



MODERN NURSERY TECHNIQUES

A Manual

Indian Council of Forestry Research & Education

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A MANUAL



INDIAN COUNCIL OF FORESTRY RESEARCH AND EDUCATION
P.O. New Forest, Dehradun - 248 006

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Foreword



Dr. Suresh Gairola, IFS
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ICFRE with its Headquarters at Dehradun is an apex body in the national forestry research system that promotes and undertakes need based forestry research and extension. The Council that came into being in 1986 has a pan India presence with its 9 Regional Research Institutes and 5 Centers in different bio-geographical regions of the country. Since then research in different fields of forestry has been a major focus of ICFRE.

There is an earnest need of publication of its research to the stakeholders in a simple and lucid manner, to improve the visibility and relevance of ICFRE. Therefore it was decided that the information available on the technologies, processes, protocols and practices developed by ICFRE has to be updated and may be published in the form of operational manuals/user manuals. It was also expressed that the manuals should be a comprehensive national level document depicting extent of knowledge in applicable form.

Accordingly, 18 scientists of ICFRE were nominated as National Subject Matter Coordinators (NSMCs) to carry out the task on the specified subject. These NSMCs were assigned the task to select and nominate nodal officers from other Institutes of ICFRE as well as other organizations if necessary, collect and collate the information on the subject from various sources in coordination with the nodal officers of ICFRE institutes.

The manual "A manual of Modern Nursery Techniques" presents the general principles and practices of nursery in Part I. Methods of propagation through seed as well as vegetative propagation have been described. Special discussion has been provided on alternatives to polythene bags in the wake of recent decision of Ministry of Environment, Forest and Climate Change, Govt. of India to discourage their use. Part II contains the package of practices of important plantation species. This is followed by tabulated information on a wider list of plantation species in the Annexure. The contributors hope that the publication would provide a ready source of information on nursery practices to tree propagators and forestry professionals.

Further, the manual has got good number of new initiatives to facilitate research through innovation. I hope that the manual will provide useful information to the diverse stakeholders and prove to be helpful literature for planning future programmes in research for development.

Dr. Suresh Gairola



Preface



Forest is a wonderful entity. A few seeds in a newly exposed area without any care, if not disturbed, are sufficient to grow and develop into trees and eventually multiply into a forest. There are several situations where man tries to intervene in this natural process to direct, modify or accelerate the development of forest or tree cover. Reforestation, afforestation and plantation outside the forest in areas such as wasteland, community land, private land, agricultural field, urban spaces, etc. are important activities towards augmenting the forest and tree cover. These activities are nowadays heavily dependent on artificial regeneration. Conservation of forest and biodiversity, though does not aim at enhancement of forest cover, yet it inevitably requires regeneration of some favoured species.

Renewal of forest crop is an essential part of forest management. Sustainable forest management implies that forest should be managed in such a way that it continues to provide goods and services to the society in perpetuity without any loss or decline. Artificial regeneration of forest requires young plants which are raised in the nursery. Plants in the nursery are raised through seeds as well as vegetative means using appropriate techniques supported with suitable infrastructure.

The task before the country of increasing forest and tree cover is formidable and cannot be achieved by forest department alone. Plantation activities generate employment besides providing a host of goods and services. The forestry sector is working to strengthen liaison and associate the common man with forestry activities in several ways. Local communities are being involved in forestry activities for over four decades through programmes of social forestry, community forestry and participatory forest management. National Agroforestry Policy, 2014 aims to boost the practice of integrating trees, agricultural crops and livestock. Development of green corridor along highways is a welcome initiative launched by the Ministry of Road Transport and Highways, Govt. of India, under the Green Highways (Plantation & Maintenance) Policy-2015. Green Skill Development Programme launched by the Ministry of Environment, Forest and Climate Change, Govt. of India during 2018 is another initiative launched to train youth towards forestry related activities and promote forestry-based livelihood. Many such programmes are expected to be implemented in near future.

To make these programmes a success, people need to be trained in techniques of raising nursery stock. This manual aims to provide technical information to the prospective tree propagators on all aspects of nursery, besides providing a ready source of package of nursery practices on important plantation species. This will be of special use to youth, entrepreneurs, farmers and other individuals and non-government organizations associated with plantation activities. It is an effort on part of National Subject Matter Coordinators (NSMCs) to prepare an easy-to-understand publication for user group of diverse backgrounds.

The publication presents the general principles and practices of nursery in Part I. Methods of propagation through seed as well as vegetative propagation have been described. Special discussion has been provided on alternatives to polythene bags in the wake of recent decision of Ministry of Environment, Forest and Climate Change, Govt. of India to discourage their use. Part II contains the package of practices of important plantation species. This is followed by tabulated information on a wider list of plantation species in the Annexure.

The contributors hope that the publication would provide a ready source of information on nursery practices to tree propagators and forestry professionals.

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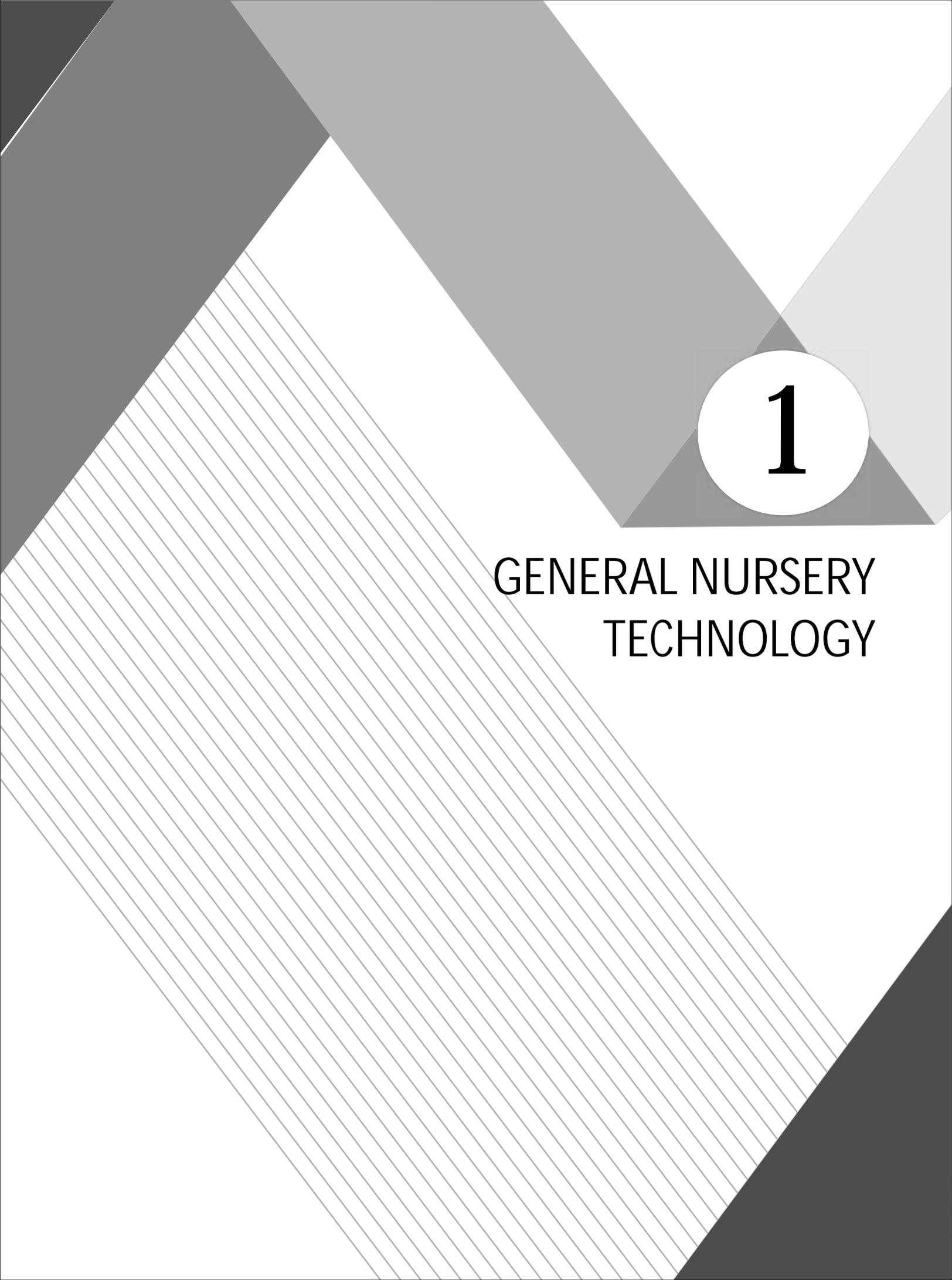
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The cover features a large, stylized number '1' inside a white circle, positioned in the upper right quadrant. The background is composed of several overlapping geometric shapes: a dark gray triangle in the top left, a medium gray triangle in the top right, and a large white triangle in the bottom right. A series of thin, parallel gray lines form a diagonal band across the lower left portion of the cover.

1

GENERAL NURSERY
TECHNOLOGY

1 INTRODUCTION

Forests are one of the most prominent constituents of our ecosystem because of their vast expanse, versatility and utility. Whether natural or planted, they are important to the mankind not only economically and environmentally but also socially, spiritually, historically and aesthetically as they sustain human life by providing a large number of goods such as fodder, fuel, timber and non-wood forest produce, and services like soil, water and biodiversity conservation, pollution control, climate regulation, recreation, etc. Forests are a source of raw material for industry and livelihood for people engaged in their establishment, management, protection and utilization. Forests improve the quality of air and play a vital role in maintaining the oxygen cycle, which is essential for the survival of all living being. When properly grown, they act as barriers against sun, wind, dust, noise and other pollutants. Trees reduce stress on human beings. They help to reduce temperature by providing shade and by intercepting, absorbing and reflecting solar radiation, specially in warmer places, where there is year-round warmth and sunshine.

Tree planting is receiving considerable attention in national policies and programmes. In the rural areas, trees play a vital role in the supply of fodder, fuel, small timber, edible products and medicines which enhance livelihood support to the farming communities. Tree plantation provides scope for economic and sustainable utilization of degraded lands where agricultural crops cannot be grown. Social forestry, community forestry, National Forest Policy, 1988, Mahatma Gandhi National Rural Employment Guarantee Act, 2005, National Agroforestry Policy, 2014, Green Highways (Plantation & Maintenance) Policy-2015, Green Skill Development Programme, 2018, etc. emphasise massive plantation efforts specially focusing on areas outside the forest. However, one of the major constraints of these programmes has been the lack of quality planting material and its availability and accessibility to the growers. Establishing tree nurseries and equipping manpower with the requisite skills is vital to achieve the target of a green India. The quality of planting material must receive greater emphasis in order to ensure that the country is able to enhance forest and plantation productivity to meet increasing societal demands and achieve the carbon sequestration target in tune with the Paris Agreement.

Growing tree is an art and science. The process of growing a forest artificially usually begins with the raising of plants in the nursery. Tree nursery plays important roles in production and supply of quality planting stocks of important tree species. A good nursery stock is a pre-requisite for a quality plantation. A healthy and vigorous stock is essential for ensuring good survival and growth of any plantation. This can be achieved only if nursery is properly designed and all nursery operations are conducted cautiously.

The success of nursery depends upon:

- Selection and development of suitable site
- Efficient supervision and administration
- Adequate planning, forecasting, control procedures and orderly timing of operations
- Use of appropriate cultural methods
- Protection from pests, diseases and other damages

Plants must have a well-developed root system with many root tips from which new roots can quickly develop. This becomes specially important in adverse environments, such as dry, rocky, saline or nutrient-deficit sites. In weed infested sites, larger plants are better as they can outgrow the weeds quickly.

This user friendly nursery manual has been prepared in such a manner to help the users to understand about nursery



practices of important tree species and to guide them to produce quality planting stock for their own use as well as for sale.

MEANING OF NURSERY

Nursery is an area where plants are raised for eventual planting out. It comprises nursery beds, paths, irrigation channels, shade house, mist chambers etc.

NEED FOR NURSERY

Plantations of many species by direct sowing of seed or planting of cuttings in the field is not successful. Planting of nursery grown seedlings is the surest method of artificial regeneration of poor sites. Success of roadside and avenue plantations also depends largely on tall and sturdy plants which can be obtained only from a nursery.

- Seeds are not available every year and throughout the year. They often have a short viability. Germination percentage of the seed in many species is low which demands efficient utilization of the seed.
- Direct sowing gives unreliable results.
- Seedlings of right size for a plantation can be ensured if they are raised in the nursery. Some locations, especially wastelands and roadside need bigger seedlings
- Beating up of failures can be done by planting sturdy seedlings of nursery
- Exotics are introduced by planting out nursery stock.
- It is economical to intensively manage plants in a smaller area as in nursery where plants are planted closely.

NURSERY PRODUCTION METHODS

Several methods are employed for raising plants in the nursery. The methods are illustrated in Figure 1. The process of raising plants through tissue culture is also known as micropropagation while other procedures constitute macropropagation. Micropropagation procedure is initiated in the laboratory leading to production of a plantlet from any of the vegetative parts or callus under artificial conditions. The plantlet is then raised in the nursery to attain plantable size.

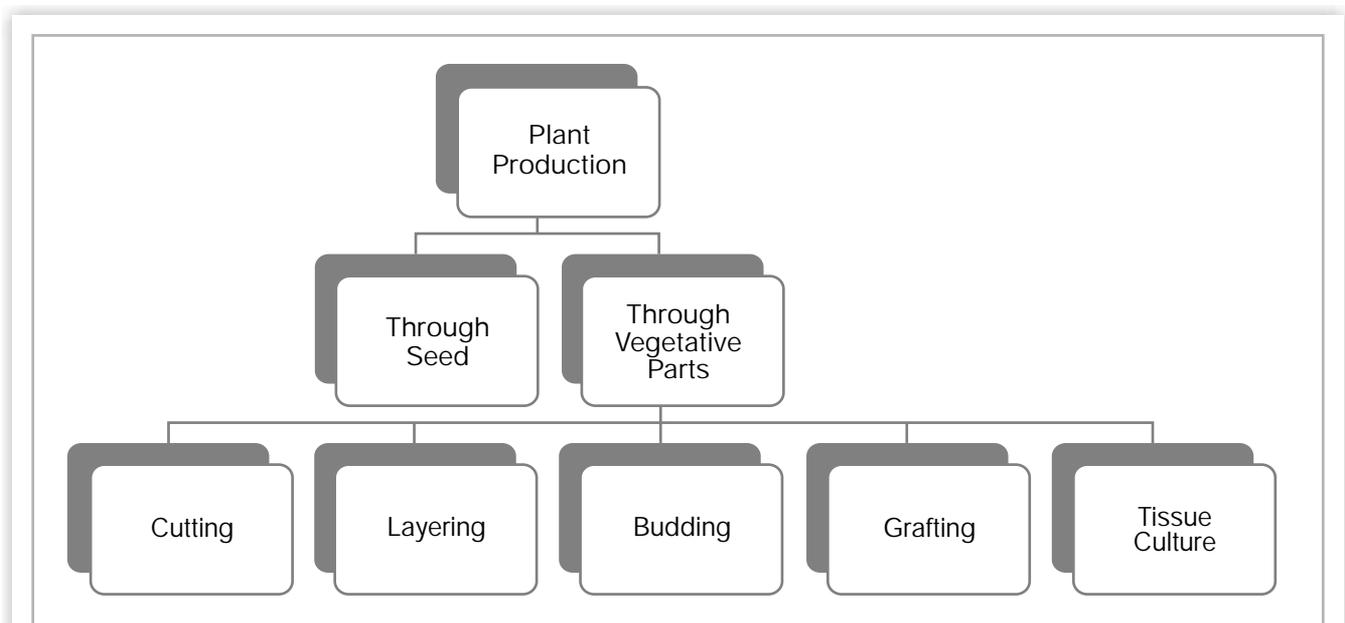


Fig 1. Classification of major methods of propagation

2 NURSERY ESTABLISHMENT

TYPES OF NURSERY

A permanent nursery is centrally and conveniently located and has permanent residential buildings for staff, stores for equipments and machinery, fencing, water arrangements etc. It is meant for supplying plants for planting on a long-term basis.

When planting programme is short (five years or less) a temporary nursery is sufficient which has just the most essential low-cost facilities and structures to produce plants for meeting the specific planting target. Temporary nursery is generally much smaller than permanent one, and is also referred to as site nursery, field nursery, or flying nursery.

In a continuing programme that is likely to go on for more than five years, it is desirable to have atleast a few permanent nurseries with proper infrastructure. However, in case of afforestation projects lasting five years or less, temporary or semi-permanent nurseries can be established in which the cost can be reduced by dispensing with some of the infrastructure elements such as permanent structures for green houses, nursery sheds, fencing with angle iron posts and modern irrigation facilities.

FACTORS TO BE CONSIDERED FOR SELECTING A SITE FOR NURSERY

It is very important to critically consider all factors while selecting the site for a nursery. One should consider not only the physical aspects for the selection of the site but also the end use of the seedlings. Following points may be kept in mind while selecting a site for the nursery, however, in reality, a decision of compromise is often made in many situations based on nursery manager's priorities.

Location

The site should be centrally located with easy access for transportation of seedlings. It should be close to the area where seedlings are to be utilized. The site should be as square as possible. Sites used earlier for agriculture may be avoided and preference be given to former forest sites where weed problems will be less and beneficial mycorrhizae forming fungi are often endemic.

Water

Enough water should be available especially during the dry season. A natural source of water, at a higher level, will be operationally cheaper, as it can be tapped by gravity. If no natural source of water is available, ground water may be used. It is estimated that the water requirement for a semi-arid area is a minimum of 25,000 litre per day during summer, for every 1,00,000 seedlings. Requirement of water will be somewhat less for moist or cold areas.

Topography and Drainage

The area should be nearly flat with good drainage. This can be managed by providing gentle slope (< 5 degrees) and channels should be dug to drain out excess water from the nursery. In the hills northern aspect is desirable up to 1,200 m elevation, Western or South Western aspect is best for moist areas and Northern for dry areas. Nursery site should not be selected close to the edge of a high forest or in the middle of the grassland. Frost pool should be avoided.

Soil

The ideal forest nursery should have sandy loam to loamy texture. Sandy soils may be given preference over heavy soils. Soil should have pH 5.5 to 7.5, moderate fertility, with a minimum of 2 per cent organic matter. The higher the



organic matter content of the nursery soil, the better it is. A high organic matter content ensures good retention of nutrients and water and may improve the working properties of the soil. The depth of soil should not be less than 25 cm. It is not always possible to get good soil everywhere. Under such circumstances, one has to get extra soil, sand as well as farm yard manure from outside; therefore, location of nursery should be close to such areas. Air-filled porosity (a measure of pore space not occupied by water when soil is allowed to freely drain; expressed as total volume of soil) of 30 per cent is considered good for raising of seedlings and rooting of cuttings.

SIZE AND SHAPE

As far as possible the nursery should be of a rectangular shape; so that it can be divided into smaller nursery beds of rectangular shape, leaving space for roads, inspection paths, heaping of manure, hut for *mali* and space for people working in the nursery to rest or take shelter during periods of rain. In bigger nursery (one ha and above), a road of a minimum width of 3 m should be constructed to facilitate transport of sand and manure inside the nursery and to carry the plants from the nursery, leaving space for turning of the vehicle.

