Select a few samples of seedlings to be discarded and use those for comparison to speed up the operation.

Grading

Note: Grading should be done after the culling has been completed. Sal seedlings should not be graded after the first culling, but after the last culling before out-planting.

Grading for all species is done so that similar lots will be sent for out planting to an area to achieve a uniform crop.

The seedling lots of fast growing spp, should be graded after having been processed for culling. Grading will be done on the basis of height and collar diameter in each bed before transportation to the field for out planting, Slow growing spp like Sal etc. spp will be graded only after the last culling just before out-planting.

Culling and grading process justification.

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 pruning can rectify some damages.

Stems: Plants should be sturdy with thick woody collars, stems should be straight but not etiolated and should be able to stand firm without support. Curved stem is usually a sign of abnormal rooting.

Roots: Plants should have a well-developed root system with woody adventive roots and straight taproots without deformations. Those grown in root trainer containers with a good medium mixture and adequate care will show a dense vigorous looking root plug.

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 many Acacia sppretain their juvenile leaves when quite mature and this should not prevent them from being selected for planting in the field. For most species, 30 to 45 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 before the dry season sets in.

3.6.6.4 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 'rougher' treatment should begin not later than halfway through the life of the seedling in the nursery. Seedlings should be exposed to full sunlight well in advance of transporting out.

The main treatment for "hardening off" 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

The following treatment can be applied to facilitate the hardening off process:

- Reduce the frequency of watering
- Reduce the quantity of water
- Cut off fertilizer applications, if any, early
- Expose plants to full sunlight as soon as possible
- Ensure that each plant has adequate space

Nursery managers often leave the practice of hardening off to the last week or two when the first rains have already 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. The seedlings should not be lifted by the stem at this or any stage.

3.6.6.5 Root trainer container sizes and growth media

Choice of root trainer container sizes depend on the time the seedlings will have to stay in the nursery before out-planting, and also the size of the seeds.

The root trainer sizes of some selected species are given in Table 7.

3.6.7 Maintenance

3.6.7.1 Watering

Germination Beds and Root Trainers: ***Watering*** with a knapsack mist nozzles is recommended. Adequate number of filling points must be provided through a network of pipelined in the growing area. The single most important factor in germination and seedling production is water but too much water can be just as harmful as inadequate 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 to adjust the knapsack sprayer nozzles to allow a finer spray. 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 medium moist (but never sodden), by watering preferably in the mornings or evenings, avoiding the mid-day period. Water deposited on the surface of leaves heats up readily in the overhead sunlight, or may have lens effect, causing the tender leaves to scorch.

Note: *If watering in the evenings, make sure to drain the first "hot" water coming out of supply lines, so that the water used for irrigation is cool.*

Over Watering: Excess water is nearly always damaging since the water tends to replace the airin the soil and cause compaction, which in turn restricts the respiration processof the plant. Further, excess water promotes development of fungal diseaseslike 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, which is why watering through knapsack sprayers only is recommended.

Over watering tends to occur in nurseries with poorly drained growing media. That is why coarse sand and not fine sand has been recommended as one of the ingredients of the potting mixture. Over compaction of the potting media in root trainers will also cause poor drainage. It should always be remembered that it is easy toadd waterbut difficultto remove it.

Under Watering: Wilting is one of the early signs of under watering. There is a tendency to apply insufficient water, wetting only the superficial layerof the container. For this reason, it is often necessary to sample some containers, 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.

3.6.7.2 Nutrient applications

The contents of the growth media recommended for most species, should be sufficient to provide the seedlings with an adequate nutrient supply during their in-nursery development stage.

3.6.7.3 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. Most weeds produce large quantities of seed, which are easily, transported by water, wind and also brought in by introduced farmyard manure. No weeds should therefore be allowed to flower and fruit along paths, roadways, unused land or the area of 5 meter around the perimeter fence of the nursery area. 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.

With the medium mixtures used in the central nurseries, no problems should be encountered with weed development in containers due to infected potting media. However if problems are detected it is good to remember that it is more difficult to eradicate weeds after they have invaded seedlings growing in containers, the pre-filled containers may be watered in advance so that any germinated weeds can be removed in advance of transplanting.

3.6.7.4 Erosion control

During the lifetime of the nursery, especially during the first monsoon periods, careful observation should show telltales of erosion in time to take remedial actions. At the first signs of "shoe string" or worse "rill" erosion on internal roads or paths between the beds, measures have to be taken to deviate or slow water flows in order to prevent damage to the bed platforms or other important areas. It is important to keep in mind that all runoff should end in the water harvesting area at the foot of the nursery.

3.6.8 Transport of Plants

This is the final responsibility of the nursery manager before the plants leave his care. All the 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 and vibration on the way from the nursery, wind damage, drying out and sun scorch. Seedlings should be handled as little as possible to minimize 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 transportation:

- From the transplant beds to a waiting area in the nursery
- From the waiting area to the trailer/truck
- From the truck to the plantation site
- From the plantation site to the planting pit.

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 transported and moved at each stage in their raised beds until they arrive at the planting pit. It is important to pack the raised beds tightly so they cannot move about in the truck.

Note: Managers have to ensure all root trainers are accounted for, that empty root trainers are collected in the field after out planting and returned to the nursery.

ANNEXURE I

Nursery Calendars

Table 1 Example of Nursery Calendar used to determine best date for sowing different species

Event	Species		
Out planting date			
Days needed from transplanting to planting out			
Days needed from germination to transplanting			
Days needed from sowing to germination			
Safety margin in case of poor germination or damping off			
Total days needed			
Sowing date	Determined by counting back from anticipated out-planting date		

Table 2 Example of a "Calendar of Nursery Activities" on a monthly basis.

Month	Activity
August/September	• Maintenance of existing seedling stock • Clean nursery • Repair/clean production areas, shade areas, hygro-pits, domed covers, buildings • Repair plant trays/raised beds • Review production program • Check schedules of Seed supplies • Root trainers, check on stock and clean used ones • Work force required: plan requirements per operation • Availability of labor force
September/October	• Continue work from August/September • Start making compost
November	• Acquire coarse sand to be used • Sieve and disinfect coarse sand • Monitor composting • Level areas for raised beds
December-February	• Clean nursery • Prepare hygro pits and domes • Start pre-germination tests • Prepare first batches of compost (sieve, disinfect) • Prepare growth medium • Start filling containers
February-May	• Start sowing seed (over 4 week period)

	• Check germination (week 2) and revise seed estimate to achieve planting goal • Pricking out begins and transplanting into root trainers completed • Finish annual report
June-July	• Clean nursery • Selection/grading begins • Weeding commences • Reduction of watering commences • Hardening off process begins • Last month to order supplies for next year production campaign; seeds, replacement tools, fertilizer, etc. • Check transport availability • Last month to order supplies for next year production campaign; seeds, replacement tools, etc. • Transportation of plants for out planting begins

Seedling development record

Table 3 Seedling development record

Measurements	**Species and Seed Identification Number**		
Shoot Height 30 days			
Stem Diam. 30 days			
Seedling oven dry weight 30 days			
Root development R:S 30 days			
Shoot Height 60 days			
Stem Diam. 60 days			
Seedling oven dry weight 60 days			
Root development R:S 60 days			
Shoot Height 90 days			
Stem Diam. 90 days			
Seedling oven dry weight 90 days			
Root development R:S 90 days			

Seed and Plant Identification Records

Table 4 Example of a Seed and Plant Identification Record

Nursery				
Division/DMU				
Range/FMU				
Beat				
GPS Coordinates				
Species				
Seed and Plant Identification Record				
Particulars	**Identification No.**			
	1/14	**2/14**	**3/14**	**4/14** and so on
Provenance: **Division**				
Range				
Beat				
Pre-treatment, if any				
Date sown				
Method of sowing				
Date of first germination observed				
Date of no further germination observed				
Germination (%)				
Date pricking out started				
Date pricking out completed				
No. pricked out for transplantation in root trainers				
Casualty after 2 months (%)				
No. Culled/ Rejected				
Out-planted in: **Division/DMU** **Range/FMU** **Beat** **Mauza/Block** **JL No./ Compartment** **GPS Coordinates**				
Remarks				

Nursery Stock Registers

Tables 5 examples of Nursery Stock registers.

Species…….…………………….
(Maintain separately for each species)

<table>
<tr><th>Date</th><th colspan="6">Clonal Seedling Stock</th></tr>
<tr><th rowspan="2"></th><th rowspan="2">O.B</th><th rowspan="2">Received/Added</th><th colspan="3">Disposed/Dispatched</th><th rowspan="2">Balance</th></tr>
<tr><th>Mode of Disposal</th><th>Transport to Field</th><th>Total</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Eucalyptus Clone no…………………... ……
(Maintain separately for each Clone)

<table>
<tr><th>Date</th><th colspan="6">Clonal (Ramet)Stock</th></tr>
<tr><th rowspan="2"></th><th rowspan="2">O.B</th><th rowspan="2">Received/Added</th><th colspan="3">Disposed/Dispatched</th><th rowspan="2">Balance</th></tr>
<tr><th>Mode of Disposal</th><th>Transport to Field</th><th>Total</th></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Total Stock

<table>
<tr><th>Date</th><th colspan="6">Total Seedling Stock</th></tr>
<tr><th rowspan="2"></th><th rowspan="2">O.B</th><th rowspan="2">Received/Added</th><th colspan="3">Disposed/Dispatched</th><th rowspan="2">Balance</th></tr>
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</table>

Total Clonal (Ramet)Stock

<table>
<tr><th>Date</th><th colspan="6">Total Clonal (Ramet)Stock</th></tr>
<tr><th rowspan="2"></th><th rowspan="2">O.B</th><th rowspan="2">Received/Added</th><th colspan="3">Disposed/Dispatched</th><th rowspan="2">Balance</th></tr>
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</table>

ANNEXURE II

Pre-germination treatments, dormancy interruption afforestation species.Seeding time, Germination period and root trainer sizes.

Table 6 Pre-germination treatments, dormancy interruption afforestation species.