The requirement of the total area for the nursery can be calculated by adding together the area required for mother beds, containers, entire plant/root shoot cuttings and beds required for rooted cuttings. Another 40% area may be added for making the paths. Area will also increase if seedlings are kept in the nursery for more than one year, specially for raising tall plants. Area required for sheds, water tank, storage of seed, manure etc. should also be kept in mind. Bags of size 18 cm x 5.5 cm need 1 m² for keeping 772 bags and slightly larger bags 18 cm x 7.5 cm need 1 m² for keeping 400 bags. Accordingly 1,00,000 bags will require 250 m² area plus 40% for paths. Thus for raising 1,00,000 polypot seedlings, an area of 350 m² may be sufficient.

SITE PREPARATION

The site should be cleared properly by removing all stumps, roots, lops and tops. Stones collected from the site may be used for metalling the main nursery road. Thorough ploughing or hoeing to a depth of 30 cm should be done, especially in places where plants are to be raised in the nursery beds. The soil should be levelled to form an even slope or, if a site is flat, should be slightly domed. As far as possible, removing of top soil must be avoided. Drainage channel should be dug as early as possible to avoid soil erosion. Drains should be dug on both sides of the paths and connected to main drain. In plains, drain should be adequately sloped and steps should be used in hills to check the flow of water.

Beds should be separated by main paths (2-3 m wide) for vehicles. Secondary paths should be 1 m wide for movement of wheel barrow. Paths between nursery beds can be 0.5 m wide for free human movement. Location of irrigation channels must be kept in mind while developing layout plan of the nursery. In the hills, nursery beds are made after terracing. At least one bed is made per terrace with path on both sides.

Size of Beds

Beds are prepared to germinate seeds, keep polypots and transplant pricked out seedlings. In the plains, beds of 10 x 1 m or 12 m x 1.20 m size are made. In the hills smaller beds such as of 2 m x 1 m size are generally prepared. However, size can be changed depending on the availability of the area. Width of beds should not be more than 1.2 m otherwise weeding of seedlings; especially in the middle part of the bed shall be a problem. The beds should be oriented in east-west direction in the plains and should follow contours in the hills. In very cold areas where lifting may be restricted due to frozen ground, orienting beds in a north-south direction will facilitate early thawing by the morning sun, and thereby lifting.

Types of Beds

a) On basis of Vertical Level

On the basis of vertical level with respect to the ground, the following types of beds are prepared in the nursery.

- Sunken Beds

These nursery beds are about 15 cm deep and used in arid areas and hot places to maximise the use of rain water, protect young seedlings from hot winds, and also to reduce the rate of evaporation, thus reducing the consumption of water. Sunken beds are also used to keep small flexible bags in an upright position.

- Raised Beds

These types of beds are generally used in moist areas. The beds are raised 15 cm above the ground to increase drainage and promote warming of seedbed. Beds are given side supports of bamboos, twigs, bricks or other locally available materials.

Seedbeds (germination beds) are generally raised beds and should be located in shade and close to beds of polythene bags where seedlings will be transplanted.



Fig 2. A permanent forest nursery

b) On basis of purpose

- Seedbeds

The plot where seedbeds are to be prepared must be ploughed and levelled and sloped (1 to 3%), depending upon the texture of soil (less slope for sandy soils). It should be ascertained that the soil in the seedbed is light. If necessary, sand and soil (1:1) may be mixed so that the seedlings can break through when germinate, and this will also be helpful when plants are lifted for pricking out. The seed beds should not be filled in completely, so as to avoid the washing away of top soil and seed. The surface of the seedbed should be made firm by sprinkling water and then using a wooden plank. These beds are generally used for the following reasons:

- For sowing minute seeds which cannot be sown individually, such as *Eucalyptus*, *Adina*, etc.
- For sowing seeds which germinate slowly or unevenly, like teak.



- For seeds whose quality is not known.
- To keep a small reserve of seedlings which can be used to replace direct seeded plants that may not germinate or that die.
- Seed sowing in seed bed is done more densely than in normal beds.
- Transplant Beds
Seedlings after pricking out from germination beds are transplanted into transplant beds. Planting is done at the prescribed bed spacing to give enough space to all individuals. Such beds are used for producing naked root plants (e.g. *Quercus*, deciduous plants for winter planting) and root-shoot cuttings of teak.
- Beds for Normal Sowing of Seeds/Planting of Cuttings
In species with bold seed and good germination (more than 70% germination), sowing is directly done in beds e.g. *Celtis australis* (khirak), *Sapindus mukorossi* (riitha), *Bauhinia variegata* (kachnar) etc. for winter planting. This is also used for direct planting of cuttings in species where rooting is above 80% in the open and planting can be done without earth ball e.g. poplar.
- Beds for Polythene Bags
These beds are the most common types of beds used in the present-day nurseries. Raising of nursery plants in polythene bags is the commonest method and is suited to almost all species e.g. *Eucalyptus*, *Casuarina*, *Acacia* (khair, babool), *Albizia*, *Leucaena* (subabul), *Gmelina arborea* (gamhar or sivan), *Tamarindus indica* (imili), *Azadirachta indica* (neem), bamboo, shisham etc. It is recommended to spread plastic sheet spread over the bed on which bags are put to check penetration of roots into the ground. Alternatively, bags are to be shifted frequently during active growth season to avoid root penetration. Some nurseries have a lining of cement concrete or bricks to permanently overcome the need of such practices.

OTHER FACILITIES/INFRASTRUCTURE IN NURSERY

Source of Water

About 25,000 litre water is daily required for irrigating one lakh plants in polythene bags during peak season (summer) by sprinkler system. Provision for 25% extra water should be made to allow for contingency. Tubewell is the most preferred source of water. It is free from seed of weeds which are normally abundant in water of ponds and canals. An open well can be another good alternative. A diesel pumping set or an electric motor coupled with a pump should be provided.

Water Reservoir

The choice between ground level reservoir and overhead reservoir depends upon cost and the necessity of using a sprinkler system. Ground level reservoir is a cheaper option and should be located at a point of elevation in nursery. It should be made of cement. Overhead tank is essential when irrigation is done with a sprinkler. Reservoir serves as backup when tubewell is unserviceable and its size will be greatly determined by frequency and length of tubewell failure. Small temporary nurseries sometimes use plastic storage tanks.

Sprinkler/Water Conveyance Channels

Sprinkler system should be installed wherever budget permits because it saves labour and result in economy in water use. Alternatively, a network of water conveyance pipes, usually made of rubber or rigid plastic, is maintained in the nursery as a low-cost option. Irrigation with furrows requires the least capital cost and works well with sunken beds but it leads to large wastage of water due to percolation of water throughout the course of irrigation channel; this method should be avoided.

Tools and Store items

Pickaxe, shovel, crowbar, watering can with rose, forks and hoe, khurpi, secateur, weighing balance, sprayer, saw, rope, tape, irrigation pipe, enamel tray etc are the basic implements in nursery. Tractor, harrow, tiller, etc. are used in big nurseries; these can be hired locally whenever needed. Suitable fertilisers, insecticide and fungicides should also be stored.

Store Room

Storage for tools, bags/root trainers, seed and other consumables should be provided in nursery.

Potting Mixture Yard

A shed for preparing soil mixture and filling of polythene bags should be provided to protect potting mixture and provide working area for filling of containers bags and protecting workers from adverse weather conditions.

Rainwater Harvesting Water Reservoir

Rainwater can be easily used for irrigation of plants in the nursery. Underground water reservoir may be constructed and rooftops can be shaped or provided with sides so that rainwater that falls on rooftops and other parts of the nursery is directed to water reservoir. Excess water overflowing from the reservoir may be channelled into the ground in a suitable part or nursery or nearby area to recharge the water table.

Compost Unit

A unit may be provided in the nursery where compost or vermicompost may be prepared from leaves of trees or domestic vegetable waste available in the area.

Source of Cuttings

A vegetative multiplication garden may be raised in a part of the nursery which would serve as source of cuttings to facilitate vegetative propagation.

Important Propagation Structures

The following table summarises the main propagation structures in the nursery:

Structure	Main Functions
Shade House	Provides shade to plant to reduce illumination and temperature.
Mist Chamber	It provides high humidity (> 85% RH) for rooting of cuttings.
Poly House	Provides conditions of higher temperature during season of low temperature for greater plant growth.
Green House	It provides controlled temperature, irrigation, humidity, light conditions for better plant growth.
Net House	Its main purpose is to grow plants protected from birds, large insects, animals and human beings.
Growth Chamber	It provides precise control on temperature, humidity, light conditions, carbon dioxide/oxygen, etc. for study of plant growth during experiments. Plants are raised in pots inside growth chamber.

A overhead structure of shade is frequently used over mist chamber, green house, polyhouse, etc. in subtropical and tropical climates to keep the temperature low during summer.



Fig 3 (a). *Shade house*



Fig 3 (b). *Mist chamber*



Fig 3 (c). *Polyhouse*



Fig 3 (d). *Greenhouse*

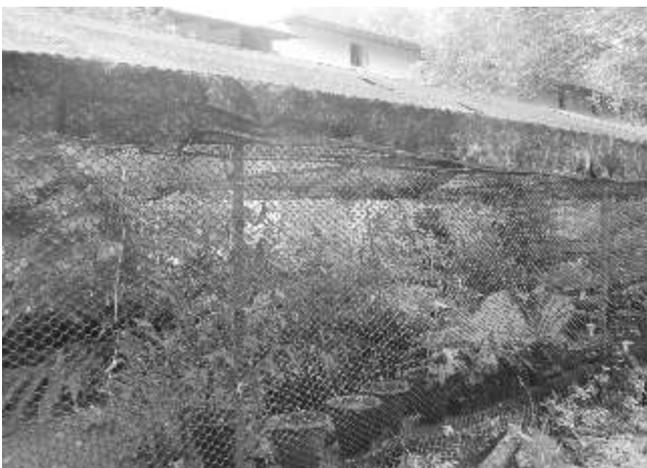


Fig 3 (e). *Net house*



Fig 3 (f). *Growth chamber*

ENVIRONMENTAL FACTORS FOR PROPAGATION IN MIST CHAMBER

The following conditions are required in the mist chamber:

Light

Light is an essential component for plant growth and development. It influences germination, rooting of cuttings, shoot growth etc.

Humidity

High humidity is required inside the mist chamber for cutting propagation prevents cuttings from drying. It also helps in evaporative cooling of the cuttings / plants permitting us to use higher light intensities for better plant growth. More than 85% relative humidity is required to prevent desiccation of cuttings/ plants.

Temperature

For rooting of cuttings temperatures, generally about 30°C temperature is required for induction of roots.

Gas exchange

The propagation structure should allow healthy exchange of gases. Build up of ethylene gas should not occur. Ethylene being a plant hormone may cause damage to the plants.

POTTING MEDIA

The better the media, the better will be development of healthy, fibrous root system. A better quality seedling is produced having good survival rate. Potting media are usually blends of different elements.

Significance of potting media

The potting media serves the following purposes:

- physically supports a growing seedling
- supplies nutrients, water and air to the root system.

Characteristics of a good potting media

A good potting medium should possess the following characteristics:

- Low bulk density (e.g. sandy loam 1.0-1.1 g cm⁻³)
- Good porosity:
 - >50% porosity
 - 20-35% Aeration porosity
 - 15-30% Water retention porosity
- Well-drained but with good water holding capacity
- Slightly acidic with good cation-exchange-capacity
- Able to maintain a constant volume when wet or dry
- Free from insects or their eggs,, disease-causing organisms and seeds or roots of weeds
- Low in silt, clay and ash content
- Easily stored for long periods of time without changes in physical and chemical properties; and
- Easily handled and blended.



Components of a potting media

A potting medium is not a single element or compound but a mixture of several naturally occurring materials, such as

- Sand
- Soil
- FYM or compost
- Mycorrhizae
- Vermiculite
- Bagasse
- Peat
- Bark and sawdust
- Perlite

Factors to be Considered while Selecting Ingredients for Media

Cost is one of the most important factors. As planting of forestry species is done in large numbers, cost per seedling becomes a critical factor. Efforts should be made to use cheaper, locally available materials. Materials such as peat and vermiculite are expensive and should be used only when their use is justifiable.

CONTAINERS

The type of container selected depends on the species to be raised, their purpose and size. Forest nurseries presently have two major types of containers:

- Polythene Bags
- Root Trainers

Pots are expensive and are not used in plantation programmes in forestry.

Polythene Bags

They are made of flexible plastic. Size of polybags may vary according to the size of the seedlings to be raised. Polythene bags are usually of 23 cm x 15 cm size For larger seedlings polythene bags of 30 cm x 20 cm size are

used. Polythene bag should have 8-10 holes of about 0.5cm diameter in the lower half. Polythene bags may be black or transparent. Black polythene bags do not allow growth of algae on the potting medium on sides and suit better than transparent ones.

Polythene bags need to be shifted in nursery frequently during active growing season to prevent root penetrating into the ground.

Advantages : Very cheap, readily available and can be made of any desired size

Disadvantages : Cannot be reused, not very easy to carry, occurrence of coiling of roots



Fig 4. Polythene bags in a forest nursery

Root Trainers

A new trend in the nursery is to use rigid containers called root trainers. Root trainers are conical shape rigid containers. Root trainers comprise cells in groups of about 16 to 30 formed into a frame of moulded plastic sheet. Cells have vertical ribs on inner surface. The lower end of the root trainers is open, the diameter the base is smaller than the top. The lower end allows air pruning of roots. The bottom opening is called drainage hole. Root trainers are kept suspended on a wire frame above ground level. Seedlings possess very fibrous root system. Root coiling is prevented.

The vertical ribs on inner surface direct the growth of roots vertically downwards to avoid root coiling. The root trainers are kept suspended on a wire frame at least 10 cm above ground. Growing medium is filled in the root trainers. As roots emerge from the base of the root trainer, they get dried up i.e. air pruned. This results in a very fibrous root system compared with polythene bags. Coiling of roots observed in the polythene bags is prevented in this method.

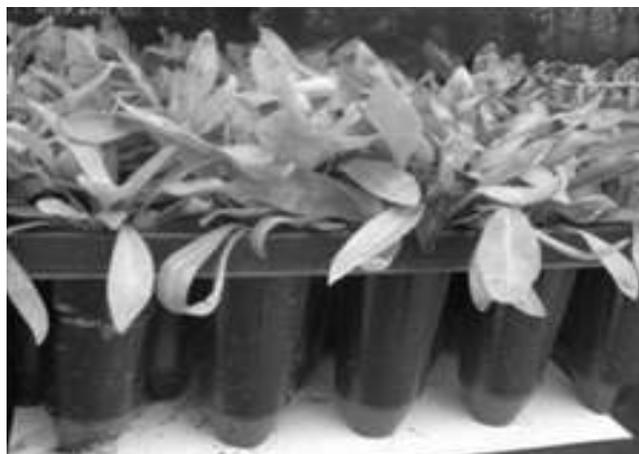


Fig 5. Root trainers in a forest nursery

The capital cost on purchase of root trainers is about 20 times greater in this method than polythene bags. Normally 150 to 300 c.c. root trainers are used. Hence growth of seedlings during the nursery stage in root trainers is slower than in polythene bags of 23 cm x 15 cm size.



The main advantages of using root trainers are as follows:

- They require lesser nursery space.
- They require less amount, of potting mixture and are easy to fill.
- They are well aerated.
- Aerial pruning of roots takes place.
- They do not cause root coiling.
- It is easy to check soil moisture and root growth during the growth of seedlings.
- Seedlings have a good root/shoot ratio.
- Lateral/ adventitious root development is considerably good.
- Labour cost on filling, weeding, watering and transportation is less.
- The containers are reusable and lasts for 5 to 6 years.
- Culling and sorting of seedlings is very easy. It helps in better utilization of nursery space as well as in maintaining the uniform size of seedlings.
- Outplanting success in many sites is found to be higher than polythene bags.

The main disadvantages of using root trainers are as follows:

- Initial cost to switch over to root trainer nursery is very high

The disadvantages associated with the use of polythene bags are:

- Requires large quantity of nursery space and potting media.
- Root growth specially lateral root growth is poor.
- Root coiling occurs which results in slow growth, poor drought tolerance and lack of wind firmness after out planting.
- Poorly aerated.
- Comparatively higher cost of weeding, watering and transportation.
- Seedlings rarely develop extensive fibrous roots to bind the core plug of the potting mixture.
- Roots come out of the bags and break off while taking out seedlings which gives a severe shock to plants postponing its recovery and growth.

Eco-Friendly Alternatives to Polythene Bags in Nursery

Polythene bags are the most common containers in the forest nurseries in India. Polythene bags have been, in fact, the major factor that shifted forest practice from the traditional naked root planting to containerized planting. There are several advantages of the use of polythene bags as elaborated earlier in this Chapter. The biggest drawback of polythene bags is that the material of these containers is not biodegradable. Polythene bags are a source of pollution. Ministry of Environment, Forest and Climate Change, Govt. of India has taken steps to do away with the use of these bags. Hence, it is imperative to look at ecofriendly alternatives. One approach would be to use bareroot seedlings with root culturing operation. Though some research has been conducted on bareroot nursery technology in our country, it has not led to its acceptance probably due to low success.

The following technologies /products are suitable for testing as replacement for polythene bags:

- Wooden Boxes
- Peat fibre pots
- Bamboo pots
- Jute bags
- Bamboo leaf sheath pots
- Coconut shell
- Paper bags and cloth bags (developed at FRI): To explore suitable substitutes of polythene bag, research was carried out at FRI Dehradun during 2009-2011. The following two containers showed good results with acceptable seedling growth and acceptable level of biodegradation of container in nursery environment:

(a) Container A : Bag made of paper pulp + cotton linter in appropriate ratio with specified quantities of non-phytotoxic fungicide and water proofing

(b) Container B : Cloth bag coated with specified quantities of non-phytotoxic fungicide and water proofing

The cost of Polythene bag, Container A and Container B per piece were estimated at Rs. 0.50, Rs. 1.20 and Rs. 2.00 respectively during 2011. It was, however, concluded that the price of Container A and Container B would come down when produced on a large scale under optimised conditions. Hence, these containers could be economically viable replacement of polythene bag.

However, water loss from these containers was significantly higher than polythene bags. The daily water loss of polythene bag, Container A and Container B during summer season were estimated at 16.07%, 20.50% and 36.26% respectively.

From these findings it is concluded that a larger study needs to be undertaken in the nursery on more species using the best substitutes identified in this study.

Earthen pots, metal containers, aluminium or copper foil bags, waste paper pulp nursery pots are also suggested as alternatives of polythene bag. Most of the alternatives, other than those developed at FRI, have not been scientifically tested.

It is therefore concluded that root trainers are the only substitutes for polythene bags that can be reliably used in operational forestry plantation programmes.



3 NURSERY OPERATIONS

A number of procedures are carried out in the nursery for production of plants and their maintenance. This Chapter provides a discussion on nursery operations.

SEED COLLECTION

Genetic quality of seed must be given highest importance as the result of poor genetic quality will be known after several years of plantation and nothing can be done at that stage to overcome the loss. As far as possible, seed should be taken from seed orchards, seed production areas or superior trees in a given stand. Seeds can be purchased from state forest departments, or from reputed seed suppliers or collected from known stands of trees. Seed collection from state forest departments or known stands of trees is considered as the better approach since the quality and provenance of seeds are known. All required species may not be available locally, hence procurement from private seed suppliers is also done in such situations. It is improper to collect seeds from population of crooked, poorly-formed, slow-growing, abnormal, unhealthy or old trees. Straight, less branched, middle-ages with good growth rate and freedom from defects and insect/disease infestation should be preferred. Following precautions are required to be followed at the time of seed collection:

- Only fully matured seeds should be collected as the unripe seeds of most species do not germinate e.g. Haldu, Harar, Bahera, Arjun and Walnut.
- Mother trees should not be damaged or heavily lopped for seed collection, otherwise the seed tree may be adversely affected.

Different species have different seeding time; therefore it is necessary to have a time table for collection or purchase of seeds (see Annexure).