Scientific name	Local name	Note
Pterocarpus marsupium	Pia sal	Soaking the seeds for 72 hours in cold water or in cow dung slurry for 48 hours
Ougeinia oojeinensis	Panjan	Soak the seeds for 24 hours in cold water.
Dalbergia latifolia	Bija sal	No treatment needed, pods broken and seeded
Symplocos racemosa	Leda	Slow growing- need 1-2 year old QPM for planting
Madhuca latifolia	Mahul	Slow growing- need 1-2 year old QPM for planting, Seeds is sown soon after collection in the nursery beds and covered with a layer of soil of 2 cm thickness
Terminalia bellerica	Bahara	Alternate soaking and drying for few days.
Terminalia chebula,	Haritoki	The deputed seeds should be either treated by fermentation process for a period of 15 to 20 days, or the seeds may be clipped at its broad end and then soaked in water for a period of 2 days and then sown in nursery beds
Anogeissus latifolia	Dhaw	The seeds are sown densely on raised beds, the soil being mixed with large quantity of coarse sand. The bed is well-shaded and 45 cm above the ground. Germination is fairly quick. The seedlings are extremely liable to insect damage. The development of the seedlings is very slow
Schleichera oleosa	Kusum	Slow growing- need 1-2 year old QPM for planting
Buchanania lanzan	Pial	Slow growing- need 1-2 year old QPM for planting
Semecarpus anacardium	Bhelai	48 hours soaking in cold water
Soymida febrifuga	Rahara	Slow growing- need 1-2 year old QPM for planting, Drought resistant, it can be tried in drought prone areas.
Azadirachta indica	Neem	The seeds do not store well and the viability falls after two weeks
Phyllanthus emblica	Amlaki	The seeds are put in cow dung slurry for 48 hours for better results
Terminalia arjuna	Arjun	Soak the seeds in cool water for 48 hours; or cover the seeds with boiling water, allow to cool and soak for 24 hours
Haldina cordifolia	Haldu	A layer of brushwood is spread over the beds and burned to produce the ash over which the seeds are broadcasted in April to May and covered with a fine layer of soil. Shading of beds is necessary.
Acacia auriculiformis	Akasmoni	Soaked in cool water for 24 to 30 hours.
Symplocos racemosa	Leda	Slow growing- need 1-2 year old QPM for planting
Amoora wallichii	Lali	Seed viability 2 months Sowing must be done in Shaded beds to obtain good germination
Bischoffia javanica	Paniala	Seed may be sown under shade or full sunlight
Cedrela toona	Toon	Toon is reported to bear ripe fruit throughout the year. The seeds are released from the capsules at intervals. Seeds are light and wind dispersed.

Chukrassia tabularis	Chikrasi	Capsules are dried in shade until they split open, and the seeds are released by gentle tumbling or shaking. Direct sun drying should be avoided, as it may cause overheating and desiccation of the sensitive seeds
Gmelina arborea	Gamhar	For quick germination, the seeds should be soaked for 48 hours. The seeds germinate within 20-50 days under ideal conditions; the average rate for a healthy seed lot is 60%
Kigelia pinnata	Sausage tree	The sausage tree is not a prolific seeder. Seeds are released when fruit rots on the ground, and plants regenerate naturally. Seeds are placed in seedling trays filled with pure river sand; they are pressed into the sand until the tip is level with the sand, covered lightly with a thin layer of sand or pure compost and kept moist. Seed usually germinate after 10-25 days. No pretreatment is needed, but germination rate is poor.
Michelia champaca	Champ	Seeds have physiological dormancy and pretreatment with GA3 at the rate of 500 ppm for 24 hours can improve the germination up to 80 %. Dormancy can also be overcome by cold stratification 5-12°C. Sand is the appropriate media for germination. Germination takes about one month.
Schima wallichii	Chilauni	Seeds are sown under shade and only lightly covered with soil. Seedling mortality in the nursery is usually about 50%. After 2-3 months seedlings are 5-8 cm tall and can be transplanted from the seedbed to containers
Terminalia tomentosa	Ason	Cold water treatment for 48 hours. The beds should not be shaded till germination begins, and then should be shaded immediately after germination

Table 7 Seeding time, Germination period and root trainer sizes for some of the species to be planted under the project

Sl no	Scientific name	Local name	Seedling time	Sed size	Root trainer Size suggested in CC	Note
1	*Pterocarpus marsupium*	Pia sal	February - May	Small	150	Soaking the seeds for 72 hours in cold water or in cowdung slurry for 48 hours
2	*Ougeinia oojeinensis*	Panjan	May - June		150	Soak the seeds for 24 hours in cold water.
3	*Dalbergia latifolia*	Bija sal	February - March	Small	300	
4	*Symplocos racemosa*	Leda	Dec - March		300	Slow growing- need 1-2 year old QPM for planting
5	*Madhuca latifolia*	Mahul	June-July	Medium	300	Slow growing- need 1-2 year old QPM for planting, Seeds is sown soon after collection in the nursery beds and covered with a layer of soil of 2 cms thickness
6	*Terminalia bellerica*	Bahara	Dec-March	Large	300	Alternate soaking and drying for few days.
7	*Terminalia chebula,*	Haritoki	Janaury-March	Large	300	The deputed seeds should be either treated by fermentation process for a period of 15 to 20 days, or the seeds may be clipped at its broad end and then soaked in water for a period of 2 days and then sown in nursery beds
8	*Anogeissus latifolia*	Dhaw	January-February, July-August.	Medium	150	The seeds are sown densely on raised beds, the soil being mixed with large quantity of coarse sand. The bed is well-shaded and 45 cms above the ground. Germination is fairly quick. The seedlings are extremely liable to insect damage. The development of the seedlings is very slow
9	*Schleichera oleosa*	Kusum	Aug-Sept	Medium	300	Slow growing- need 1-2 year old QPM for planting
10	*Buchanania lanzan*	Pial	April-May	Medium	300	Slow growing- need 1-2 year old QPM for planting
11	*Semecarpus anacardium*	Bhelai	December - January	Large	300	48 hours soaking in cold water
12	*Soymida febrifuga*	Rahara	May- June	Medium	300	Slow growing- need 1-2 year old QPM for planting,Drought resistant, it can be tried in drought prone areas.
13	*Azadirachta indica*	Neem	July-Aug	Small	150	The seeds do not store well and the viability falls after two weeks
14	*Phyllanthus emblica*	Amlaki	Jan-Feb	Small	150	The seeds are put in cow dung slurry for 48 hours for better results
15	*Sapindus laurifolius*	Ritha	February - April	Medium	300	
16	*Terminalia arjuna*	Arjun	Feb -April	Large	300	Soak the seeds in cool water for 48 hours; or cover the seeds with boiling water, allow to cool and soak for 24 hours
17	*Haldina cordifolia*	Haldu	February to March	Small	150	A layer of brushwood is spread over the beds and burnt to produce the ash over which the seeds are broadcasted in April to May and covered with a fine layer of soil. Shading of beds is necessary.
18	*Acacia auriculiformis*	Akasmoni	February-March	Small	150	Soaked in cool water for 24 to 30 hours.
19	*Eucalyptus tereticornis*	Eucalyptus	Feb	Small	150	
20	*Symplocos racemosa*	Leda	Dec - March	Medium	300	Slow growing- need 1-2 year old QPM for planting
21	*Amoora rohituka*	Tiktaraj				
22	*Amoora wallichii*		June-July	Medium	300	Seed viability 2 monthsSowing must be done in Shaded beds to obtain good germination
23	*Bischoffia javanica*	Paniala	Feb-March	Small	150	Seed may be sown under shade or full sunlight
24	*Cedrela toona*	Toon	Feb -June	Small	150	T. ciliata is reported to bear ripe fruit throughout the year. The seeds are released from the capsules at intervals. Seeds are light and wind dispersed.
25	*Chukrassia tabularis*	Chikrasi	Jan-March	Small	150	apsules are dried in shade until they split open, and the seeds are released by gentle tumbling or shaking. Direct sun drying should be avoided, as it may cause overheating and desiccation of the sensitive seeds
26	*Cinnamomum cecidodaphne*	Sugandhakokila	Feb-March			
27	*Duabanga sonneritoides*	Lampate				
28	*Gmelina arborea*	Gamhar	April-June	Medium	300	For quick germination, the seeds should be soaked for 48 hours. The seeds germinate within 20-50 days under ideal conditions; the average rate for a healthy seed lot is 60%
29	*Kigelia pinnata*	Sausage tree	Dec-June	Small	150	The sausage tree is not a prolific seeder. Seeds are released when fruit rots on the ground, and plants regenerate naturally. Seeds are placed in seedling trays filled with pure river sand; they are pressed into the sand until the tip is level with the sand, covered lightly with a thin layer of sand or pure compost and kept moist. Seed usually germinate after 10-25 days. No pretreatment is needed, but germination rate is poor.
30	*Michelia champaca*	Champ	August-November	Small	300	Seeds have physiological dormancy and pretreatment with GA3 at the rate of 500 ppm for 24 hours can improve the germination up to 80 %. Dormancy can also be overcome by cold stratification 5-12°C. Sand is the appropriate media for germination. Germination takes about one month.
31	*Schima wallichii*	Chilauni	May-July	Small	150	Seeds are sown under shade and only lightly covered with soil. Seedling mortality in the nursery is usually about 50%. After 2-3 months seedlings are 5-8 cm tall and can be transplanted from the seedbed to containers
32	*Terminalia tomentosa*	Ason	February - April.	Large	300	Cold water treatment for 48 hours. The beds should not be shaded till germination begins, and then should be shaded immediately after germination
33	*Terminalia myriocarpa*	Panisaj	Jan-Feb	Small	150	
34	*Terminalia crenulata/ T. alata/T. tomentosa*					

ANNEXURE III

Common nursery problems, symptoms, causes and solutions

Symptoms	Possible causes	Controls	Remarks
Seeds do not germinate	Substrate dry	Supply water	
	Seed too old, or was stored in a bad manner and lost it's germination power	Acquire fresh seeds from a better source	Seeds from known/tested /certified seed source should be preferably used
	Pre-seeding treatment for dormancy interruption not done or was not properly done	Fresh seeds properly pre-treated may be used as prescribed.	Please refer any standard seed germination manual for pre-treatment
Germinated seedlings wither and die	Lack of water	Check sand substrate and if dry, supply water through knap-sack. If not dry, the cause is a fungal or bacterial disease (see below)	
Germinated seedlings die, often with brown or white fungal growth between seedlings.	Fungal or bacterial disease	Coarse sand substrate was not sterilized. Remove all and start over with clean sterilized coarse sand substrate	Too densely seeded germination beds can suffer same symptoms
Clonal cuttings don't root, lower stems turn brown	Fungal or bacterial disease	Coarse sand substrate was not sterilized. Remove all, clean and disinfect root trainers and start over with clean sterilized coarse sand substrate	
	Heat stress	Not enough ventilation. Take care to open ventilation holes during hot periods with adequate supply of water through knap-sack.	
Plants grow slow; leaves turn light green	Insufficient light	Space plants wider; remove shade	
	Cool weather	Look for additional passage for sun light	
	Poor substrate	Amend substrate as needed; spray foliar nutrients as required	
	Improper pH	Amend substrate as needed	Not likely
	Excess water	Do not overwater; watering only through knap-sack check substrate compaction; improve drainage	Overwatering or media compaction probable cause