SEED PROCESSING

The seed of most of the species is extracted from fruit. The cones of trees like pine or other coniferous trees should be dried in sun instead of breaking them by hard hitting because drying in sun helps in opening spontaneously. Seeds of pulpy fruits can be extracted by rubbing them in water followed by washing, drying cleaning respectively e.g. *Diploknema*, Mulberry, Bel, Kadam, etc.

The collected seeds must be dried properly before storing to minimise the possibility of damage. However, excessive drying should be avoided. Insecticide, rodenticide should be kept near the seedlot to prevent damage from insects and rodents. Properly treated seeds should be stored in a place of good ventilation and free from moisture to safeguard them from decaying or losing viability.

ESTIMATING QUANTITY OF SEED

It is necessary to compute the required quantities of seed before collection or procurement to reduce wastage of seed and money. Factors like germination percentage, number of plants to be raised and amount of losses involved, all affect quantity of seeds. It is convenient to have a seed weight chart depicting the species wise details of the number of seeds per kilogram to make it handy while computing the quantity of seed required. The information about seed weight and germination percentage of important tree species is given in the Annexure.

When sowing is to be done in beds (rather than containers) the following formula is used:

$$W = \frac{A \times D}{P \times N} \times 100$$

Where	W	=	Weight of seed required (in grams)
	A	=	Area of beds (m ²)
	D	=	No. of plants required per m ²
	P	=	Plant percent of the species (i.e. percentage of seeds, by number, which develop into seedlings of plantable size)
	N	=	No. of seeds per gram

In practice, twice the quantity of seed should be used for drill sowing and 6 times for broadcast sowing.

When sowing is to be done in containers, the calculation of quantity can be illustrated using the following example:

Let us assume that

50,000 plants of *Acacia catechu* are to be raised.

1 kg contains 40,000 seeds; Germination percentage	=	90%;
Loss during transplanting	=	16%;
Mortality in polythene bags or nursery beds	=	15%;
Undersized or unhealthy seedlings	=	12%
Hence plant percent = 0.90 x (1-0.16) x (1-0.15) x (1-0.12)	=	0.90 x 0.84 x 0.85 x 0.88
	=	0.565 = 56.5%
Therefore, no. of seeds required = (50,000 x 10) / 56.5	=	88,496 seeds
	=	88,496 / 40,000 = 2.12 Kg (approx.)

A general scheme is to sow one seed per bag if expected germination percentage is above 90%, two seeds per bag if it is 65-90% and three seeds if it is 40-65%. After germination is over, surplus seedlings are pricked out and transplanted into polythene bags where germination has failed. Only one seedling should be retained per bag.

In case of poor or unknown germination, sowing can also be done in germination beds. Seedlings are then pricked out and transplanted into containers.

SOWING TIME

Sowing time depends upon time to seed ripening, growth rate of species and size of plants for out planting. Spring sowing is practised for most of the species and the plants are planted out during rainy season. When tall plants are required for out planting or when stumps are to be made, seeds are sown in rainy season to give plants of proper size by the next rains. Where there is a danger of plants becoming very tall in one year, growth rate may be retarded by late sowing, less watering, less quantity of manure and fertiliser, transplanting, pruning of root and shoot.

Seed viability and dormancy are also important factors, which decide the sowing time. Species with very short seed viability must be sown immediately otherwise the germination percentage will go down drastically. Seeds with long viability should be sown when temperatures are moderate, i.e. between September to October and February to March. The time from sowing to out planting, which depends on growth rate of species and out planting season, should also be kept in mind so that the nursery stock attains plantable size at time of out planting. Whether the required plants are to be of six months, one year or one and a half year age will also affect the sowing time.



PRE-SOWING TREATMENT

In order to achieve early and uniform germination seed of most of the species should be soaked in water at room temperature for 24 hours before sowing. This is, however, not done in species with very minute and light seed e.g. *Eucalyptus*, *Kadam*, *Adina cordifolia*, etc. or in recalcitrant seeds.

- Seed of some species e.g. *Albizia*, *Acacia*, *Cassia*, *Acrocarpus*, *Leucaena* etc germinate quickly if seed is put in hot water (container removed from fire before water starts boiling, seed is dropped in it and it is allowed to cool).
- Seed of *Robinia pseudoacacia*, babul and other leguminous species with very hard and impermeable seed coat germinate quickly if seed is treated with conc. sulphuric acid for 2 minutes and then soaked in cold water for 24 hours.
- Teak seed is alternately wetted and dried to hasten germination. Teak also germinates quickly if it is treated with fresh cow dung in a pit. The pit is watered daily to maintain moisture. After one week, seeds are dried in the sun for 3-4 days. This process is repeated for 7-8 weeks.
- Seeds of temperate areas that ripen during autumn season germinate better and quicker if seeds are subjected to stratification (moist chilling at 0.5 to 5 °C temperature) for about one month before sowing.

SOWING METHOD

Seed is sown either in lines, dibbled into small pits or broadcast depending upon seed size, germination percentage and container. Minute seeds are sown by broadcast while bold seeds are sown in lines. Spacing in nursery beds is kept at 10 cm – 15 cm between rows and 5 cm-6 cm between plants within row, depending upon species. Very minute seed e.g. *Eucalyptus*, *Adina*, *Anthocephalus* (kadam), *Casuarina* are mixed with equal quantity of sand at sowing time to facilitate uniform dispersal. Such seeds need to be sown on upper layer of bed and covered with a fine layer of sand or soil. The seed is watered lightly with a fine rose-can to avoid splashing them out of soil. Sowing in containers is done after making small holes near the surface.

Medium sized seeds of *Acacia*, *cassia*, *Albizia*, *Prosopis* etc should be sown about one centimetre deep. Large sized seeds e.g. *Azadirachta*, *Tamarindus*, *Erythrina*, etc. should be sown about two centimetre deep. Very large seeds e.g. of *Tectona*, *Zizyphus*, *Swietenia* etc. are sown at three centimetre depth. In general, the sowing depth should be 1 to 2 times of seed diameter.

In polythene 1 to 3 seeds are sown depending upon germination capacity of the seedlot but after 15-20 days of germination, only one seed should be left per polythene bag. Immediately after sowing, irrigation should be done with a fine rose can.

TRANSPLANTING

Seedlings from germination beds are pricked out and planted in containers or transplant beds. This operation is called transplanting or pricking out. Transplanting should be done when seedlings have 2-3 pairs of leaves. Late transplanting results in death of seedlings due to damage to roots during pricked out or results in root coiling. Before pricking out, soil should be moistened. A scoop should be used to lift a group of seedlings. Individual seedlings are then separated. If required, the pricked out seedlings may be kept in water for 2-3 hours pending their turn for planting in the container. A hole is made at the point of transplanting and root is vertically inserted in it without coiling. Hole is closed over upto the collar of seedlings. Transplanting should be done in shade and transplants should be kept in shade for one week till they establish. Irrigation must be done immediately after transplanting with a fine rose can

When seedlings are grown in polythene bags, the polythene bags should be shifted frequently during active growth season so that roots of seedlings do not go deep into the soil after rupturing the bag. Seedlings of conifers which are

retained in nursery for more than one year (e.g. deodar, fir, spruce) are also shifted in nursery for similar reason even if they are not in polythene bag.

SHADING

Seed beds of minute seeds and young seedlings of shade-bearing species e.g. *Michelia champaca* (champak), camphor etc require shade in initial stage. Transplants also require shade, otherwise young seedlings desiccate and perish in the sun. Protection of frost-tender species from frost is also essential. Shade can be provided by trees, thatch, mat, plastic or tin sheet or by a shade house made of net. Plants grown in shade get used to it and need to be hardened off before out planting. This can be done by decreasing the period of shade.

IRRIGATION

Excess watering is as harmful as less watering. For most species, one irrigation a day by thoroughly saturating the polythene bag, is sufficient. During winter one irrigation in 2-3 days will suffice. Evening times are best for irrigation but in large nurseries, irrigation is conducted throughout the day to cover the entire area. Water should not fall on young seedlings with much pressure.

Since the concentration of soluble salts in plant tissues increases as moisture levels decrease, it is important to monitor the water content of the growing medium. In the presence of excessive soluble salts, growing media should not be allowed to dry out. Maintaining adequate moisture levels can be difficult in porous growing media and requires careful attention.

Irrigation water should ideally have pH of 5.5 to 7.5, and salt less than 400 ppm, beyond sodicity develops and plants show drying of leaf tips and eventual loss of growth. Quality of irrigation water needs to be checked in arid and semi-arid environments. Electrical conductivity is best if low (<250 micromhos/cm). At moderate level (250-750 micromhos/cm, aluminium sulphate can be added. Levels above are not fit for most of trees. About 25 g aluminium sulphate/100 litre water can reduce pH from 6 to 5. Sodium absorption ratio should preferably be <10%. SAR of 10-15 can be corrected by adding gypsum. SAR above this range should preferably be avoided.

However, a more practical approach to the problem of saline soil or water in forestry sector is to raise tolerant species. *Acacia nilotica* and *Eucalyptus* can be grown with <50% reduction in growth upto 5dS/m salinity (one deci-Siemen/metre equals one milli mhos/cm). *A. nilotica* can tolerate salinity upto 15dS/m while *Ceiba pentandra* and *A. auriculiformis* do not survive beyond 2.5 dS/m.

Effect of saline water is more on root growth than on shoot length. However, EC 8-10 mmhos/cm and SAR upto 30 can be used in *Acacia nilotica*, *Pongamia pinnata*, *Prosopis juliflora*. Water with EC 4-6 mmhos/cm and SAR upto 15 can be used in *Acacia tortilis*, *Azadirachta indica*, *Lawsonia glauca*, *Parkinsonia aculeata* and water of EC less than 2 mmhos/cm in *Eucalyptus* hybrid.

WEEDING AND HOEING

Undesired plants (weeds) come in the nursery with manure, irrigation water and with seed of the desired species. These compete with desirable plants for moisture, nutrients, light and space, and hence these need to be removed periodically. Weeding is especially essential when seedlings are small, otherwise they are suppressed by weeds. Weeding is done with khurpis by uprooting them. Damage to seedlings should be avoided. Removal of weeds by uprooting also results in hoeing (loosening of soil) to provide better aeration and reduce run-off of water. Weeding should be avoided when soil is wet otherwise it results in removal of soil with roots of weeds and exposure of roots of desired species.

FERTILITY MAINTENANCE

N, P and K are three major nutrients required by plants in large quantities. FYM applied at the rate of 20 tonne/ha provides most of the nutrients for plants. Only well-decomposed FYM should be used. The need for fertilisers depends upon



Sand



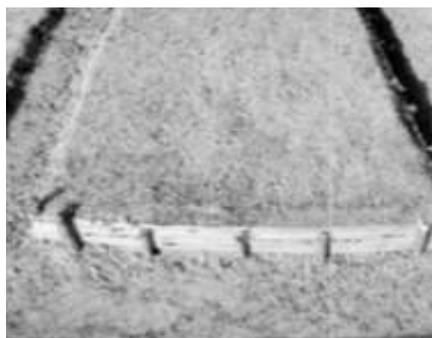
Soil



Farm yard manure



Seed bed



Sunken bed



Line Sowing



Filling of polythene bags



Plastic cane used for watering



Transplanting of seedlings

Fig 6. Soil mixture, sowing and transplanting operations

species. The following doses are recommended for some species.

Eucalyptus	:	N 100 kg; P 200kg; K 100kg/ha
Chirpine	:	N 200 kg; P 200kg; K 400kg/ha
Teak	:	N 400kg; P 200kg; K 400kg/ha

P and K are applied as based dressing (mixed while preparing soil mixture). N is applied as top dressing (applied to seedlings after emergence) in 2-3 split doses.

N is supplied by urea (46% N), ammonia sulphate (20% N), sodium nitrate (16% N). P is supplied by single super phosphate (16% P_2O_5), triple super phosphate (48% P_2O_5), rock phosphate (33% P_2O_5), basic slag (12% P_2O_5). K is supplied through muriate of potash (60% K_2O). DAP (di-ammonium phosphate) has 21% N and 53% P_2O_5 .

In case of visible deficiency of nitrogen during growth of seedlings, spray urea (1 kg urea per 20 litre water).

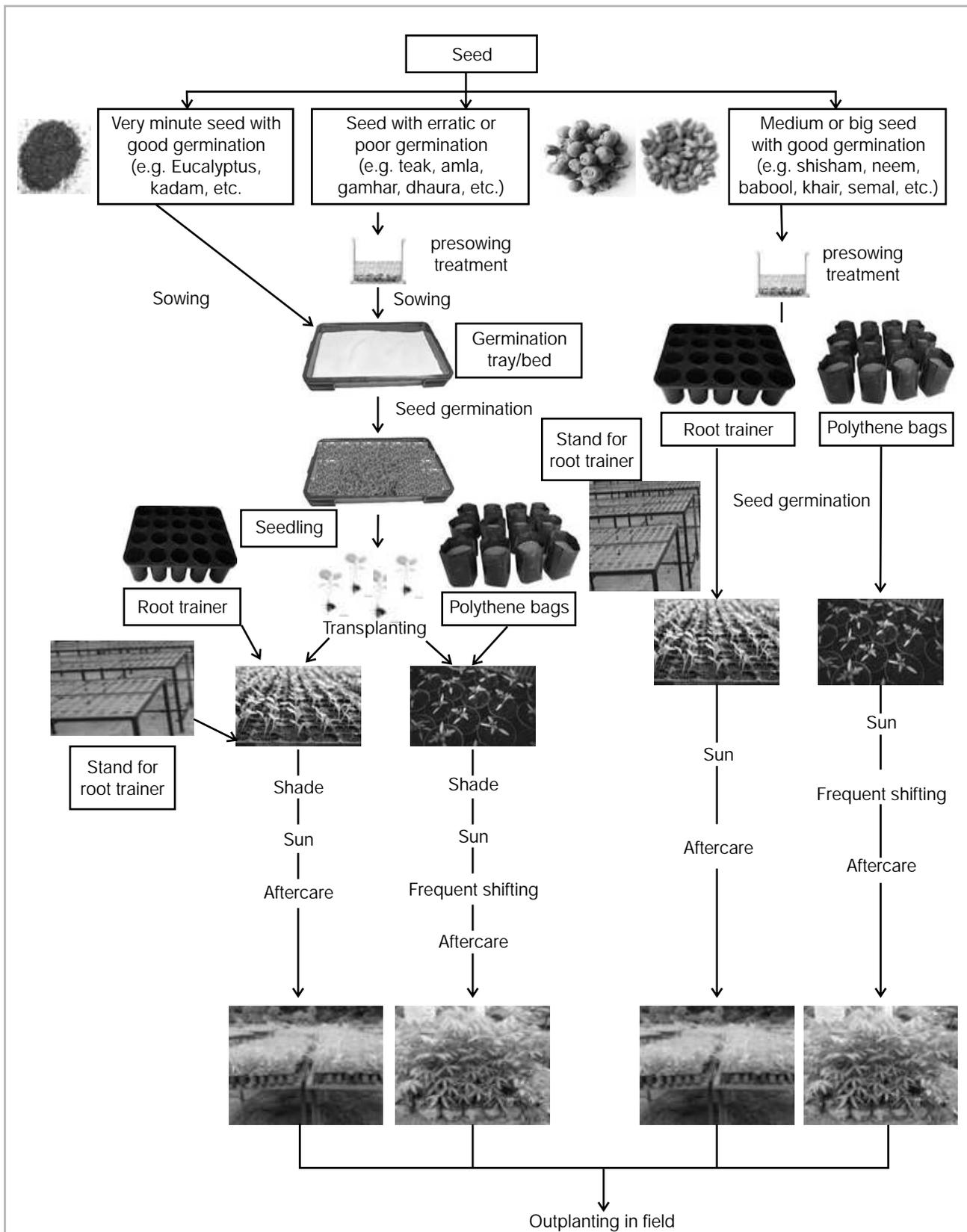


Fig 7. Schematic representation of major steps in raising nursery stock through seed



CONTROL OF DISEASES

Periodical spray of insecticides and fungicides is essential to control insect and fungal diseases in the nursery. Some of the common fungicides and insecticides are Captan, Zineb, Blitox, Cumin, Dithane M-45, Thimet, Chloropyrophos etc. These should be used if disease or insects appear according to the manufacturers' instructions.

PROTECTION AGAINST WHITE ANTS AND RATS

Considerable damage is caused by white ants and rats in the nurseries. White ants live in colonies deep inside the soil and their number increase rapidly where vegetative waste is available. In order to control them, Chlorpyriphos 20 EC should be sprayed after mixing 3 to 4 litres of insecticides in 1000 litres of water. For the control of rats zinc phosphide or aluminum phosphide should be used.

HARDENING

To reduce seedling mortality in the field, seedlings need to be hardened off in the nursery. This can be done by reducing the frequency of watering in the last two months of seedlings nursery life; this promotes lignification of the stem. Roots protruding out of the polythene bags should be pruned at least 15 days before outplanting followed by watering. These operations help in acclimatisation of seedling to the outplanting shock.

GRADING OF PLANTS

The seedlings in the nursery are graded before sale or transport to the planting site. Undersized, lanky, inferior or unhealthy seedlings are separated from normal seedlings. Plants are often graded according to collar diameter and height. Seedlings less than 45 cm are usually not sent for plantation. They are retained in the nursery till they attain the desired size. There is an increasing tendency on part of planting agencies to plant bigger sized seedlings, i.e. about 3 metre in height. Such plants are able to withstand biotic and abiotic stresses of planting sites better than smaller plants. Bigger size plants entail greater cost of production, deserve greater price in the market and hence should be kept separate.

TRANSPORTATION OF SEEDLINGS

Seedlings are very delicate and should be handled properly. The containerised seedlings should always be held by the bag and never hung by the plant itself. Seedlings should be watered before carrying them to the field. Seedlings should be transported in trays, boxes or baskets and not tied in bundles with strings or grass. In case of stumps, they should be bundled, wrapped with a moist sack and transported to the field. The plants should be kept in shade and plants not planted the same day should be sprinkled with water in the morning and evening. While transporting bare root seedlings, the nursery beds from which the plant is taken should be irrigated, seedlings should be graded and bundled, their roots warped with hessian cloth (*taa*) and kept in shade.

4 VEGETATIVE PROPAGATION

MEANING AND PURPOSE

Vegetative propagation involves use of plant parts other than seed. Vegetative propagation is done from well-differentiated vegetative parts, hence the propagules maintain physiological condition of the propagated part and genetic consistence of the parent tree. Vegetative propagation captures and transfers all genetic potential to the new tree. Hence, it has long been used to multiply horticultural varieties.

Vegetative propagation has been widely used in the establishment of clonal seed orchards and vegetative multiplication gardens. Exceptional individuals, including hybrids and sterile hybrids are propagated vegetatively. The original tree from which the parts to be propagated are taken is known as the ortet. Each plant propagated from an ortet is called a ramet. The set of ramets from the same ortet is a clone.

When vegetative propagation is used to multiply a select genotype, this practice is known as cloning. Clonal forestry is becoming increasingly popular in plantation forestry as in *Eucalyptus*, *Casuarina*, *Populus*, *Salix*, etc.

Cuttings retain physiological maturity of donor plants, hence plants from cuttings generally flower and seed earlier than seedlings. This is another reason behind popularity of vegetative propagation in horticulture.

METHODS OF VEGETATIVE PROPAGATION

Methods of vegetative propagation are broadly classified as macro-propagation and micro-propagation techniques. There are three main methods of macropropagation used in forestry: cuttings, grafting/budding and layering. Micro propagation involves tissue culture techniques and is being used on a large scale in *Eucalyptus*.