Wilted seedlings; seedlings fall over (bottom leaves may turn yellow)	Dry substrate	Supply water	
	Damping-off (fungal disease) or root rot	Do not overwater; treat medium with registered fungicide	
	Substrate too wet	Do not overwater	Overwatering or media compaction probable cause
	Root maggots	Use registered soil insecticide	
Chewed seedlings	Rodents or birds	Check fence, control birds & lay traps for rodents to remove them	
	Slugs	Use slug bait (commercial slug bait) or shade traps	
	Various insects	Use recommended insecticide or use light-traps	
Large holes in leaves;	Caterpillars or grasshoppers present	Handpick, spray with registered insecticide or soap-nicotine solution or B. thuringiensis .	
General leaf yellowing; no wilting	Nutrient or mineral/minor elements deficiency	Amend substrate as needed; spray foliar nutrients	Not likely
	Insufficient light	Space plants wider; remove shade	
Inter-venal yellowing of leaves; no wilting	Nutrient or mineral deficiency	Supply nutrients cocktail rich in Nitrogen and trace elements like Boron	Probably Nitrogen but can be Boron if very light yellow.
	Waterlogged substrate results in poor transport	Check for substrate compaction and over watering	
Leaves stippled with tiny white spots	Spider mites	Treat with soapy water and nicotine	
	Air pollution (ozone)		Not likely
Leaf margins turn brown and shrivel	Dry Substrate	Supply water	
	Fertilizer burn	Lower concentration of foliar fertilizer applications	
	Potassium Deficiency	Apply potassium foliar fertilizer	Not likely
	Cold injury		Not likely
Discrete brown spots on leaves; some spots may coalesce (grow together)	Fungal or bacterial leaf spot disease	Use fungicide, see controls under specific disease; submit sample for diagnosis if necessary	Remove the infected leaves & burn
	Chemical injury	Do not apply chemicals that are not registered for use on plants; apply chemicals at registered rates; some chemical injury occurs from drift	
	Burns from lens effects water droplets	Supply water as fine mist through knap-sack; prevent droplet formation; don’t spray in strong sunlight conditions	Water in evening and morning only

Brown dead areas on leaf margins	Leaf scorch	Scorch is usually caused by hot, dry weather, but root rots or other root damage can also be involved	If symptoms are uniformly distributed along edge of beds it is probably mechanical damage through rubbing during page of personnel.
Small, brown spots surrounded by yellow haloes on leaves: leaves wither	Halo blight (bacterial disease)	Avoid overwatering which spreads the disease; remove affected plants; use fixed copper bactericide	Remove affected plants & burn
Leaves with shiny white spots	Spider mites	Use soapy (nicotine) water spray	
Young leaves curled, distorted, and yellow; clusters of tiny insects on leaves and stems	Aphids		
Leaf margins rolled upward; leaves brittle and puckered along veins; plants stunted		Control leafhoppers that spread the disease; eliminate weed hosts; rogue infected plants	Remove affected plants & burn
Rust-colored powdery spots surrounded by yellow haloes form on and leaves, stems.	Rust (fungal disease)	Use registered fungicide, see controls under specific disease; submit sample for diagnosis if necessary	Remove affected part & burn
Soft, watery spots on leaves and stems; white moldy growth on these plant parts; plants wilt and die	White mold (fungal disease)	Use registered fungicide, remove old plant debris; make sure no overwatering has been taken place and ventilation is sufficient	Remove affected plants & burn
Black, sooty growth on leaves and stems.	Sooty mold (fungus that grows on honeydew substance secreted by aphids and other insects.	Identify insects; if aphids, Treat with soapy nicotine water.	Remove affected part & burn
White powdery growth on upper leaf surfaces	Powdery mildew (fungal disease)	Use registered fungicide	Remove affected part & burn
Leaves shredded or stripped from plant	Hail damage		
	Rodents	Check fence around nursery	
	Slugs	Use slug bait (commercial slug bait) or shade traps	
Leaves with yellow and green mosaic or mottle pattern; leaves may be puckered and plants stunted	Virus disease	Weed control; remove affected plants; remove old plant debris from nursery area.	Remove affected plant & burn

Leaves curled, puckered, or distorted	Herbicide injury	If lawn herbicides are used in area around nursery, apply after wind has died down and do not apply in heat of day	
	Virus disease	Same controls as above	
	Aphids		
	Aphids		
Rough, brown, raised areas on underside of leaves	Oedema, physiological problem due to uneven water supply	Water during dry periods; make sure watering is even.	
Leaves rolled or tied together.	Small caterpillars; leaf rollers, leaf tiers.	Use soapy (nicotine) water spray & biological control agent/ B. thuringiensis .	
Entire plant dies	Root rot, probably Phytophthora	Remove plant debris; ensure medium is not over compacted; do not overwater.	Remove plant debris & burn