Cuttings

Cuttings form the earliest and easiest method of vegetative propagation. These are sections taken from the tree branch or seedling stem and subjected to root induction treatment in an appropriate medium. Cuttings are cheaper than other methods of vegetative propagation, although usually more expensive than seedling, and hence these are the preferred means of vegetative propagation. Cuttings of most other species are planted in media in mist chamber for rooting. Poplar cuttings are planted at 80 cm x 60 cm spacing because plants reach about 3-5 m height in nursery in one year.

Raising of plants through cuttings is becoming progressively more popular these days thanks to the current emphasis on clonal technology e.g. *Eucalyptus*. Few species are commercially planted only through cuttings e.g. poplar (*Populus*) and willow (*Salix*). Plants grown through cuttings are true-to-type and carry all the genetic characters of the plant from which cuttings are prepared. On the other hand, due to segregation and recombination of genes during sexual reproduction, seedlings raised through seed show considerable variation in growth and form.

Only a few species are commercially planted only through cuttings. The major advantage is that plants grown through cuttings are true-to-type. Propagation of forest trees by cuttings (in preference to seeds) should be practised only when

- some extremely good individuals are available
- trees are not expected to produce required quantity of seed.
- seeds do not germinate well

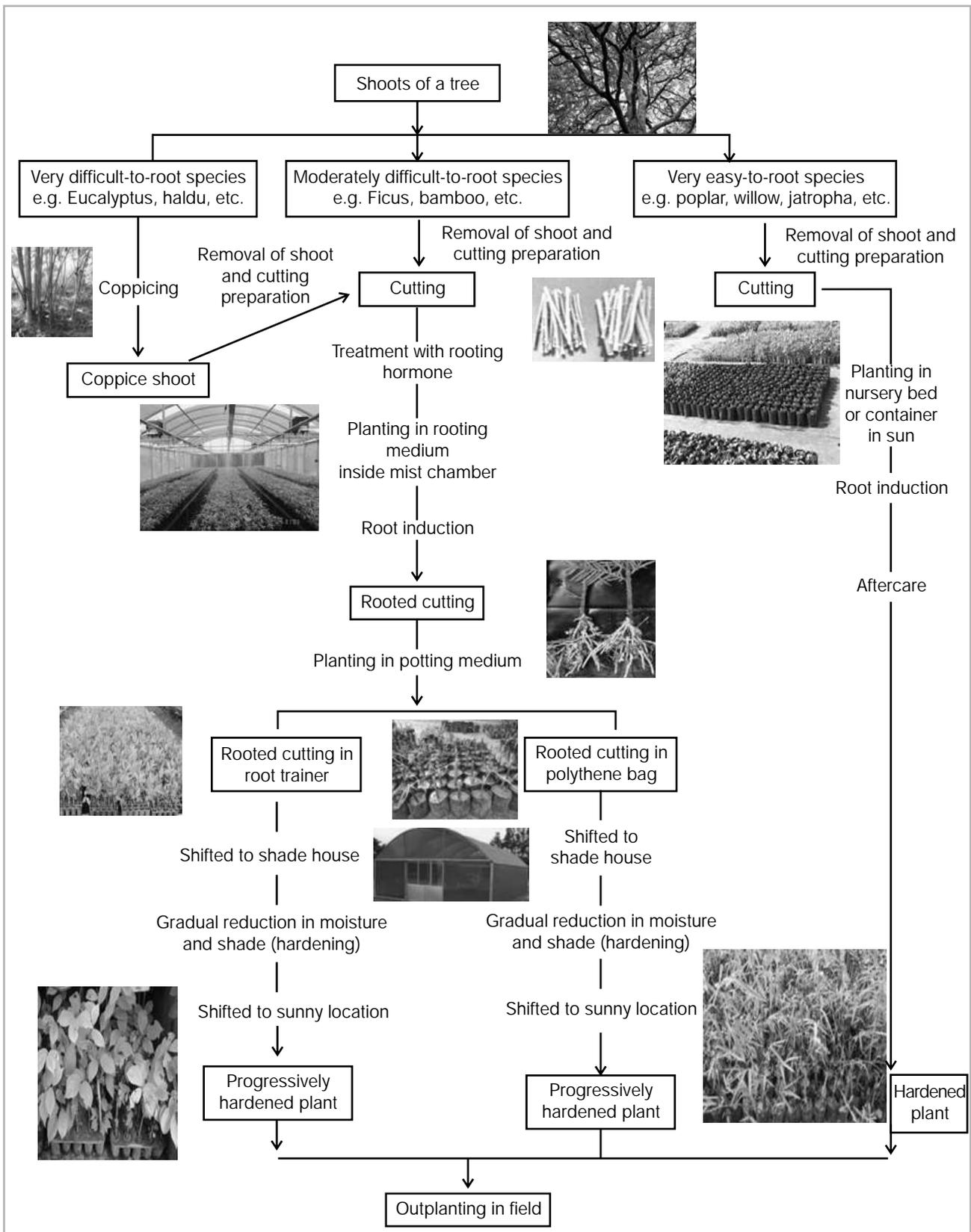


Fig 8. Schematic representation of major steps in raising nursery stock through cuttings

Many of the general procedures in raising plants through seeds are applicable to cuttings as well. The following points deserve special mention in propagation through cuttings:

- Genetic quality

For propagation through cuttings, it is important to use good clone/ variety, only then its higher cost will be justified. Cuttings should be taken from a good clone. If clones are not developed in a species, cuttings should be collected from the best available trees.

- Species, age and season

Rooting varies with species, age and season; these can be determined through experimentation. Some species are easy-to-root e.g. poplar, *Salix*, *Morus* (mulberry), etc. Some species do not root at all e.g. conifers. *Eucalyptus* roots only when cuttings are taken from coppice shoots (shoots arising from lower part of stem when tree is felled). Cuttings of mature trees root poorly; cuttings of juvenile plants root better although the response is species-specific. Cuttings should be prepared in the correct season. Cuttings of most of the temperate species root better during early spring season.

- Storage of cutting

Cuttings need special care during storage and transportation. The cuttings should be stored for the minimum possible time. If cuttings are to be transported over long distances, wax their ends, pack them in gunny bags and keep them moist during transportation. They should be planted as early as possible after they are severed from the mother plant. Applying wax to the upper cut end of cutting reduces chances of desiccation and improves survival. Cuttings immersed in water for 2-10 hours prior to planting sprout and root faster in many species.

- Cutting size

Cuttings should be taken from 1-2 cm thick branches. A sharp tool (e.g. secateurs) should be used to make cuttings. At least 3-5 buds per cutting should be present and the top cut should be at least one centimetre above the highest bud. Appropriate cutting length and thickness should be used. Hardwood and semi-hardwood cuttings usually perform better than softwood cuttings in forest trees. Cuttings of pencil thickness and about 22 cm length are usually recommended. Softwood cuttings of shorter size are, however, quite successful in *Eucalyptus*. In poplar 1-2.5 cm thick cuttings made from stems of one-year-old nursery stock are recommended.

- Treatment with growth regulator

Auxins are applied to the cuttings. IBA, IAA and NAA are popular auxins applied to the cuttings. Cuttings are treated at the base with 200 to 10,000 ppm concentrations of these growth regulators. The most common treatment is 1,000 to 4,000 ppm IBA or IAA applied in powder form. Alternatively, base of cuttings can be dipped for a few seconds in 5,000-10,000 liquid solution of these growth regulators. Several rooting formulations e.g. Rootex, Seradix, etc. are commercially available in the market as alternatives. Poplar, mulberry (*Morus*), willow (*Salix*) do not need any rooting hormone and roots very quickly.

- Planting environment and maintenance

Cuttings need to be planted in high humidity condition in special structures called mist chamber. Cuttings are planted in rooting medium, usually sand or vermiculite, and kept in mist chamber till roots are formed and a dense mass of secondary roots, about 3-5 cm length, develops. The rooting medium should be kept moist throughout the rooting period to facilitate better root initiation and development. Where mist chamber is not available, cuttings should be planted in a shady area having high humidity. After this, the cuttings are removed from this medium and planted in container with potting mixture, same as that for seedling, and retained in high



humidity environment for few days. They are gradually hardened off and transferred to open nursery area for further growth. Poplar and willow cuttings are, however, directly planted in the nursery beds, rather than in containers or mist chamber, due to quick and 100% rooting and very rapid root growth.

- Multiplication rate

Multiplication rates of cuttings are low, they need large areas for donor plant hedges. ageing problem complicates clone testing. Some tree species, such as the poplars and willows, are very easy to propagate by stem cuttings.

Grafting and budding

Grafts are plants obtained by fusing a part from the tree, to be propagated, with another part which has its own root. This involves the removal of a vegetative part from the parent tree (the scion) and its attachment to a part with its own root (the root stock) so that the tissues fuse. Heteroplastic grafts belong to different species, while homoplastic grafts belong to the same species.

According to the position of the scion, there are top and side grafts, depending on whether the scion is inserted into the top or the side of the stock. Grafting is relatively simple technique and it avoids rooting problems. However, it is expensive and not applicable for mass propagation.

Budding is similar to grafting, but in place of shoot (scion), a bud is taken and fused with the rootstock in the budding procedure.

Layering:

Layers are sections of the tree which are induced to form root and then separated from the tree. The procedure consists of making a wound in a branch of the tree and covering this with a medium which retains moisture (moss, earth, etc.). Healing causes the formation of a callus from which adventitious roots may grow. The most common type of layering is aerial layering in which the covering is done with a medium other than soil and the operation takes place rather high off the ground. Wire has been successfully used



Fig 9. Rooted cuttings of *Taxus baccata*

during air layering to induce rooting at FRI Dehradun.

When long, low, flexible branches are available, these can be inserted into the soil and it is known as ground layering. Usually the part propagated is a branch, but in some species interference with the roots can cause them to sprout, constituting a form of layering in that they do not separate from the stem. Layering is relatively simple technique and it avoids rooting problems. However, it is also expensive and not applicable for mass propagation.

Tissue Culture

The latest among the technologies for vegetative propagation are micro propagation through tissue culture techniques. Tissue culture refers to the culture of cells with the potential mitotic activity, in an appropriate medium under aseptic conditions. Micro-propagation using tissue culture method provides unique opportunities to rapidly multiply the elite trees either through organogenesis or through somatic embryogenesis.

In organogenesis, the explants under favorable media give rise to axillary or adventitious shoots which can be separated and rooted under another medium and hardened to plant out to the field.

In somatic embryogenesis, embryo-like structures arise from the explants or callus which can be germinated as a normal plant under specific media combinations. In somatic

embryogenesis, embryos are induced either directly from the explant or from an intervening callus. Somatic embryogenesis is very promising because, the multiplication rate is very high and there are good prospects for automatic handling. However, the method is expensive, there are risks of post-effects, loss of genotypes and certain selection required during the process.

Detailed description of tissue culture methods is beyond the scope of this manual.

Vegetative propagation has been historically used for maintenance of genetic uniformity, since it offers the fastest way to get improved material into production by reproducing the genetic makeup of the selected individuals. However, consistency in phenotypic effect is not always ensured by vegetative propagation. Some of the ramets can have somaclonal variation, where the differences have genetic origin.

Propagation methods can introduce effects that are non-genetic, but are confounded within the genetic unit. These non-genetic effects that can be confounded with genetic effects are called C-effects. In connection with vegetative propagation, the C-effects can be caused either by differences in donor plant physiology or by differences in the environment during propagation.



Fig 10. Air layered shoots



Fig 11. An layered shoot of *Diploknema butyracea* severed from mother plant after root induction



APPLICATION OF VEGETATIVE PROPAGATION IN FORESTRY

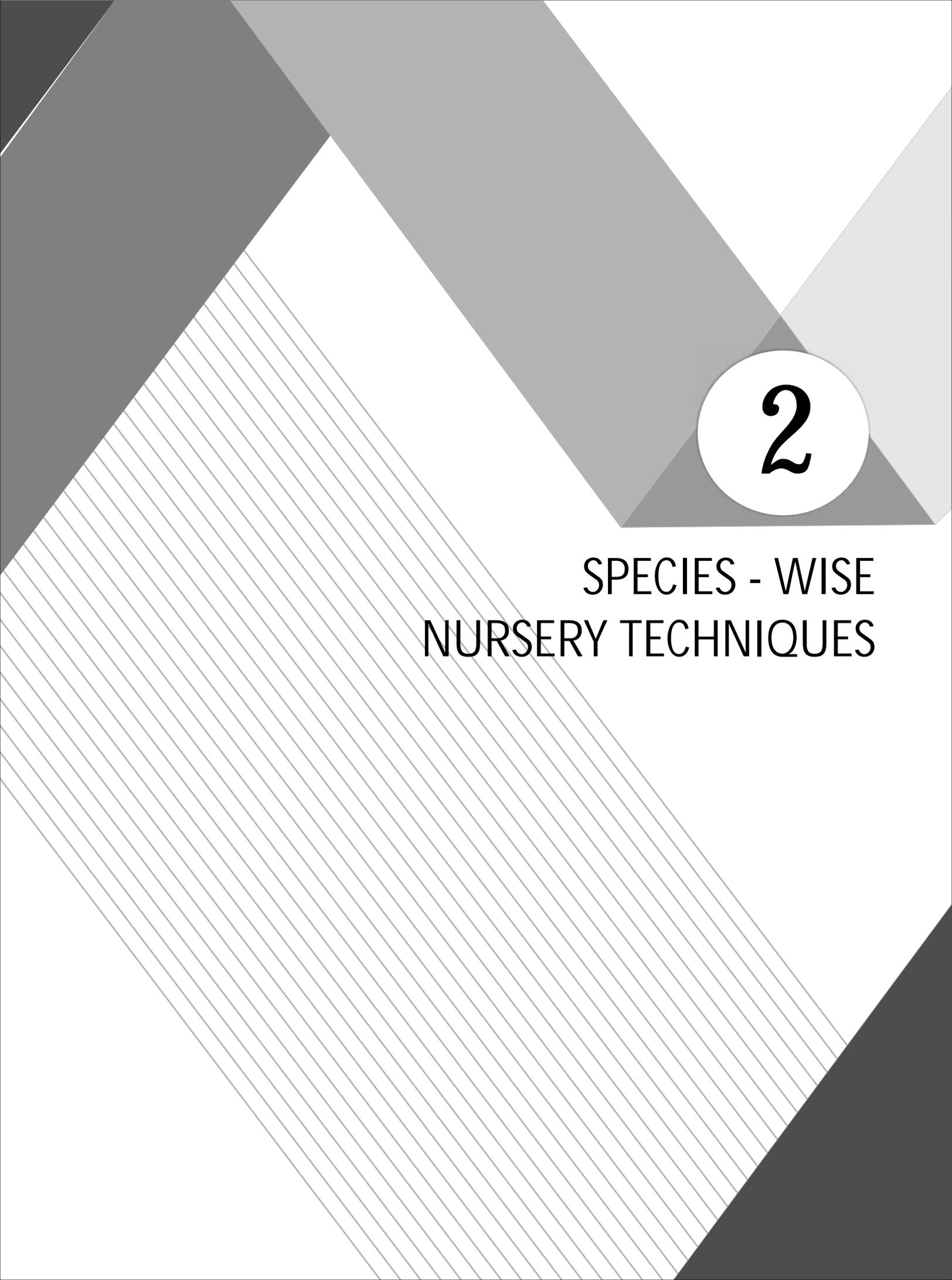
Vegetative propagation of trees was originally used for the species like *Populus* and *Cryptomeria* which reproduced vegetatively under natural condition. Soon it began to be used to multiply the selected superior trees for use in seed orchard and also to preserve germplasm in banks. Large-scale propagation protocols from cuttings at costs similar to those of seedlings have been developed in some forest tree species.

Vegetative propagation has been used in forestry for production of quality planting stock. It has been used as a fast and economical method of raising superior planting stock in the intensive management of forests. It has also been used for propagation of problem trees.

Vegetative propagation could be effectively used in species, which are not able to produce seeds frequently like bamboos. Propagation by vegetative means may be easy, more rapid and economical than by seed in many cases. In some tree species, germination may be poor or slow or there may exist complex dormancy problems or the seed may lose its viability very quickly like in recalcitrant species. Moreover, seedlings of many species grow slowly and take a long time to reach marketable size. In all these cases, use of vegetative multiplication is a more convenient method of propagation.

In addition to the above benefits, some forms of vegetative propagation can be used for production of disease free plants. In tree species that are often susceptible to some pests and diseases and while some may be partially or entirely resistant. Vegetative approaches like grafting will help to produce resistant clones.

Vegetative propagation can also be used to speed up the reproductive cycle for accelerated breeding and testing. Vegetatively propagated plants are precocious in bearing than seed propagated plants. Early induction of flowering thus induced will help to reduce the rotation of the tree species and also to increase the productivity.

The cover features a large, stylized number '2' inside a white circle, positioned in the upper right quadrant. The background is composed of several overlapping geometric shapes: a dark grey triangle in the top left, a light grey triangle in the top right, and a large area of fine, parallel diagonal lines in the bottom left. The text 'SPECIES - WISE NURSERY TECHNIQUES' is centered in the lower right area.

2

SPECIES - WISE
NURSERY TECHNIQUES

1 *Abies pindrow* Royle

Abies pindrow (silver fir) with spruce (*Picea Smithiana Boiss*), commonly referred as high level conifers, covers extensive areas in the Northwest Himalayan States of Himachal Pradesh, Jammu and Kashmir and Uttarakhand, occupying about 31% of the total coniferous area and accounting for about 49% of the total growing stocks in these states. These forests are the very valuable resource and play an important role in the economy of these states, besides helping in soil and water conservation in the catchment areas of major rivers. occurs in Western Himalayas from Afghanistan to western Nepal. It is generally found on northern aspects and in shady localities, forming forests at altitudes between 2100 - 3600 metres but sometimes descending below and up in cool ravines. *Abies pindrow* is an evergreen tree with a narrow, conical crown; it can grow more than 60 metres tall. The straight, cylindrical bole can be 240 cm in diameter. It is an important timber tree in the western Himalayas. The species grows very slow. It is useful softwood for timber, railway sleeper, packing cases, pulpwood, etc.

SEEDLING PRODUCTION

It becomes difficult to collect seed manually on the maturity dates, as most of the seed gets dispersed in the air from mature cones. Results of artificial ripening of cones revealed that the collection time can be successfully preponed to fifteen days of maturity date through their artificial ripening at room temperature. The maturity achieved through this process gave seeds, as well as those allowed to mature under natural conditions. A simple method to judge the suitable time for cone collection is; by putting a cone in a water container, if it starts floating in the upper half of the water, cones collection of the species may be initiated. Harvested cones are kept for air drying for 1-3 weeks either in sun or at room temperature and then partially or wholly disintegrated cones are tumbled, shaken and screened to separate seeds. Due to low viability and infrequent seedling, it has been recommended that seeds in sufficient quantity should be collected to tide over the lean seed years for raising plantations without fail. The number of seeds per kg is 25000-27000.

Good seeds years occur once in 3-5 years. Cones are collected during first fortnight of October and dried in the sun till seeds can be extracted by shaking. About 10 kg cones produce one kg clean seed. Seeds can be stored in gunny bags and should be exposed to sun at short intervals. It has also been found that storage of seeds in deep freezers/low temperature walk-in cabinets improves the seed longevity. Therefore, seeds of these species should be stored at low temperatures (below 10 °C). It can be stored for more than two years at low temperature of -10 °C to -12 °C.