Symptoms & Signs of Fungal and Bacterial Leaf Spots		
Abnormaliy	**Fungal**	**Bacterial**
Water- Soaking	not common	common
Texture	dry- papery	slimy- sticky
Odor	usually none	fishy, rotten
Pattern	circular with concentric circle	irregular- angular; initially does not cross veins
Disintegration	uncommon	common
Color changes	common; red, yellow, purple halos	uncommon

Fungicidal control:

Root rots

Root rotscan be diagnosed by stripping away the outer cortex and looking for white healthy tissue; brown roots indicate disease (fig. 3). Samples should be collected and sent to nursery pest specialist for culture and identification. Disease outbreaks can be suppressed with ***fungicides*** by preventing the fungus from spreading to healthy tissue, but they should not be expected to cure seedlings that have already been injured, which should be removed and containers should be disinfected immediately. Recommended treatment by Research Circle West Bengal for seed beds (Bulletin No: 2 1990 -1991): application of 19.3 gms of a 50% dust of BLITOX-50 or 26.0 grm of 65% dust of ZINEB, or 22.5 gms of 80% dust of CUMAN, or 20.5 gms of 83% dust of CAPTAN, or 22.5 gms of a 75% dust of THIRIDE applied per square meter of seedbeds one day prior to sowing.

Prevention of Damping-off.

Damping-off diseases can be prevented:

- Acquire disease free plants and seeds. Know your supplier. Do not be afraid of fungicidal coatings on seeds, which will be direct, sown. Seed borne disease can also be avoided by soaking the seeds for 15 minutes in a bleach soak prior to sowing.
- Use sterile well drained soil mediums. See section on growing media mixes. Try to maintain a soil mix pH at the low end of the average scale, i.e. pH 6.4 is less susceptible to root rot than a pH of 7.5. Know the pH of your irrigation water, and condition it if necessary to maintain a lower pH while the plants are still in the germination room.
- Plants must not have their crowns below the soil line. Seeds must not be covered more than 4 times the thickness of the seed.
- Use plant well draining potting mixtures in the containers and avoid excess watering.
- Avoid overcrowding and overfeeding of plants. It is important to maintain constant levels of growth with proper aeration and sun light.
- Avoid working with plants (taking cuttings or transplanting) when the soil is wet. Do not use water from ditches or drainage ponds or rain barrels in the germination room.
- Avoid spreading soil from infested areas or tools which have been used out of doors. Disinfect tools and containers with one part bleach in four parts water or with 70 percent rubbing alcohol (isopropyl).
- In the germination room, sow all your seeds on the surface of the media (disinfected course sand), then cover the seeds to necessary depth with the same material.
- In the germination and rooting areas (hygro-pits), mist seedlings once or twice per day

with water containing a known anti-fungal agent such as:

– Captan (or other approved fungicide)

– Cheshunt compound, a copper/aluminum formulation, or

– Chamomile tea, or

– Clove tea, or

– a one-time light dusting of powdered cinnamon on the soil surface, or

– a one-time light dusting of powdered charcoal on the soil surface, or

- One of the most important measures for damping-off prevention is to provide constant air movement. Air should circulate freely 24 hours per day.

Damping-off control.

Fungicides may be applied as a soil drench after planting. They may be incorporated into the soil before planting as a dust. They can be sprayed in mist form on all seedlings as a precaution until they have been transplanted into individual pots. Once transplanted, only those seedlings known to be especially sensitive to damping-off need be misted with fungicide daily until the first or second seed leaves have emerged. Any locally available fungicide should be applied, som common chemicals recommended for use are:

- Captan (sold as Captan) controls most pathogens, but not Rhizoctonia.
- Metalaxyl (sold as Subdue or Apron) controls Pythium, Phytophthora, and Aphanomyces.
- Iprodione (sold as Chipco) controls most pathogens, but not Pythium, Phytophthora, or Aphanomyces.
- Etridiazole and Thiophanate-methyl (sold as Banrot) controls most all pathogens.
- PCNB-etridiazole (sold as SA-Terraclor or Super-X) good general purpose fungicide.
- PCNB-quintozene (sold as Terraclor, Fungi-clor, or PCNB) controls Rhizoctonia and Sclerotinia species.
- Fosetyl-A1 (sold as Aliette) controls Pythium, Phytophthora, & Aphanomyces.

Insect control.

Insects can be controlled by, for mammals, non toxic means. Most leaf eating or leaf/stem-sucking insects like Hemyptera, Aphids, Orthoptera (grasshoppers), Coleoptera and Lepidoptera larvae (caterpillars), etc. can be controlled with a thoroughly sprayed application of soap water, while for mammals harmless biological insecticides such as Bt (Bacillus thuriengensis), and Bb (Beuveria bassiana) can be used as alternatives especially against caterpillars (Bt) and moths or other flying insect pests (Bb). If difficult to acquire in India the PMC can supply these biological agents.

Soapy nicotine water application.

Insects breath through their skins (carapaces) and will suffocate when not able to do so. Soapy water has a high surface tension causing the insects sprayed with a soap water-solution to be enveloped in a "soap bubble" making it impossible for them to breath. To ensure all insects on a nursery crop are enveloped in such bubbles, it is necessary to finely spray all leaves including their undersides. The water-nicotine soap solution can be made with any cheap (preferably liquid) soap. If (when using commercial soap powder) spray nozzles get blocked, 1-2% ethanol can be added to the solution. Preparation as follows: add 250ml of nicotine sulphate and 400 gms of crude soap to 100 liters of water and mix thotoughly, or boil (soak/steep for 25 hours is option) 1.25 kg tobacco leaves in 10 liters of water, add 400 gms of crude soap and mix with 90 liters of water . The treatment can be repeated as necessary and will not harm the crop.

Bacillus thuringiensis application.

Bacillus thuringiensis is an insecticide with unusual properties that make it useful for pest control in certain situations. Bt is a naturally occurring bacterium common in soils throughout the world. Several strains can infect and kill insects and because of this property it has been developed for inset control. At present Bt is the only "microbial insecticide" in widespread use and several products have been developed (available in India) because of the safety associated with Bt-based insecticides.

Properties: Unlike typical nerve-poison insecticides Bt acts by producing proteins that react with the cells of the gut linings of susceptible insects. These Bt proteins paralyze the digestive system and the insect stops feeding within hours. Bt-affected insects generally die from starvation, which can take several days. Even dead bacteria containing the poison are effective insecticides. The most common strain of Bt (*kurstaki* strain) will kill only leaf- and needle feeding caterpillars, while the Bt *israelensis* strain are widely used against larvae of mosquitos, black flies and fungus gnats. Among the various Bt strains insecticidal activity is specific, strains have been developed against leaf beetles and mosquito larvae that don't effect catterpilars. Many manufacturers produce a wide variety of products of which many are available in India.

Disadvantages: Bt is susceptible to degradation by sunlight. Most formulas persist on foliage less than one week following application, some of the newer strains become ineffective in about 24 hours. So repeated applications may be necessary. Since Bt does not kill rapidly, users may assume incorrectly that it is ineffective a day or two after application. This, however is merely a perceptual problem, because Bt-affected insects eat little or nothing before they die.

Advantages: The specific activity of Bt is generally considered highly beneficial. Unlike most insecticides Bt insecticides do not have a broad spectrum of activity, so they don't kill beneficial insects. This includes the natural enemies of insects (predators and parasites). As well as beneficial pollinators, such as honeybees. Therefore Bt integrates well with other natural controls. Perhaps the major advantage of Bt is that it is essentially non-toxic to people, pets and wildlife This high margin of safety has recommended its use on food crops or in other sensitive sites where pesticide use can cause adverse effects.

Application: The greatest use of Bt involves the *kurstaki* strain used as a spray to control caterpillars. It can be applied either as a liquid with sprayers, through an overhead irrigation system, as dusting or in a granular form.

Beauveria bassiana application.

Beauveria bassiana is a fungus, which causes a disease known as the white muscadine disease in insects. When spores of this fungus come in contact with the cuticle (skin) of susceptible insects, they germinate and grow directly through the cuticle to the inner body of their host. Here the fungus proliferates throughout the insect's body, producing toxins and draining the insect of nutrients, eventually killing it. Therefore, unlike bacterial and viral pathogens of insects, Beauveria and other fungal pathogens infect the insect with contact and do not need to be consumed by their host to cause infection. Once the fungus has killed it's host, it grows back out through the softer portions of the cuticle, covering the insect with a layer of white mold (hence the name white muscadine disease). This downy mold produces millions of new infective spores that are released to the environment where they will degrade over 24-48 hours, depending UV intensity. Beauveria is a naturally occurring fungus in soils throughout the world, and has been researched for control of soil borne insects (e.g. the May beetle in Europe, the Argentine stem weevil in New Zealand). Many soil insects, however, may have a natural tolerance to this pathogen, which is not exhibited in many foliar **pests. Therefore, commercial development of this fungus for biological control** has primarily been targeted against foliar feeding pests. All are foliar formulations of the spores of the fungus, and as the spores are microscopic, can be applied with standard spray equipment. BotaniGard®22WP can also be used as a dip for cuttings, and for soil applications - landscape and containers.

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Insect/Pest	Symptoms	Control	
		Chemicals	**Trade names with Dosis**
Sucking insects: Aphids, Jassids, Thrips, White flies, Mealy bug (white wolly patches)	Discoloration of young leaves and shoots for sucking of sap from affected part	Di-methoate 30 %E.C. Or Methyl demiton 25% E.C.	Demicron, Rogor 30 EC/ Tara 909, or Metacystox 25 E.C Dose: 1 ml / liter of water
Red spider mites	Discoloration of leaves often with white spots, aggravates in hot season.	Dicofol 18.5% E.C or Endosulfan 35% E.C.	Kelthane 18.5 % E.C. Dose 2 ml/ liter of water Or Thiodan, Endosel or Endosulfan, Dose: 2 ml/liter of water
Leaf eating caterpillars & Beetles	Holes on leaves and cutting of leaves	Methyl Parathion 50% E.C. Or Endosulfan 35% E.C.	Metacid 50% or Thiodan, Endosel or Endosulafan Dose 2 ml/liter of water
Termites and other root eating insects	Wilting and gradual death of seedling	Aldrin 5% dust or Aldria 30% E.C.	Aldrin 5 % dust Dose: 150 gm/40 sq. meter before nursery preparation. Aldria 30% Dose: 2 ml /liter of water application as drench spray
Damping off (Fungal disease)	Decaying of seedlings at collar region and death	Captan 75%	Deltan/Captaf Dose: 2 gm/liter of water, application as drench spray
Root rot/wilt (Fungal disease)	Drying of seedlings and gradual death. Uprooted seedlings showing decaying of root	Captan 75% Or Carbendazim 50%	Eavistin 50% or Deprosal 50%, Dose 1 gm/liter of water application as drench spray
Leaf spot/seeding blight (Fungal disease)	Discoloration of leaves and formation of discolored spots of different sizes. At times seedlings look like burned for quick discoloration of maximum number of leaves (blight)	Mancozele 2.5 gm/liter Or Copper oxychloride 50% : 4 gm/liter	Dithane- M -45 or Elitox
Courtesy Silviultural (N) Division, Planning and Research Circle West Bengal Forest Department (Bulletin No.2 of 1990-1991 Appendix III			