The seeds soaked in cold water for 48 hours before sowing in the nursery. Floating seeds are discarded. Winnowing or aspirators are used for grading of seeds. Seeds are sown in October-November before snowfall. Seed rate in the bed is 30 g/ sq m. Germination begins after snow melts. Germination rate is 70-75%. Seedlings are kept in the nursery for 4½ years. In first rains, seedlings are pricked out at 7.5 cm x 10 cm spacing, in second rains at 10 cm x 15 cm spacing and third rains at 15 cm x 22.5 cm spacing. Last pricking is usually done into polythene bags. Side shade is necessary; growth is better on warm moist soils. Seedlings grow slow and reach 22 cm height in the fourth rain when they are planted out.

Silver fir is very slow growing species and require 4 ½ years in nursery to attain plantable size of 20-25 cm, this includes 1½ years in germination beds and remaining period in the transplanted beds. Seedlings of Silver fir are raised in permanent nurseries located at the lower limit of natural zone of these species. In the past, low-level nurseries were tried to save time required for producing plantable stock but were subsequently given-up, as these nurseries did not offer any advantage over the nurseries in the natural zone of these species. Moreover, it was also observed that the seedlings raised in low-level nurseries resulted in low survival percentage comparatively, when planted in the field. Therefore, the location of the nursery in the natural zone of the species is an added advantage.



Traditionally, Silver *fir* was sown during the month of November / December. For good result, sowing of this species in the nursery beds is recommended after snowfall in the month/April. Sowing is done in 6-inch high raised beds. Before sowing formaline treatment of nursery beds against damping off is of utmost importance in controlling damping off. For the treatment of 1 m² bed area, 250 cc. of formaline dissolved in about 4-5 liters of water is recommended to be sprinkled at least 15 days before sowing. The quantity of water added to the germination bed should be sufficient to penetrate/soak the soil at least up to 15 cm depth. Afterwards, the beds should be immediately covered with polythene sheet for percolation of formaline fumes into the soil. The polythene sheet is removed after two days of formaline application and the soil is raked to allow fumes to escape. During raking of the soil, it should be ensured that the untreated soil does not get mixed up with the treated topsoil. The beds are then left as such for about ten days before seed sowing to avoid toxic effect of formaline on seed.

In a standard nursery, beds should have soil, sand and forest manure in the ratio of 1:1:1 respectively to produce quality seedlings of these species. Line sowing proved better than broadcast sowing. Silver *fir* seed should be sown in 2-4 cm and 4-6 cm wide strips, respectively spaced 10 cm apart. Depth of 10 and 15 mm has been found suitable for sowing and seed should be covered with manure for better germination. Density of sowing depends upon the viability of seed, e.g. seed having 70-80% germination, 100 g (approximately) of Silver *fir* seeds is sufficient for bed area per m². In nursery, germination is observed after 15-20 days of sowing. Though the germination will complete in a month time, but a few seedlings may emerge even after a month. Silver *fir* needs shade at early stages of their development. Shading in the germination beds provided with the help of net made up from wooden battens of 125 X 0.3 cm dimensions have been found suitable. The gap between two consecutive battens is to be kept approximately 0.7 cm. This type of shading permits about 30-40 percent direct sunlight on the beds. This arrangement prevents the seedlings from direct sunlight, which saves nearly 25 % of the seedlings which otherwise die during summer season, if this precaution is not adopted. These wooden battens can be rolled at the time of watering and when no shade is required. The Himalayan Forest Research Institute designed this shading material, however agroshade net of 35:65 available these days may also be tried. Irrigation and weeding in nursery may be done as and when required. Transplanting of seedlings is necessary to encourage fibrous root development and to grow the seedlings into sturdy plants to withstand the planting shock, otherwise develop long tap root which results in ill health of seedlings. Only one transplanting (manually) is recommended in raised beds during raining season. Nursery experiments conducted on transplanting through July, August and September have indicated that transplanting of Silver *fir* done during August gives the best performance. One and half years aged seedlings are recommended to be transplanted in the month of August at a spacing 15 X 8 cm i.e., 84 plants/m² bed area. Silver *fir* seedlings less than 7.5 cm in height respectively should be culled at the time of transplanting, as the performance of these seedlings in transplanting beds have been found quite poor and ultimately it results into wastage of resources and time. The mean root length of Silver *fir* seedlings at the time of transplanting is about 15-25 cm. Furrows for transplanting are not always dug sufficiently deep which results in the root coiling and consequent deformities of roots. Experiments conducted on root pruning at the time of transplanting have indicated that root pruning of Silver *fir* leaving about 10 cm of root length intact, improves the growth and survival percentage of seedlings. Hence roots of these seedlings should be pruned leaving 10 cm root intact before transplanting for better performance and fibrous root system. Shading in transplanting beds is essential as well after transplanting particularly during summer months. Seedlings may also be affected by cutworm attack in nursery which results into debarking of roots and stem as well. Application of Phorate @ 10 g /m² has been recommended to control cutworm attack in these nurseries. Irrigation, weeding and hoeing is recommended as and when required.

VEGETATIVE PROPAGATION

Vegetative propagation is not practiced for raising of seedlings of this species in the nursery for commercial planting.

2 *Acacia auriculiformis* A Cunn. ex Benth.

ABOUT THE SPECIES

Acacia spp. are mostly thorny trees or shrubs, a few are climbers which belong to family Fabaceae (Leguminosae) subfamily Mimosoideae. *Acacia auriculiformis*, popularly known as Akashmoni or Australian wattle, is an evergreen, tall straight tree with dull-green, thin crown and smooth white bark. It reaches a height of 9-11m, rarely upto 15m in about 30 years. It is a native of North Australia and Queensland; but frequently planted in various parts of India as an exotic suitable for introduction in dry regions. It has been successfully raised in West Bengal, Bihar, Andhra Pradesh for forty years and more recently in Karnataka, Odisha, Uttar Pradesh and Maharashtra. The place of tree leaves is taken by phyllodes which consist of the leaf stalk modified into a flattened blade. This species has been found useful for paper making. It is reasonably good firewood and can also be used for making cheap furniture.

It is a light demander species. It is an evergreen tree retaining considerable foliage during the year. It is not browsed by the cattle. Dispersal of seed is by wind.

SEEDLING PRODUCTION

Sowing of seed is done in containers such as polythene bags. Propagation is also done by direct sowing of seed in bed or plantation sites, and through root suckers.

SEED COLLECTION AND STORAGE

The tree seeds profusely every year. Ripened seed is collected from the tree from February to March by lopping. Pods turn from brown to black on ripening. They are spread in the sun for 5-9 days; they open out to release seeds. Seeds are separated by hands. If stored in air tight bottles, tins, earthenware, pots, in cool dry place, the seeds can retain their viability to a large degree upto 2 years. The seeds are liable to attack by ants.

The seeds weight 30,800 to 42,000 per kilogram. The germination capacity is quite high i.e. 50% to 95%.

PRE-TREATMENT OF SEEDS

Seeds should be soaked in cold water for 24-36 hours before sowing. Sometimes the seeds are also treated by immersing in boiling taken off the fire and left to cool and soak for 12 hours.

NURSERY TECHNIQUES

The seeds can be sown either in nursery beds or in containers. Containerised plants (generally polythene bag plants) give better results. Mixture of local soil and cowdung in the ratio of 3:1 is used as a potting media. Seeds are sown in nursery in the Month of March in nursery bed at a spacing of 5cm × 5 cm under shade. As seeds are liable to be attacked by ants, a light spray of kerosene oil is helpful. Overhead shade should be given during germination period, which should be removed after germination is completed. A thatch barrier of one side of the bed is generally given to cut off direct hot winds. Germination starts in 15-21 days and completes within 30 days in favourable localities. The seedlings are planted out in the field in June-July with the monsoon when the stock should have average height of 30 cm.

This species has comparatively high resistance against oxygen deficiency and may be useful for planting in swampy ground and stiff soils. It is also a promising species for sterile soil in coastal area.



3 *Acacia catechu* (L.f.) Willd

ABOUT THE SPECIES

Acacia catechu (Khair) is a small to moderate sized deciduous tree of family Fabaceae. The tree occurs in tropical and subtropical climate in plains and low hills upto 1200 m altitude in north and central India in areas of 500 to 2160 mm rainfall. Timber is suitable for agricultural implements, tool handles, house posts, oil and sugarcane crushes, spoke and hubs of wheels, etc. It is also used as fuel and yields good quality of charcoal. The most important product obtained from khair is Katha or catechu which is internally used in pan preparations and in medicine. It is a good fodder tree and is extensively lopped for goats and sometimes for cattle also. Spent chips after extraction of katha and cutch can be utilized for preparation of hardboards.

SEEDLING PRODUCTION

It can be established by direct sowing, transplanting and stump planting.

SEED COLLECTION & STORAGE

The tree seeds well almost every year and produces fertile seed at an early age. Seed ripens in November-December or early January and even the February. The pods turn reddish black on ripening. The pods are collected off the trees or by lopping branches. The pods are dried in the sun and then thrashed to separate seed, which is properly cleaned, dried in the sun and stored in air-tight containers. As the seed is susceptible to insect attack, it should preferably be not stored for more than 6 to 8 months. Germination percent is 5.1 to 17.0 after 1 year's storage and 9.4 after 2 year's storage. Only freshly collected seed are used as khair is a good seeder every year. About 40,000 seeds weigh one kg. The number of pod is about 4590 per kg. Seed yield per tree is about 0.5 to 2.0 kg.

PRE-TREATMENT OF SEED

Pre-sowing treatment of seed with sulphuric acid hastens germination. Soaking in cooling boiled water for 6 hours is more effective than soaking in cold water for 24 hours.

NURSERY TECHNIQUE

Two seeds are sown per bag at a depth of 1.5 cm in February-March. Germination starts in a week and takes 2 weeks to complete. The germination percentage generally varies from 70 to 80. The number of seedlings is reduced to one after the seedlings have grown about 5 cm. Polythene containers are regularly watered. When the plant have grown to height of about 15 cm, nitrogenous fertilizer like calcium ammonium nitrate of 2 gm is added to every plant for about four times during May and June. Shifting of plant is done in May and June. The seedlings become fit for planting out in July when they are about 3-4 months old and 50-60 cm high.

In germination beds, sowing can be done in well prepared nursery beds in February-March. Seed beds must have a well-drained sandy-loam soils. Spacing adopted is 20 cm between lines and 2 cm between the seeds in line. Depth of sowing is about 0.5 cm. Germination begins in 5-7 days. When seedlings have sufficiently grown, they are transferred from the seed beds to plastic bags about 10 cm X 15 cm.

For stump planting, Stumps are prepared of 12-15 months old well developed seedlings. The root and shoot portion should be 23 to 31 cm and 2.5 to 5.0 cm respectively. Just before planting, the stumps are freshened to remove the desiccated portions of shoot and root. Stumps can be stored without affecting the survival percent for 3 days. Planting of stumps should be done soon after the break of monsoon, however, under irrigated conditions, stumps can be planted during March-April also.

VEGETATIVE PROPAGATION

Vegetative propagation is not practiced in the species for commercial planting.



4 *Acacia nilotica* Willd ex. Del

ABOUT THE SPECIES

Acacia nilotica Willd ex. Del, commonly known as babul, babool, prickly acacia, black piquant, Egyptian acacia, Indian gum arabic tree or gum arabic tree encompasses nine subspecies distinguished by the shape and pubescence of the pods and the habit of the tree: *indica*, *kraussiana*, *leiocarpa*, *nilotica*, *subalata* and *tomentosa* in Africa, *cupressiformis* and *hemispherica* in the Indian continent, and *adstringens* in both continents. Those subspecies were long considered to be separate species till the 1970s.

Babul is a medium sized, thorny, nearly evergreen tree that can reach a height of 20-25 m but may remain a shrub in poor growing conditions. The trunk is short, thick (1 m in diameter) and cylindrical, covered with grey bark. The crown may be flattened or rounded. The root system depends on the growing conditions and subspecies: a deep taproot in dry conditions and extensive lateral roots in flooded conditions.

The leaves are 5-15 cm long, alternate and compound with 7 to 36 pairs of elliptical, 1.5-7 mm long x 0.5-2 mm broad, grey-green, hairy leaflets. Flowers are sweetly scented and bright to golden yellow in colour. The fruits are linear, flattened, narrow indehiscent pods, 4-22 cm long and 1-2 cm broad, dark-brown to grey in colour and glabrous or velvety. The pods contain 8 to 15 elliptical, flattened bean-shaped dark seeds. There are two groups of *Acacia nilotica* subspecies. The first group (*nilotica*, *tomentosa*, *cupressiformis*, *indica*) consists of tall riverine trees that grow in seasonally flooded areas. Their pods have a characteristic "necklace" shape with constrictions between the seeds. The second group (*adstringens*, *kraussiana*, *leiocarpa*, *subalata*) grows in drier areas and has straight-edged pods.

Babul is a multipurpose tree: it provides timber, fuel, shade, food, fodder, honey, dye, gum and fences. It also impacts the environment through soil reclamation, soil enrichment, protection against fire and wind, and as a haven for biodiversity and ornament. It is widely used in ethno-medicine. Babul is a useful fodder source, and sometimes a very important one, particularly in dry regions. The foliage and the pods dropped during the dry season can be a fundamental source of nutrients in periods of feed scarcity. Babul originated from Africa, the Arabian Peninsula and the Indian subcontinent.

Babul mainly occurs in plains on flat or gently undulating ground and ravines. It grows best on the alluvial soils in riveraine areas subject to periodic inundations. It flourishes even in alkaline soils. A considerable amount of moisture in the soil is essential for its success. Even the existence saline water in the sub-soil is not injurious.

Babul occurs in tropical and sub-tropical regions of India. In its natural range the absolute maximum shade temperature varies from 40°C to 47.5°C. The average annual rainfall in its normal habitat varies from 200 to 1270 mm. The tree normally tolerates temperature range varying from 4°C to 47°C. For good development the optimum lower limit of rainfall is about 600 mm.

FRUITS

Abundant fruits are produced almost every year during April and May. The pods are indehiscent and show considerable variation in colour and shape from dark brown to grey and straight to curved, glabrous to velvety in texture. The pods are thick but compressed having 6 to 16 seeds per pod. Seeds lie transverse to the long axis of the pod.

SEED COLLECTION

Babul seeds are available in abundance and can be collected using one of the following options: From natural fruit fall, From standing trees, From felled trees, From animal pens. Seed Seeds are dark, black-brown in colour, smooth,

compressed, 7-8 mm in diameter with a hard seed coat. Considerable variation exists in seed quality from one origin to another. Seeds from moist localities are generally bigger as compared to seeds from dry locality. Seed weight studies indicate a variation for 5500-11,600 seeds per kg.

SEED STORAGE

Seeds can be stored in gunny bags, tins or baskets. Seeds must be stored in cool and dry place with good air circulation. If seeds are to be stored for a long time, they need to be completely air dried and kept in air tight containers.

TREATMENTS OF SEEDS

The seeds coat of babul seeds is very hard and impermeable. It requires pretreatment to hasten germination. Babul seeds can be pretreated by one of the four methods described below:

- Immersion in cold water for 48 hours
- Immersion in hot water (80° C) for 30 minutes. The water is heated till the temperature rises up to 80°C. The container containing hot water is removed from the heat and seeds are immersed in the water for 30 minutes. After treating with hot water the seeds are soaked in ordinary water for 24 hours prior to sowing.
- Soaking in sulphuric acid (90%) for 2 to 10 minutes. Seeds after soaking in the sulphuric acid are removed, washed and dried prior to sowing.
- Seeds collected from goat/sheep pens do not need any further treatment. When, seeds are required to be sown immediately after collection, this is probably the best and convenient method. Animals may be fed with Babul pods for this purpose. Out of the above treatments the hot water treatment is safe, quick and effective and thus recommended.

NURSERY PRACTICES

The treated seeds are sown in nursery beds either by broadcast sowing or by dibbling method. However, the dibbling, method is preferred. Babul is seldom raised in nursery beds. It is generally raised in polythene containers. Two or three treated seeds are sown in each bag, about 1.5 cm deep during February-March i.e. about 5 months before transplanting in the field. The soil mixture used in polythene bags consist of soil and compost in 2:1 ratio. Germination commences one to three weeks after sowing and is mostly completed in a months time. The germination of the seed is epigeal. The radicle emerges and descends.

PLANTING PRACTICES

Size and quality of planting stock Seedlings attain a height of 30 to 40 cm in a period of 6 months. Experience indicates that medium sized stock, between 30 to 40 cm tall with a woody root collar, has a better survival rate. The seedlings should be transplanted at this stage when the root shoot ratio is optimum. Further growth of shoots leads to imbalance in root shoot ratio and a large number of casualties of planting out. Mortality in plantation is high for undersized and weak seedlings. Grading of seedlings is, therefore, important.

DIRECT SOWING

This is the easiest and most common method for raising babul plantation in the field. Several methods have given satisfactory result. The successful ones are by broadcast sowing (seed rate 2.5 – 3 kg ha⁻¹), dibbling in lines, patches or mound sowing during June (seed rate 1 kg ha⁻¹).

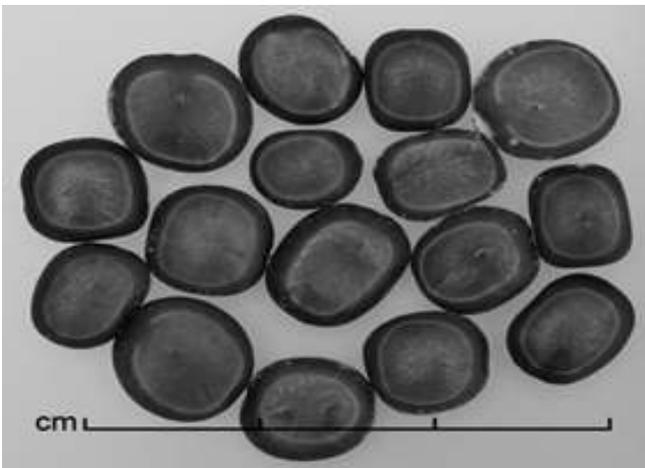


ROOT SYSTEM

Babul species has a very long tap root system. As the growth advances, several lateral roots also develop at the end of the first season and after some time the tap root and lateral roots cannot be easily distinguished. Seedlings of plantable size are graded in the nursery. The gradation depends to a large extent on local experience and the establishment of local standard. The main objectives of a grading system for planting stock are: To eliminate seedlings with damaged or diseased tops or roots. To eliminate seedlings below the minimum standard of size and root development.

PLANTING

Babul is planted in manmade forests under several environmental conditions using different methods of establishment. The seedlings are generally planted in pits having the size of 30 cm³. The most common spacing adopted for plantation is 4m x 4m. On road sides, deeper pits of the size of 45 cm³ are preferred. Mound planting is practiced where there is fear of water logging specially on dug up road sides. For proper growth and survival it is necessary to give one or two watering after planting. This is specifically required in arid regions. Irrigation after planting is not a prerequisite in areas having sufficient soil moisture and precipitation. Higher survival rate and better rate of growth is reported when soil and water conservation measures are also adopted.



A. nilotica seeds



A. nilotica plantation

5 *Acacia senegal* (L) Willd

ABOUT THE SPECIES

Acacia senegal, locally known as khor, kumath, kumta or Gum arabic tree, is a small thorny deciduous tree, usually gnarled and of straggling form when young but developing into a fairly straight tree after 15 to 20 years. The tree belongs to the family Fabaceae (sub-family Mimosideae). It attains a height of 3-5 m and a girth 30-60 cm. In habit and appearance the tree resembles *A. modesta* but is readily distinguished by its smooth pale bark, its infra-stipular spines in groups of three and its large pods.

This is a tree of the arid regions of India, occurring in Rajasthan, south-east Punjab and parts of Gujarat (Saurashtra, Kutch), mainly on the dry rocky hills in the Aravallis and the sandy tracts to the west of the Aravallis. It is planted for gum over large area.

Acacia senegal is found in the Dry Tropical forests and Tropical Thorn forests. The tree occurs on the poorest soil on rocky hills and sandy tracts. The soil on the Aravalli range where the tree is most abundant are usually shallow, stony, poor and unstable. In the region lying to the extreme west of the Aravallis, the soils are of the desert type, consisting mainly of a wide expanse of aeolian sands heaped up in a series of dunes or ridges. Most of these soils have high percentage of soluble salts. It occurs in the plains of south Punjab and west Rajasthan as also on hill-slopes on the Aravallis, ascending to 700 m.

The seeds of *A. senegal* is used as a vegetable in Rajasthan. Its wood is hard, heavy and strong. It is durable and is not attacked by white-ants. The wood is used for making cart wheels, sugarcane crushers, Persian wheels, posts, weavers' shuttles and agricultural implements. The tough roots and stems of young trees are suitable for tool-handles. It is also used as fuel. This tree yields the true "gum Arabic" which is an important article of commerce. The gum Arabic is used for numerous purposes e.g. in confectionery, manufacture of chewing gums, in the finishing of silk and in the preparation of ink and water colours.

SEED COLLECTION AND PROCESSING

Ripe pods are picked from standing trees. Seed can be extracted from the pods by trampling or by beating with sticks and then removing the husk by winnowing. Approximately 8,200-10,900 seeds weigh a kilogram. Germination commences 2-6 days after sowings and is complete in 75 days. The germination capacity is about 70% and plant percent 37-70. Ripening of fruits takes place in October-November and seed fall in December to March. It produces abundant seed every year and regenerates freely under adverse condition.

NURSERY TECHNIQUES

This species is easily raised in the nursery. For container planting, sowing is directly done in the polythene bags. Root trainers are not used, but they can be easily employed for its propagation. Seeds are sown in containers. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Sowing is done in germination beds if naked root planting is desired, this practice is on the wane. Seedlings grow rapidly and attain plantable size within three months.



6 *Acrocarpus fraxinifolius* Wight. & Arn.

ABOUT SPECIES

This genus contains 3 species of trees restricted to tropical S.E. Asia, out of which only one, *A. fraxinifolius* is native to India. Its trade name is Mundani and belongs to the family Fabaceae. It is an unarmed tree with large bipinnate leaves consisting of numerous large leaflets, red or orange flowers with only 5 stamens in dense erect racemes and stalked, thin, flat pods with many seeds. It is a lofty deciduous timber tree. It is a very large lofty deciduous tree with a straight, cylindrical, often buttressed stem. It is one of the tallest trees found in India.

The natural habitat of the tree is in the evergreen forests of the Western Ghats from South Kanara southwards chiefly on hills slopes upto 1200 m and in the Eastern Himalayas in West Bengal, Bhutan, Sikkim and Assam. The species thus has a disjunct distribution. In Southern India it is fairly abundant in the Nilgiris, Coorg, Hassan Ghats, parts of Shimoga, North and South Kanara, Anama lais, Palni hills, Tiranelveli, Kerala forests and Andhra Pradesh (Kurnool district). In Eastern India in Assam, it occurs in Goalpara, Cachar. In West Bengal it occurs in Kalimpong and Duars forest division and in Meghalaya in Garo and Khasi hills at low elevations. It also occurs in Sikkim. In its natural habitat, the absolute maximum shade temperature varies from 35°C-42.5 °C and the absolute minimum from 2.5°C-17.5° C to 21.4°C. In India it grows on different type of soil in different regions such as Western Ghats (quartzose gneiss), Deccan plateau (laterite rock), Eastern Himalayas (red soils), West Bengal (light brown clay). It is sensitive to frost and in open condition liable to wind damage. The wood is mostly used for planking, flooring and shingles. It is a good light furniture wood. It also finds use in tea box, packing case and crate manufacture in the regions where it occurs.

SEED COLLECTION AND PROCESSING

Fruits ripen from April-June. In West Bengal, best seed is reported to be obtained from the last week of April to the middle of May and in Karnataka from the end of February till the onset of rains.

Mature pods are recognised by their black colour. They are collected by lopping branches or off the ground, dried in the sun for 3-4 days on mats and then beaten with a stick, or crushed between the palm of the hand, so as to loosen the seeds. One kilogram of fruits gives 125 g of cleaned seeds. About 1100 fruits weigh one kilogram. Seed keeps well for long periods without losing viability altogether. The seed has a hard seed coat.

NURSERY TECHNIQUES

The species is usually raised by direct sowing in lines. If required to be raised in nursery, the seed is sown broadcast in shaded beds as soon as possible after collection. 3 kg of seed will suffice for 10 sq. m nursery bed. Watering is done twice daily till germination and thereafter on alternate days. The beds should be kept well weeded. Once germination occurs, seedlings develop rapidly and take possession of the nursery bed (or the ground), shading and crowding out the smaller seedlings from later germination. Thus it is generally impossible to obtain a large number of seedlings from nursery. The seedlings are transplanted into polythene bags or in unshaded nursery beds as soon as they are high enough to handle. They are planted out during the monsoon rains of the same year.

7 *Aegle marmelos*

It is found wild almost throughout India, except in the arid zone of Rajasthan and in the high rainfall zone of the Western Ghats. It is extensively planted all over the country for its fruits. It is a small to moderate-sized deciduous tree with branches armed with spines. In its natural habitat, the absolute maximum shade temperature varies from 40-50 °C and the absolute minimum from 2.5 -15.0°C. The tree occurs in mixed deciduous forests both on flat and undulating terrain ascending up to 1,200 m elevation in the sub-Himalayan tracts and outer hills. It is found typically on stiff, dry, clayey, alluvial soils, after growing gregariously. Natural reproduction by seed is, as a rule, not adequate. The wood is commonly used as posts and for shafts, axles and naves of carts. It is also used for railway keys, brake blocks, cheap turnery, tool handles, combs and toys, and for agricultural implements. It can also be used as fuel.

SEED COLLECTION AND PROCESSING

The seeds should be obtained from the fruits collected off the trees and not from the ground. They are washed to remove the mucilage and dried for a few days in the sun. They may be coated with red latif necessary, to keep off ants. The seeds are rather perishable and cannot stand storage for long; they should, therefore, be used as soon after collection as possible. The seeds weigh 5,300/kg (Punjab seeds 1,120/kg). Germination trials in Haldwani (Uttar Pradesh) gave 56% germination.

NURSERY TECHNIQUE

Seedlings are most commonly raised in containers i.e. polythene bags and root trainers. Seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds. Fresh seeds should be sown in nursery beds during June-July and covered with earth, followed by regular watering to the extent required. The seedlings will be ready for planting in the in next season. As the growth of seedlings is slow. It may be desirable to retain backward seedlings for another 1-2 years, if necessary. Under gardening conditions, seeds are sown in pots in April-May. The seedlings are ready for planting out in the second or third season. Seedlings should be tended during the rains and protection should be provided against stray cattle and goats.



8 *Ailanthus excelsa* Roxb

ABOUT THE SPECIES

Ailanthus excelsa Roxb. belongs to the family Simaroubaceae. The genus is native from South East Asia to northern Australasia. They are also known as "poverty trees". The vernacular names of *A. excelsa* are White palle (English), Ardu (Hindi), Mattipal, eru, perumaram (Tamil) and matti (Malayalam). It is an indigenous species commonly found in south of the Ganges, West Bengal, Bihar, Orissa, coastal areas of Andhra Pradesh and dry belts of Tamil Nadu. It also occurs in Rajasthan and Maharashtra. In its natural habitat the maximum and minimum temperature varies from 45°C to 47.5°C and 0° to 12.5°C respectively, and mean annual rainfall ranges from 500 to 1900 mm, sometimes even up to 2500 mm. It can grow on a variety of soils but thrives best on porous sandy loams. It avoids clayey soils with poor drainage and waterlogged areas. It can grow even on shallow dry soils but the growth is poor. *A. excelsa* has given better performance as compared to other species in lateritic soils. The tree can be seen growing up to an elevation of 900 m.

Ailanthus has been recommended as an excellent short rotation plantation species. *Ailanthus* has no adverse effect on the crops sown as under storey if proper care is taken. For having better results, the spacing adopted should be at least 6 x 6 m. The rotation of *Ailanthus* is considered as 20 years but it was found to go 30 years or more. The lopping of leaves commenced from the fourth year onwards. The leaves are used for fodder and wood is used in cottage industries for making toys, low cost cricket bat and in match box industry. The amino acid compositions, the solubility patterns and the high abundances of low molecular weight proteins indicate that the isolated seed protein of *A. excelsa* may be a potential food protein. It is estimated that an average tree gives about 5 quintal leaf fodder per year. The cultivation and maintenance cost would be approximately Rs. 80,000 ha⁻¹ under rain fed conditions and Rs. 92500 ha⁻¹ under irrigated condition. The approximate expected yield would be 200 tonnes of wood in the rainfed condition and 475 tonnes under irrigated lands in 6-7 years rotation. It is reported that fodder cowpea could be recommended as a compatible crop for *Ailanthus* based agroforestry system.

SEED COLLECTION AND PROCESSING

The seeds are generally available in April - June and natural regeneration comes up in July. Its natural regeneration in the forest is usually not promising. The seeds are very light and winged and are dispersed by wind. If the seeds fall on bare ground germination takes place early in the first rainy season after the fall of the seed, but the seedlings rarely survive due to the sensitiveness of the seedlings and their intolerance of heavy weed growth. Large proportions of seeds do not germinate and are destroyed. The natural regeneration of *A. excelsa* can be seen in urban areas in abandoned houses, adjacent to boundary walls and also along the farm boundaries.

The seeds which are buried deep, fail to germinate and seedlings in depression die due to poor drainage, weed competition and attack of pests. Natural regeneration through coppice and root suckers is adequate. Coppice shoots are thinned for better development. Seed Collection and Storage: Since the seeds are light weight, the fruit bunches at the end of the branches should be cut with long handled tools as soon as they show signs of ripening. The seeds are dried on a clean floor so as to prevent seeds to be away by winds. The seeds are then separated and stored in sea air tight tins after being thoroughly dried. The seeds should be used in the same year as they cannot stand storage till the second year. The seed loses viability fast but under proper storage conditions they can remain viable for up to 8 months otherwise the normal viability is 4-5 months. The number of seeds in one kg is about 8000-10,000.

As reported, the seeds of *Ailanthus excelsa* exhibit orthodox storage behaviour as viability period increased with the decrease in storage temperature and seed moisture content. Seeds dried to 5.7% moisture content remained viable, with

50% of the initial germination, up to three years at 5°C and up to one year at ambient temperature.

SEEDLING PRODUCTION

For nursery establishment the soil should be light, pore and well drained. The seed beds should be well raised to all drainage. Studies concluded that soaking the seeds in water for three days interrupted with the leaching (changing) at 24h interval enhanced the germination of seed to the maximum of 51 per cent. The production of higher recovery of seedlings revealed that 50 g m⁻² produced higher number of seedlings. Another study showed that compared with water, soaking in 2.5% KNO₃ recorded an increase of 28% in germination. Vigour parameters such as root growth, shoot extension, and dry matter production of 21-day seedlings were also considerably enhanced under this treatment.

Sowing of seeds in beds is carried out in the month December-January. The seeds are sown in the mother beds cover with soil. The seeds may also be sown directly in the poly bag. The germination is epigeous; it starts 8-10 days after sowing a completed in about 40-45 days. No pre-treatment is required for seeds. Mixing of seeds with ash or pulverized soil ensures uniform sowing. It is reported that germination percentage, germination energy and germination values were all greatest when seeds were sown at a depth of 0.5 cm depth and lowest when sown at 1.5 cm depth.

The germination percentage is nearly 60-70 percent. The nursery beds are irrigated regularly but they require gentle al light irrigation as seedlings are susceptible to diseases such: damping off with heavy irrigations. Over watering causes damping off and root rot in the plants. The young seedlings in nursery are very delicate and unable to compete with weeds. Timely regular weeding of the nursery beds is necessary to avoid suppression and killing of seedlings. Regular weeding and watering are beneficial in increasing both survival percentage and height growth. One month or one and a half month old seedlings from mother beds are pricked out into plastic container and kept it they become fit for planting. *A. excelsa* can also be planted by root shoot cuttings 2-3 cr in diameter, which is prepared from nearly one year old seedlings Soil, sand and farm yard manure in the ratio 3:2:1 is general used as potting mixture for poly bog rising. The application of manure mixed with water boosts up plant growth. It is also reported that *Ailanthus excelsa* is able to tolerate extreme soil pH of 10.5, when the soil is mixed with sand and farm yard manure at 2:1:1 ratio, in terms of germination, seedling growth and chemical attributes of the seedlings.

The seedlings or saplings may be affected by web worm *Atteva fabriciella*. Severe defoliation affects plant growth and may cause death of the plant. The full grown larvae are grey in colour and live gregariously under a silk web spun over the leaves and shoots. They are controlled by application of 0.1 per cent of endosulphan and malathion

VEGETATIVE PROPAGATION

Vegetative propagation is used to maintain the genotype that is adapted to the plantation site. It provides large number of quality plantation stock within short period of time.

ROOTED CUTTINGS

The method of vegetative propagation adopted for *A. excelsa* is branch cuttings and coppice shoots cuttings. The age is the deterrent factor on rooting of branch cutting. Most of the young trees showed the better rooting. Particularly, the trees upto four years showed good rooting percentage. When the tree is left to grow long enough to prove their genetic worth it is difficult to clone them. Cuttings are collected from lower and outer portion of the canopy from healthy, vigorous branches measuring 2 cm in diameter and 23 cm length. The leaves and terminal soft portions are excised and treats with different concentrations of IBA upto 3000 ppm. The cuttings were kept in 300 cc root trainer with the potting media of sand, coir pith and vermiculate. The root trainer will be placed into the poly tunnel and which around 90% humidity will be maintained. The rooting response can be seen only in the month of October and November.

With regard to vegetative propagation of *Ailanthus excelsa*, a study revealed The semi-hardwood branch cuttings of 10 to 15 inches length and 3 to 4 inches girth has to taken and treated with RIDOMIL @ 2.5 gm in one litre of water for a few minutes to avoid fungal infection in the polytunnel (propagating unit). Then, the cuttings have to be treated with 3500 ppm



of IBA concentration by quick dip method and this concentration is reported to be the suitable for obtaining maximum rooting (up to 38%) in the stem cuttings. These cuttings are kept in polytunnel directly in fine sand. The temperature was maintained between 30°C and 35°C and relative humidity at 70 -85%.

COPPICE SHOOT CUTTINGS

Ten years old selected *A. excelsa* trees have been coppiced at ground level and allow 15-25 cm base above ground level. The cut ends have to be given an antifungal treatment. After 35-40 days coppice shoots are ready for the harvest. Each tree would yield 15 nodal cuttings. The shoots should be green and fleshy within 5-10 cm. the type of cutting selected is playing pivotal role in success of rooting.

Splice grafting approach was proved little success in *Ailanthus excelsa*, wherein Sixty days old scions can be collected from sprouts of matured tree's stem cutting. A simple slant cut of the same length and angle need to be made in both the root stock and scion with a grafting knife. They are placed together in a way so that cut surfaces remain in contact maximal. After joining the scion with rootstock a polythene strip has to be wrapped around it. During this processes care need to be taken to minimize the desiccation of scion and root stock. Initially for two weeks, these grafted plants are kept in mist chamber. After one-month survived grafted plants are transferred to shade house.

It is also reported that In vitro cloning of *Ailanthus excelsa* L. can be achieved by using apical and axillary bud explants from mature trees. However, survival rate and growth performance was highly season dependent, with satisfactory survival in early winter only. MS basal medium with KT (2.0 mg/L), GA (0.2 mg/L) and tyrosine (10 mg/L) induces high frequency of development of axillary shoot buds in three to four weeks. Elongated shoots can be successfully rooted on half strength MS medium fortified with IBA (1.5 mg/L).

9 *Albizia lebbbeck* Benth.

ABOUT THE SPECIES

Albizia lebbbeck Benth., commonly known as Siris, is a moderate sized or large deciduous tree, usually with a straight bole and broad crown. The tree belongs to the family Fabaceae. The tree is recognized by its pale straw coloured large pods which remain hanging on the tree, being specially conspicuous in the hot weather when the tree is more or less leafless and the pods rattle with every puff of the breeze, producing a sound like that of frying of meat. The size of the seed varies greatly depending upon the locality and environment.

It is found in parts of Assam, Bengal, Maharashtra, Karnataka and Tamil Nadu, and the Andamans where it often attains a girth of 1.8m with a clean bole of 7.6-9 m. In the Kumaon foot hills, it attains girth upto 4m and height upto 26 m. In Punjab, Madhya Pradesh and the dry zone of the Central India it occurs as smaller tree generally with 1.2 to 1.5 m girth, 13-15m height and a 4m clean bole. In the Western Himalayas it ascends upto 1500m elevation usually along the banks of streams. It is found not only in the forests but also in avenue plantations almost all over the country.

The species prefers well drained loam; but it is not very exacting. It can grow in mild alkaline and saline soil. It is found in the foothills, bhabar, tarai and outer hills of the Western Himalayas up to an elevation of 1100 m, in hilly as well as plain terrain. It occurs in the Tropical Wet evergreen forests, Tropical semi-evergreen forests, Tropical moist deciduous forests, and Tropical dry evergreen forests.

SEED COLLECTION AND PROCESSING

The fruits develop rapidly and are nearly full sized by August. In north India they ripen by December or January the pods are all ripe. In the southern India they ripen earlier. They hang on the tree until March. From July onwards old yellow pods may be seen hanging side by side with young green ones.

The seeding time is January-March, the best time for seed collection being February. The seeds are liable to be damaged by insects and good proportion of the seed crop is thus destroyed both on the tree and on the ground. It is, therefore advisable to collect it as soon as possible after the pods attain a light brown colour. Collection is best done by climbing the trees and picking of the pods or by knocking them off with the aid of long stick. The pods are dried in the sun till they open and seeds are extracted by lightly beating them with a stick if necessary. Seeds are then dried in the sun and poor seeds are removed. About 880 pods weigh a kilogram. Seeds can be stored in gunny bags.

The seeds weight also varies considerably with the period of storage. In the Andamans it was found that while 8000 fresh seeds weighed a kilogram. after 2 years storage 10,270 seeds weighed a kilogram.

PRETREATMENT

Pretreatment of seed is necessary to achieve good germination. The chemical scarification consists in immersing the seeds for 5 minutes in concentrated sulphuric acid, washing the seeds with water. With chemical scarification the germination percent is reported as 75% and germination is completed in 10 days after sowing. Mechanical scarification is also effective treatment to enhance germination percent. Soaking in water brought to boiling for 24 hours is an effective method for pretreatment of seed.



NURSERY TECHNOLOGY

Two seeds are sown in container, usually polythene bags of size 13 cm x 25 cm are used. Germination takes place from 7 days to 25 days. If tall plants of 2 m height are desired, polythene bags of 30 cm x 45 cm or 35 cm x 50 cm size are used. Addition of bio-fertilizer and *Rhizobium* and *Phospobacter* will give bigger girth.

For stump planting, sowing is done in germination beds and seedlings are pricked out from the germination beds to transplant beds when they have 2-3 pairs of leaves. Stumps i.e. root-shoot cuttings, can be made when the plants are about 15 months old at the break of second rains, consisting of 3.5 to 5 cm shoot and 22 to 25 cm root. The optimum time for planting is soon after the monsoon rains have set in i.e. from mid-July to mid-August, the earlier planted the better.