ANNEXURE IV

Guidelines for disinfection of root trainers, tools and equipment in nurseries.

Items	Treatment	Remarks
Wooden supports	Old engine oil or chemicals against termites	Engine oil can be diluted with diesel fuel at 1:10 (1 Liter used oil : 9 liters diesel fuel)
Used root trainers	Soak at least 10 minutes in a 10% household bleach or potassium permanganate solution. (1 part bleach powder, liquid bleach concentrate or potassium permanganate powder : 9 parts water) H2O2 (35%) 1:100 solution can be used as alternative above 2 (bleach or potassium permanganate)	Wash thoroughly and soak 24 hours in water first To prevent noxious smell, add some dish washing soap drops to surface which will prevent gas from escaping
Tools like knives, flats, secateurs	Either soak as containers in 10 % solution above, or wipe with concentrated bleach or potassium permanganate	Wipe small tools between starting each operation
Flat work surfaces	Wipe with concentrated house hold bleach or potassium permanganate	Wipe at start of each day
Irrigation water	Disinfect with 1 ppm chlorine by chlorinating water in raised tank with 1 ml household bleach per 1000 liters or add slow release chlorine tablet (swimming pool tablet) Same concentration of potassium permanganate can be used also.	Renew at regular intervals as use indicates. Swimming pool water should have an 8 ppm chlorine concentration, irrigation water needs a much be lower concentration at 1 ppm is sufficient.
Substrate	Coarse sand (or other media components except compost) can be disinfected (pasteurized) by spreading moist components as 10 cm thick layer on black plastic sheet covered with another but transparent plastic sheet in direct sunlight for at least a day with frequent turning followed by another day without top plastic sheet cover in full sun ,again with frequent turning.	Layers should not exceed 10 cm thickness and turned every hour during both treatments, covered and uncovered.
Diseased and other unhealthy culled plants	Remove from nursery	Should be destroyed burning
Shoes and clothing	Issue staff boots and work clothes to wear only during work at the nursery. Install shallow dip basin at entrance to nursery with 10% household bleach solution for shoe/boot sole disinfection.	Outside visitors' shoes are a source of soil borne diseases (nematodes) and clothing for weeds

ANNEXURE V

Useful tools and equipment

Axes
Balance (grams)
Balance (kg)
Bar, crow
Barrows, wheel

Beds, raised for 60, 150, 300 ml
Benches, wood or metal (for sitting)
Boots (rubber)
Beds raised
Brooms
Buckets, plastic
Cans, watering
Containers, measuring
Containers, seed storage
Cutlasses
Cutters, wire
Drums, 200 litres
EC meter
Files, sharpening
First aid kits
Forks, digging, pitch
Funnels, plastic
Ground cover, black polypropylene
Hammer, nails
Hoes
Hoses
Knives, hand pruning
Knives, budding
Labels, plastic
Lamps
Lens, hand
Levels, carpenter's
Machine, calculating
Mixer cement (hand)
Nozzles, heavy and mist spray
Pencils, drawing
Pencils, marking
Pens
pH meter
Pipe repair kit
Pliers, cutting
Rakes, garden
Refrigerator
Rose heads, watering cans
Root trainers (60, 150, 300 ml)

Rule, carpenter's
Saw, bow
Saw, hack
Scissors
Screwdrivers
Secateurs
Shears, pruning
Sheets plastic transparent 200 micron
Sheets polypropylene compost cover
Shovels
Shredder manual, biomass
Spanners, adjustable and fixed
Sprayers, knapsack
Sticks, height measuring
Sieve, 2000, 300 – 400 micron
Tables, work
Tanks, water raised
Tape, 50 ft
Thermometer, steel, long stem, or….
Thermometer (kitchen)

Rule, carpenter's
Saw, bow
Saw, hack
Scissors
Screwdrivers
Secateurs
Shears, pruning
Sheets plastic transparent 200 micron
Sheets polypropylene compost cover
Shovels
Shredder manual, biomass
Spanners, adjustable and fixed
Sprayers, knapsack
Sticks, height measuring
Sieve, 2000, 300 micron
Tables, work
Tanks, water raised
Tape, 50 ft
Thermometer, steel, long stem, or….
Thermometer (kitchen)