Direct sowing can also be done in the field; it is done just before or at the break of monsoon. Sowing may be done in well worked up patches, mounds, pits, or lines. The commonst method is line sowing on well loosened soil; with frequent weeding right from the beginning which may give about 70% success.

10 *Albizia procera* (Roxb.) Benth.

ABOUT SPECIES

Albizia procera (Roxb.) Benth. is commonly known as safed siris and belongs to the family Fabaceae (subfamily Mimosoideae). This is a fast growing species of fairly large, deciduous, straight-stemmed tree, often branching at considerable height with large branches and a round head. It is a valuable timber for general house construction, carriage and carts, motor lorry, agricultural implements, etc. The tree gives gum copiously. The bark is used for tanning. The tree yields good fodder.

SEED COLLECTION AND PROCESSING

Seeds ripen from January to May, depending upon locality. Ripe pods which are distinguished by their dark brown or nearly black colour are either collected from the trees by cutting off the branchlets or from the ground when freshly fallen; but it is advisable to collect them directly from the trees. Pods are dried in the sun for a few days until they open and seeds are extracted either by hand or by gentle thrashing. The seeds are cleaned of pod fragments and defective ones are removed by winnowing. A kilogram of dry pods yield about 250 -375 grams of clean seeds.

The seed can be stored in good condition for at least a year, if kept carefully in sacks in a dry well-ventilated place. Seed kept in a gunny bag for 2 years, germinates as freely as fresh seed. Seeds stored for 15 years showed a germination capacity of 20%.

PRETREATMENT

The seed generally required some kind of pretreatment.

Hot water : Soaking in hot water immediately before sowing will give quicker and more even germination.

Boiling water : Seeds are soaked in boiling water and allowed to cool down and soak for 24 hours.

NURSERY TECHNIQUE

Pretreated seeds are sown in containers – either polythene bags or root trainers. For producing containerised stock, seeds are sown in March-April in potting mixture. These are regularly watered. With the onset of rains these develop into healthy plants which give almost 100% success in the field. In Dehradun conditions polythene bags of 23 x 13 cm and potting mixture having soil, sand and FYM in the ratio of 3:1:1 are used. Since the seedlings develop strong tap roots, the polythene containers are shifted periodically to avoid the root from striking and penetrating into the ground.

The traditional technique was to sow seeds in nursery beds in lines about 8 cm apart and the seedlings spaced about 5 cm within the lines. About 30 g seed is sown per square metre of nursery bed. The germination of the treated seed commences in about 3-4 days and takes about 2-3 weeks to complete. A germination percentage of 50-90 can be expected. The seedlings raised from March sowing attain a height of about 35 cm by July when these are planted out in pits in the field. In case the seedlings do not attain plantable size by July, these are retained in the nursery for one more year. In drier areas at least 15 month-old seedlings are planted in the field.

Stumps prepared from one- or two-year-old plants give very good success and are used for planting new areas or for



filling the gaps. In Bihar, seeds are sown close in drills 15 cm apart, in March-April and watered well. When about 7.5 cm high, the seedlings are pricked out to wider spacing if the plants are required for stump planting in the following year. Pricking out of seedlings is done when they have two pairs of leaves. 15-month-old seedlings are better suited for making stumps.

Albizia procera nodulates well through the native strains of *Rhizobium* which fix enough atmospheric nitrogen needed for growth. Nursery soil is inoculated with soil from a good forest of the species. Artificial inoculation improves the growth and development of seedlings. Application of nitrogen at the rate of 10-20 kg N/ha of soil as a starter dose helps in early establishment of seedlings without suppressing the development of nodules. Phosphorus application at the rate of 20-40 kg P/ha enhances the growth and development of seedlings. Application of VAM culture develops resistance in seedlings against drought conditions.

Seedlings can be outplanted with ball of earth around the roots, or as transplants when leafless or through root and shoot cutting. Plants upto collar diameter of 1.8 cm are suitable for both entire and stump planting.

11 *Azadirachta indica* A. Juss

ABOUT THE SPECIES

Neem is a versatile multipurpose tree native of dry forest areas of India, Pakistan, Sri Lanka, Malaysia, Indonesia, Thailand, Myanmar and Africa. In India it occurs throughout the drier parts including the states of Uttar Pradesh, Bihar, Orissa, Maharashtra, Gujarat, Rajasthan, Karnataka, Andhra Pradesh and Tamil Nadu. Neem trees are attractive broad-leaved evergreens that can grow up to 30 m tall and 2.5 m in girth. Their spreading branches form rounded crowns as much as 20 m across. Being a tropical / sub-tropical plant, it is found in areas with annual mean maximum temperature upto 32.5 to 42.5°C and minimum temperature of 4 to 21°C. Temperatures below 4°C and frost are unfavorable. Neem comes up well in areas with an average annual rainfall of 450 - 1200 mm. Neem grows well on almost all kinds of soils which are well drained. It grows well in loamy, clayey and black cotton soil. It also thrives better than other species on dry, stony, clayey and shallow soils. It can also come up on soil, where there is hard calcareous or clay pan just below the soil surface. It does not grow well on sodic soil and grows moderately on alkaline soil. Seedling of 6 -12 month old are out planted into the above pits during the rainy days. The spacing normally applied for neem is 5 x 5 m or 10 x 10 m. wider spacing is recommended for agroforestry practices. Neem is grown for seeds and timber. The tree starts fruits from the 4-5th year and steady yield from the 10th year. Each tree at this age can yield 20-25 kg of fruits tree⁻¹. The ratio of seed to pulp is about 1:2. The rotation age for timber is 35 - 40 years and for fuel wood is about 8 years. The timber yield is about 108 - 137 m³ ha⁻¹.

SEED COLLECTION AND PROCESSING

Neem seeds are collected from June to August. Fresh seeds collected should be used for sowing. Fruits on collection should be depulped and shade dried and then treated with fungicides like Agrason or Cerason and then used for sowing. Soaking in cold water for a few hours helps in removing pulp. Storing neem seed for 5 months at 40% natural moisture content at 16 degree centigrade is possible. For short storage the seeds are closed in polythene bags and exposed to air once in a week to keep them viable. Long term storage of Neem seeds for more than 10 years is done at 4% moisture content and -20 degree Centigrade temperature. Storage of seed in earthen pot containing wet sand (30% moisture) helps to retain viability upto 60% at the end of 3 months. On an average 5000 seeds weigh one kilogram.

SEEDLING PRODUCTION

Germination rate of Neem varies between 15% (stored seeds) and 85% (fresh seeds). Hence, to ensure higher viability of the seeds, their immediate sowing in nursery is recommended. Pre-soaking the seed for 24 hours in cold water and removal of the endocarp or cutting of the seed coat at the round end with a sharp knife also increase its germination capacity. Sowing of seeds in nursery beds made up of fine river sand is done in drills 15 c/m apart. Seeds are sown 2.5 cms deep at distance of 2 to 5 cms in the lines and lightly covered with earth to safeguard against birds and insects which often eat radicles of the germinated seeds on the surface. The beds are sparingly watered to prevent caking. Germination occurs in 1/2 weeks time. Once the hypocotyl is erect the seedling is transplanted into the containers. Seeds are sown 3 / 4 months before planting date. Potting mix comprises of 50% sandy loam, 40% river sand and 10% compost by volume.

Seeds of neem can be directly dibbled into poly bags of size 20 x 10 cm or 20 x 15 cm with soil, sand and FYM in the ratio of 1:1:1 or 2:1:1. Soil with high clay content or pH 8 and above should be avoided. Fresh seeds should be graded and large size seeds are sown in poly bag the rate of two seeds per bag. Healthy seedlings can be used for pricking in



containers. This will ensure uniform size seedlings in the containers. Normally, neem seed do not require shade except, during pricking out stage. Shifting of poly bags once in a month and timely weeding helps to obtain healthy seedling. The bed should be watered twice a day till germination and after germination once a day and after three months the seedlings are watered at temporary wilting for hardi them in the nursery. Seeds with poor germination, could be sown in the primary mother beds at optimum de cm to 2 cm. The seeds are sown by drills 15 cm apart. After germination, at 30 - 40 days the pulled seedlings are pricked into poly bags as above.

VEGETATIVE PROPAGATION

The plus trees of Neem were selected based on height of the tree, GBH, crown area, number of fruits in one foot branch, total fruit yield, oil percentage and azadirachtin content. Branch Cuttings (25 cm length and 0.5 to 1.0 cm diameter) were collected from selected superior trees. The cuttings were dipped in 0.1 % bavastin for 3 minutes and after washing with water, treated with IBA 1000 ppm at the base of the cuttings. The top cut end of the treated cuttings was sealed with paraffin wax to reduce the water loss. Then the cuttings were planted in sand bed filled with coarse sand in mist camber or poly-tunnel (80 to 90 % RH and 30 to 32° C temperature) for adventitious rooting. Rooting occurred in 30 to 40 days after planting. The rooted cuttings were transplanted to polythene bags containing sand, soil and farmyard manure (1:1:1) and hardened in shade condition (25%) followed by open sunlight for about 20 to 25 days. The hardened propagules were used for field planting.

12 Bamboo

ABOUT PLANT

Bamboo is the tallest and fastest growing woody, perennial grass on earth with approx. 90 genera and 1200 species globally. India has highest area (13.96 million ha) under bamboo while China has highest bamboo diversity (144 species). India is the second richest bamboo diversity country with 136 species (125 indigenous and 11 exotic).

Bamboo represents a great natural and renewable resource with capability to produce maximum biomass per unit area and time compared to other forest plants (Rao *et al.*, 2008). Bamboos are found in the North East, Madhya Pradesh, Maharashtra, Odisha, Andhra Pradesh, Karnataka, northern part of West Bengal, Bastar region of Chhattisgarh, the Western Ghats and Andaman and Nicobar Islands.

Bamboo is quite versatile as it occurs from the moist, primeval forests to the cool mountain foothills. Bamboos grown in flatland are usually more productive than in the hills. Culm yield and above ground biomass in the flatland are about four times as much as those in the hill side. Among the land of different slope gradients, a gentle terrain with a slope at 10 to 30 degree is most favourable for bamboo stand growth. Most bamboos occur in well-drained, sandy-loam to clay loam soils. Soil pH range of 5.0-6.5 is the most suitable for bamboo; some species may grow even at pH 3.5. Bamboo can neutralize acidic soil. Saline soil is not suitable for bamboo growth. Among soil characteristics, soil nitrogen content, organic matter, texture, aeration, base exchange capacity and depth are very important.

Commercially, the most important species are *Bambusa balcooa*, *B. bambos*, *B. nutans*, *B. pallida*, *B. polymorpha*, *B. tulda*, *Dendocalamus brandisii*, *D. giganteus*, *D. hamiltonii*, *D. strictus*, *Melocanna baccifera*, *Ochlandra travancorica*, *Schizostachyum dullooa* and *Thyrsostachys oliveri*. Their strength, straightness and lightness combined with extraordinary hardness, range of culm sizes, abundance, easy propagation and the short period in which they attain maturity make them suitable for a variety of purposes. The annual production of bamboo in India is about 14.6 million tonnes and annual yield varies from 1 to 3 tonnes per ha. Pulp and paper industries use 35 per cent of the bamboo followed by housing and rural sectors. The bamboo and rattan industry of India is worth US\$ 4.35 billion.

Modern technologies allow use of bamboo as a durable and high-quality wood substitute. Premium products such as bamboo flooring, laminated furniture, mat boards, strand lumber, etc. have huge international demand with big pro-poor financial impact and employment potential. Bamboo bridges and pre-fabricated houses have large potential in defence, disaster management and low-cost housing. Pack-flat and knockdown furniture are novel concepts.

A bamboo plant typically consists of four main vegetative parts:

- rhizome
- roots
- culm
- branches

The rhizome, culm and branches are segmented by solid node portion while the internode may be invariably hollow, though there are notable exceptions like *D. stocksii*. Nodes are protected by sheath and are the key growth points from which other vegetative parts develop and grow. Roots are not segmented nor do they have protective sheath. The rhizome is the underground portion of the bamboo and serves as the foundation base.

Three distinct types of rhizomes (Fig. 4.1) are recognized which influence the aboveground growth characteristic of bamboo (NMBA, 2005):



- *Sympodial rhizome*

This is a typical clump forming rhizome in which each rhizome is dominant and secondary culms develop from it, e.g., *B. bambos*, *D. strictus*, etc.

- *Monopodial rhizome*

This is a typical non-clump forming horizontally growing rhizome best described as runner. Here, one axis is dominant, i.e., rhizome and secondary axis culms develop from the lateral buds in runners, e.g., *Phyllostachys edulis* (moso bamboo), etc.

- *Amphipodial rhizome*

Some bamboos, e.g., *Guadua angustifolia*, *M. baccifera* (muli bamboo), etc. have rhizomes that have traits common to both monopodial and sympodial and can be described as amphipodial.

Most bamboos flower and fruit once in their lifetime, either sporadically or gregariously. The flowering cycle of bamboo is fairly long and varies widely among species and in most situations flowering and seed formation is not very predictable. The flowering cycles among the 1250 species have been reported to vary from 3 to 120 years. Most of the common species in India like *B. bambos*, *D. strictus*, *B. tulda*, *B. nutans*, *D. brandisii*, etc. have flowering cycle of about 40-45 years, while in species like *O. travancorica* and *M. baccifera*, it is about 30 years. Some species like *B. balcooa*, have not been found to flower even in 120 years.

Several methods are available for propagation of bamboo from seed as well as through vegetative means, including tissue culture.

PROPAGATION THROUGH SEEDS

Propagation through seeds is the easiest and simple process of reproduction albeit with an unpredictability in seed availability. Seed propagated plantations maintain genetically variability required for survival of species.

Bamboo flowers gregariously and dies after profuse fruiting. The seeds abundance generally lasts only for 1-3 years. Bamboo seed viability is poor and reduces drastically after 3-4 months of collection (Thapliyal *et al.*, 2015). Only when the flowering cohorts are clearly identified and documented it may be possible that the next flowering event be predicted and plantations through seeds be planned. Some of the bamboo species (*B. vulgaris*, *B. balcooa*, *D. stocksii*) has not been reported to set seeding for such species vegetative methods or tissue culture approaches are suitable for mass multiplication. Indian bamboo has been studied for gregarious flowering and it was found that 70 out of 72 species flower gregariously (Gadgil and Prasad, 1984).

SEED PRODUCTION AND BAMBOO FLOWERING

After going through status of flowering cycle and seed production of important bamboo species in India through literature, old herbarium records, personal observation, bamboo flowering records by NMBA, information available in project completion and status reports of ICFRE, apparently following information is generated:

- It appears that duration between consecutive gregarious flowerings remains same. This knowledge can be used not only to develop flowering prediction model but also for preparation of large scale propagation plans with long-term view.
- Most of the important Indian bamboo species have approx. 40-50 years flowering cycle. Flowering cycle of some species is 40-45 years (*D. strictus*) (Thapliyal *et al.*, 2015, Pers. comm, Yogeshwar Mishra), 43-49 years (*B. bambos*) (Naithani and Sanwal, 2017), 38- 45 years (*M. baccifera*) and 44-48 years (*B. tulda*) (Thapliyal *et al.*, 2015).
- An interesting trend was noticed among widely distributed and important Indian bamboo species that each species flowered at least once in every decade at different location. It implicates that we can always expect

seeds of important bamboo species, which can be used for large scale propagation programme if we were able to maintain a national network with the help of forest department and agencies involved in bamboo.

PRODUCTION OF QUALITY PLANTING MATERIAL FROM SEEDS

Propagation of bamboo through seed has not been considered as a reliable and sustainable propagation method for due to unpredictable and long intervals of flowering and fruiting. Also seed loose viability quickly (1-3 months) in natural conditions. Most nurserymen prefer to sow it fresh (Banik, 1980). Recently, plenty of work has been done for storage of bamboo seeds and ICFRE and other research institutes has developed longer storage protocol which requires low temperature facilities (Thapliyal *et al.*, 2015).

Flowering clumps of bamboo produce seeds next year, so seeds from the selected mother clump can be collected. Bamboo plantation developing from these seeds ensures large genetic base and abundant variation.

PROPAGATION THROUGH VEGETATIVE METHODS

During non-flowering period, propagation of bamboo is carried out through vegetative propagation. Propagation through vegetative means is also dubbed as clonal propagation and is suitable to multiply desirable bamboo genotypes in large number to produce quality planting material. Vegetative propagation methods are further divided in two broad segments i.e., macro- and micro-propagation. Under macropropagation offset planting, rhizome, splitting, culm and branch cuttings and layering are used while in micro-propagation techniques like clonal propagation through axillary and meristematic bud proliferation and multiplication by somatic embryogenesis and organogenesis are employed. The oldest report of macropropagation in bamboo is on rooting of cuttings of 3-5 year old culms of *D. strictus*.

Macropropagation is considered as an easily applicable method for vegetative propagation of plants.. Most of the important Indian bamboo species respond differentially to various methods of macropropagation (Table 5.3), which have been discussed in brief in following paragraphs.

MACRO-PROLIFERATION

During early 1990s, this technique was standardized in Plant Physiology Discipline of FRI (Kumar, 1991). This method includes splitting of rhizomes from seedlings from second years onward and could be done twice in a year (Fig. 5.7). In *B. bambos* and *B. tulda*, reported rate of multiplication rate was 3.5 and 2.5 per year while in *A. falcata* (gol ringal) multiplication rate up to six per year was obtained. This technique is so simple and that it became a universal technique of mass multiplication. Also, rhizome splitting can be continued at least for 5 years or 10 multiplication cycles (Banik, 1995). In tissue culture raised plantlets of *D. asper*, *B. balcooa* and *B. nutans* this technique is being applied to reduce cost and increase of clonal planting stock by 2-3 times a year.

OFFSET PLANTING

An offset is the base of a single culm with the rhizome axis and roots, mostly from 1-2 years old culms from periphery of a clump are selected. This method is laborious and rate of multiplication is slow and hence, not much in demand these days. It is mostly used for establishment as mother plant in a germplasm bank (Banik, 1995).



Macro-proliferation of *D. strictus* by culm splitting

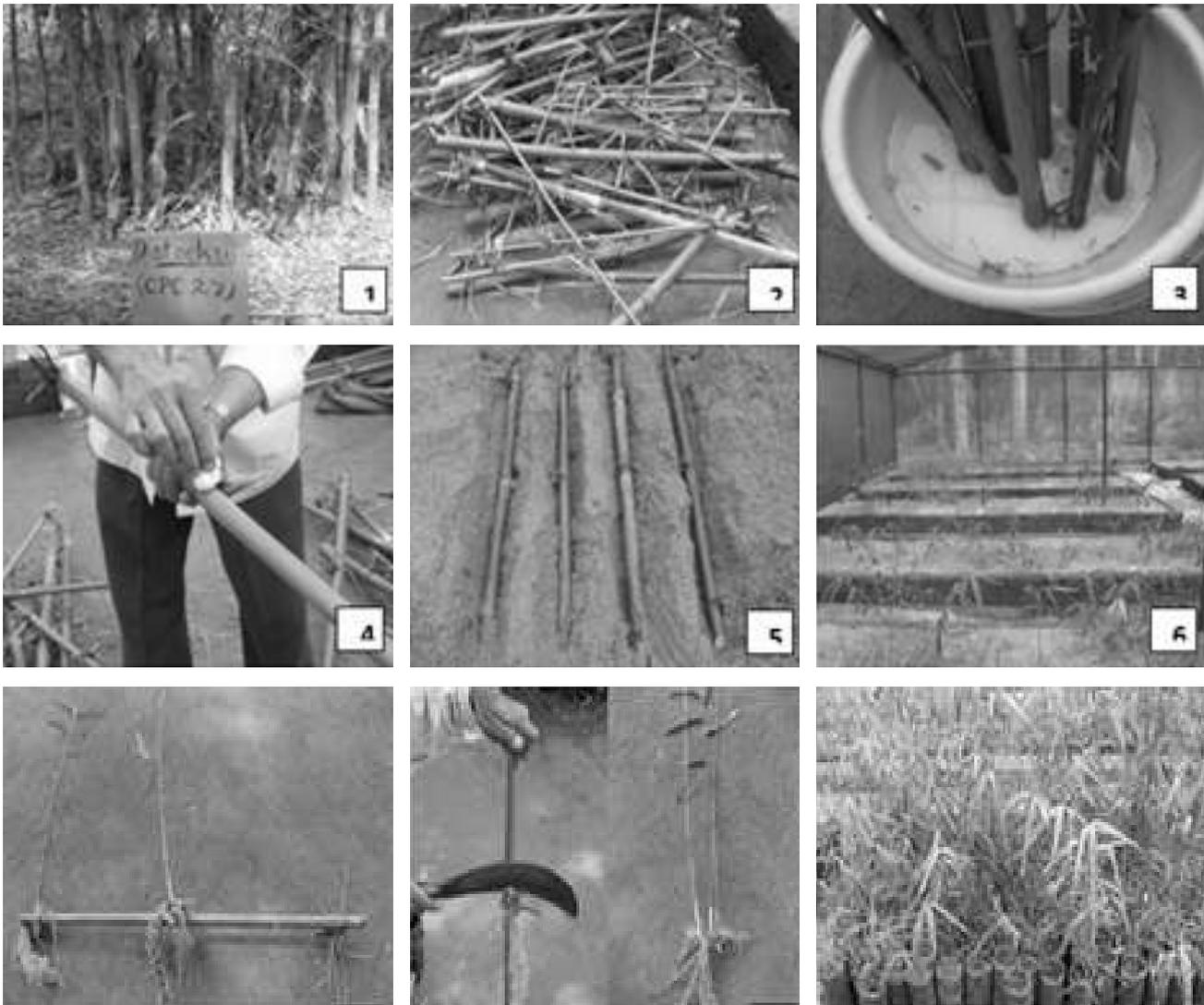


RHIZOME CUTTING

In monopodial bamboos, cutting is prepared with sections of fresh living rhizomes with at least a bud of the preceding year along with a portion of the 30 cm long culm (Seethalakshmi, 2015).

CULM CUTTINGS

This method has been proven useful for thick wall bamboo species such as *B. nutans*, *B. tulda*, etc. (Banik, 1995; Seethalakshmi, 2015). From healthy clump, 2-3 years old single culm is harvested and cleaned. From this culm, 1-3 noded cuttings are prepared and treated with auxin, mostly with 100 ppm NAA. In case of single node culm cutting, cutting dipped in 100 ppm NAA for 24 hours before planting and propagated either horizontally and vertically. In case of culm with 2-3 nodes, a cavity is made in the middle of culm and approximately 100 ml NAA (100 ppm) is poured and cavity is sealed. In case of solid bamboos like *D. stocksii* and *D. strictus* instead of making cavity, bamboo is dipped in auxin in big vessel and sometimes applied on nodes with help of cotton. Culms are planted in the bed horizontally, followed by adequate misting.



Propagation of solid bamboo (*D. stocksii*) using bi-nodal culm cutting



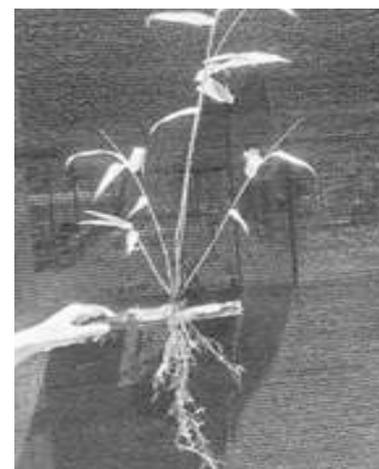
Propagation method of thick walled bamboo (*B. nutans*) using binodal culm

BRANCH CUTTING

Bamboo with small lumen or solid stem with stout branches is ideal for branch cutting. It is being successfully used for species like *B. balcooa*, *B. vulgaris*, *G. angustifolia*, *D. somdevai* and *D. asper*. Long (up to 1 m) branches with 2-5 nodes are harvested from culm and the branch is trimmed to 2-6 nodes followed by treatment with auxins. Branch cuttings are planted at least 7-8 cm deep into nursery bed. After 30-60 days, rooting occurs for cuttings planted during June to August in north India and during April-August in North-East India. This is a quick method of macropropagation but only limitation is time taken (12-30 months) for rhizome development (Banik, 1995).



(a) Rooted branch cutting of *B. balcooa*



(b) *B. vulgaris*

AIR LAYERING OR MARKOTTING

A culm or a branch is slightly wounded at nodes and tightly wrapped with moist rooting medium while attached to the mother plant. Application of auxins on wound sometimes gives better rooting. It is an alternate method of macropropagation but generally not used by the nurserymen.

MICRO-PROPAGATION

Micro-propagation has been identified as suitable alternative for rapid and large-scale plant production using small amount of explants. Most of the protocols developed involve seed/seedling derived explants, which ensure high genetic diversity as well as longevity of vegetative growth.



13 *Bauhinia variegata* L.

Bauhinia variegata (kachnar), a member of family Caesalpiniaceae, is a medium sized deciduous tree, with elongated spreading crown & bluish green foliage. It reaches a height up to 15 m (49 ft.). Bark is dark grey in colour. It grows in plains of north, east and central India. In the Himalayas, it grows in low and mid-hills in the Himalayas up to 1800 m altitude. It is adapted to tropical and subtropical climate with hot, dry summer and mild winters. The annual rainfall in its habitat ranges 500-2500 mm, as it usually avoids arid tracts with rainfall of less than 500 mm.

It bears flowers of usually white, pink or purplish in color. Tree is a moderate light-demander, frost and drought-hardy, susceptible to fire. It grows best in sandy loams & well drained soils.

Its leaves are a good fodder. Wood is used for agricultural implements and fuel. Several part of the plant have diverse medicinal uses. Bark is an astringent tonic & dried buds are useful in diarrhoea. Leaves, flowers & flower buds are sometime eaten as vegetable.

SEED COLLECTION AND PROCESSING

Pods are collected before they dehisce during May and June, and dried in the sun to release the seeds. Seed germinates better after cleaning which prevents it from fermented mass & pulp. About 2800 to 3500 seeds weigh a kilogram. Seeds can be stored in sealed tins in cool and dry place for a year. Germination capacity is 95 per cent.

SEEDLING PROPAGATION

Seedlings are raised in polybags. About 2-3 seeds are sown in each bag.

Seedlings are also raised by sowing in germination beds. Seed is sown in drills, 20-25 cm apart and seed to seed 5 cm apart at a depth of 1 cm. To enhance and to facilitate uniform germination seeds are soaked in water for about 24 hours. They are mulched and watered till germination takes place. Seeds germinate readily with a germination percentage of 95.

Application of fertilizers may be done for healthy stock of seedlings. N may be applied @ 60 kg/ha, P₂O₅ 40 kg/ha & K₂O 40 kg/ha. P & K can be applied as basal dose at the time of sowing & N in two splits, first half at the time of sowing & second half as top dressing. FYM added at the time of preparation of beds helps in improving structure of the soil & provides proper medium for the growth of seedlings.

About 2-3 months old nursery raised seedlings are used for planting out in the first rains. 12-15 months old plants may be used for stumps.

Adults & nymphs of *Psylla simlae* feed on the sap of leaves & young twigs. Sucking pests like *Psylla simlae* can be controlled by spraying 0.025% methyl demeton or 0.03% dimethonate whereas defoliators can be controlled by spraying 0.05% fenitrothion or methyl parathion.

VEGETATIVE PROPAGATION

Vegetative propagation is not used for operational planting of this species.

14 *Bombax ceiba* L.

Bombax ceiba (semal, simbal) is a large deciduous tree, light timber which is suitable for making packing cases, match splints and match boxes with a straight cylindrical stem and horizontally spreading branches in whorls reaches up to 40 m (131 ft) in height. Semal is a strong light demander, resists slight frosts, but is affected by severe frosts in hills. It occurs almost throughout India except the arid region, ascending upto 1200 m, occasionally even upto 1500 m altitude. It grows sporadically in mixed deciduous forests of sub-Himalayan region, moist mixed deciduous forests of West Coast, and evergreen forests of Bengal and Assam. It is very common in tarai and bhabhar areas of Uttar Pradesh and Bihar. It prefers a deep sandy loam soil, commonly found on flat alluvial deposits near rivers where it reaches its best development.

SEED COLLECTION & STORAGE

The seeds are collected locally from mid-March to mid-May. The seed can be stored in sealed tins for 1 or 2 years with only a slight decrease in germinated capacity. Viability of the seed stored in gunny bags decreases considerably at the end of one year and is completely lost after 2 years.

SEEDLING PROPAGATION

Semal can be raised by direct sowing, entire planting as well as stump planting. The seed is sown in the nursery in May about 5 cm apart in lines 23 cm apart, and watered till the break of rains. No pre-treatment of seed is required. The freshly collected seed gives the best results.

They are suitable for stump planting when about 1 year old. Where entire transplanting is done, 1 year old transplants may be used. Stumps are prepared from 1 or 2 year old nursery raised seedlings keeping only 4 cm of shoot and 30 cm of root after pruning of all side roots. The stump diameter at the collar may be 8-20 mm. The optimum time for stump planting is soon after the break of the regular monsoon rains, though the species is not fastidious from the point of view of the season of planting.



15 *Boswellia serrata*

ABOUT SPECIES

It is a handsome, moderate-sized to large, deciduous tree with a light spreading crown and somewhat drooping branches. It is characterized by a well-marked and compact distribution in central India between 16° to 31° N latitude and 73° to 86° E longitude. It is found in Bihar, Rajasthan, Gujarat, Maharashtra, Punjab, Orissa, Madhya Pradesh states of India. It is absent in the Western Ghats region. It is also roughly not found south of the Krishna River. It is a rare tree in Saurashtra (Gujarat) with very typical leaves. In its natural habitat, the absolute maximum shade temperature varies from 40-47.5° C and the absolute minimum from 0°-10° C. Its habitat, the rainfall ranges from 500-2000 mm. It is characteristically found often gregarious on the slopes and ridges of hills, up to an elevation of about 1150 m. The occurrence of this species is to a great extent determined by edaphic factors. In the Siwalik Hills on gneisses, mica-schists, Erinpura granite, limestone and shales. In parts of Madhya Pradesh and Maharashtra, it occupies the hotter slopes and ridges of hills, usually on trap and sometimes on ridges of hills. Salai is a strong light-demander. It is also resistant to drought. The trees are killed by girdling in favor of extraction of oleoresins in unscientific way. The wood is faintly scented with rings visible have been found to be not the actual growth rings but most often "false" rings streaked with darker wavy brown lines.

NURSERY TECHNIQUES

Seedlings are most commonly raised in containers i.e. polythene bags and root trainers. Seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds. Seedlings can be raised in polythene bags filled with a mixture of loamy soil and decomposition Farm Yard Manure. Two to three seeds are sown in each polythene tube (15 cm × 10 cm). Germination takes place within a fortnight. The species is rarely raised in bed as the root system of the species is delicate as does not stand rough handling. Seedlings of *B. serrata* have been raised in donas (leaf containers) made of *Butea monosperma* or in bamboo baskets.

16 *Buchanania lanzan* Spreng

ABOUT SPECIES

It is a small to medium sized nearly evergreen tree with a small crown and short trunk belonging to the family Anacardiaceae. It is commonly known as Piyar, pial. The occurrence of this species is very sporadic. It is widely distributed species from Sutlej eastwards along the outer Himalayas and Shiwalik hills to Nepal ascending upto 1200 m and absenting from the eastern Himalayas. Southwards it extends to central India, through Bihar, Orissa, Rajasthan, and Maharashtra to Tamil Nadu and Kerala. The normal annual rainfall varies from 750 to 2180 mm in its area of occurrence. The tree is a moderate light demander. The tree has economic importance for its edible fruits. The kernels (Chironji) are eaten raw or roasted and used in various sweet preparations. The timber is moderately strong, very light and non durable. The timber is not brought to use except for local uses such as boxes, doors, and furnitures of the cheaper class. The leaves are used for fodder. A copious gum exudes from the wounds of stems which is considered useful for dressing, dyeing and printing of textiles.

SEED COLLECTION AND STORAGE

The fruits ripen from April to May and fall immediately before or at the commencement of the rainy season. Only freshly fallen fruits should be collected from the ground as the seeds exposed to the sun for any time have a low percentage of fertility. The fruits can be collected from the tree also. Due to the oily nature, seeds are quickly attacked by insects. Clean seed is obtained after removal of pulp. The seed keeps well at least for one year when stored in a sealed tin. The seed weight varies from 4300 to 5300 per kg, the germination capacity from 10 to 80% and plant percent from 80 to 87 giving 3070 plants from one kg. of seed.

NURSERY TECHNIQUE

Seedlings are most commonly raised in containers i.e. polythene bags and root trainers. Seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds. Freshly collected seed should be sown in the well drained nursery beds in the month of May-June. No pre-treatment of the seed is required. The seeds sown 0.5cm to 1.0 cm deep germinate well in the seed beds. The germination normally starts within 10-15 days and gets completed in 30 days. Freshly collected seed gives as high as 85% germination but it progressively falls with the passage of time. It is better to sow the seeds directly in big sized polythene bags and keep these in the nurseries for a period of two years as the seedlings are delicate and cause considerable mortality in transplanting from seedling beds.

DIRECT SOWING

The species shows good results by direct sowings at the commencement of rains, the seeds are dibbled at a depth of 0.6cm in the well pulverized soil, resulting about 30 percent plants. Of the reasons for low germination percent of the species is probably due to the use of unripe seeds for direct sowing and devouring of ripened seeds by various game animals and human beings.



17 *Butea monosperma* (Lam.) Taub.

Butea monosperma (dhak, palash), family Papilionaceae, is a medium sized deciduous tree that attains a height of 15 m (49 ft.) and 3-3.6 m in girth. Bark is rough, fibrous slate grey to pale brown, blaze fibrous, pink veined with red, innermost layer exudes a sticky red juice. Flowers are bright red tinged with orange. It is a tree of tropical and subtropical climate and grows up to 1000 m altitude. It thrives in rainfall of 750-1900 mm. It grows in the plains throughout India on a wide variety of soil, in water logged situations, on black cotton soils and also on saline soils.

Flowers yield orange dye for coloring cotton fabrics but has little permanency. Its leaves are lopped for fodder for buffalo and are used in making leaf plates, and cups and bidi wrapping. An important use of dhak tree is as a host of lac insect for production of rangini lac. It is suitable for raw material for the production of newsprint either alone or in mixture with bamboo-pulp in proportion of 60:40. Timber is mainly used as fuel and gun powder charcoal.

SEED COLLECTION & STORAGE

Pods ripen in May-July and are collected off the trees in the middle of May to middle of June. It is not necessary to extract the seed from the pods as they equally germinate well. The extracted seeds weigh about 9850 to 14790 per kg. Seeds can be stored in sealed container for at least one year. Fresh seeds give higher percentage of germination and plant percent, being 73 to 100 and 50 to 80 respectively.

SEEDLING PROPAGATION

The species can be easily propagated by direct sowing and stump planting.

NURSERY TECHNIQUE

The segmented pods are sown in the month of May in lines 15 cm apart, seed being 10 cm apart in the lines. Seeds do not require any pre-sowing treatment. About 50 g of seed is sufficient to sow each square meter of nursery area. 6 months old nursery raised seedlings are used for planting. The seedlings may be planted out in the first season or kept for stump planting in the next season.

18 *Casesalpinia sappan* Linn.

ABOUT THE SPECIES

It is commonly known as Brazil wood, this species belongs to family Fabaceae (subfamily Cesalpinioideae). It is a middle sized to thorny tree, reaching a height of upto 12 m and a girth of upto 45-75 cm or a straggling shrub, with a few small and scattered prickles or sometimes without prickles. It looks quite handsome when laden with large panicles of yellow flowers. It is said to be indigenous to parts of Burma, Africa, Philippines and Central America, but is now cultivated as a hedge plant and has run wild in several places in India, such as South India, Maharashtra, Madhya Pradesh, Bihar, Odisha, etc. The flowers appear in the latter half of the rainy season. The fruits ripen in the winter, and produce an abundant crop of seeds. It often bears flowers and fruits within 14 years of planting

SEED COLLECTION AND TREATMENT

The seeds can be collected from ripe pods during the cold season and can be stored without loss of viability. Soaking the seeds in water for 12 to 24 hours may be beneficial in accelerating germination. The seed weight ranges from 1,760 to 2,260 to a kilogram.

NURSERY TECHNIQUES

The plant is easily propagated from seeds either by direct sowing or entire planting. It coppices freely when cut down. In Malaysia it is reported to be raised by planting hardy wood cuttings 2.5 cm in diameter and 1.2 m long.



19 *Cassia fistula* Linn.

ABOUT SPECIES

Cassia fistula Linn. is commonly known as amaltash. The trade name of is Rajbriksh. It belongs to the family Fabaceae. It is a middle sized to large tree 8-12 m in height and 48-75 cm in diameter with a clear bole of 4-7 m. This is one of the most widespread of forest trees in India, usually occurring in deciduous forest throughout and ascending to 1,220 m in the sub Himalayan tract and outer Himalayas, from the Indus eastwards, upto Assam. It is common throughout the Gangetic valley, Central India, Deccan and South India, In Maharashtra State, it occurs as a scattered tree in the Deccan and Konkan forest, ascending to 1,130 m in the Khandesh Akrani, It is particularly abundant in the bhabar tracts fringing the Himalayas, especially in miscellaneous forest. It has been introduced in the Andamans, It is often cultivated in gardens, The tree is not gregarious, but is scattered in mixed deciduous forests, often of a somewhat open type; it occurs fairly frequently in sal forest.

In its natural habitat, the absolute maximum shade temperature varies from 35-47.5°C and the absolute minimum from 0 to 17.5°C. The mean annual rainfall ranges from 500 to 3,000 mm or even more. It is found on a variety of geological formations and can grow on poor shallow soil, as on the dry outer slopes of the Himalayas. It appears to thrive equally well on trap, granite and sandstone soil. It is frequent on Khurda laterite. It is a moderate light-demander. It can, however, stand a certain amount of shade. It is not frost-hardy in the great frost of 1905 in Northern India. Young seedlings are killed by frost up to ground level, but they sprout again. It is decidedly drought hardy. It is not at all browsed even by goats. It coppices vigorously. It produces root-suckers freely. It has comparatively superficial root system. It is immune to browsing by cattle and goats and hence it is found in grazing grounds.

SEED COLLECTION AND PROCESSING

Ripe pods are collected off the trees in March-April, the seeds separated from the soft pulp and washed with cold water before drying for storage. The damaged seeds have to be removed carefully.

The seeds are highly impermeable to water and may be stored for many years with no loss of vitality. Seeds stored in gunny bags for 13 years have given about 30% germination. Seeds are best stored in gunny bags in a cool dry place. Those stored for one year, germinate more quickly than fresh seeds, though the percentage of sound seeds in the former may be reduced owing to insect attack. The seed weight is slightly variable ranging from 7,090 to the kilogram to 6,000 to the kilogram.

NURSERY TECHNIQUES

Pretreatment of seed is necessary to accelerate germination. Soaking of seed in boiling water 5 minutes is reported to have given 75% germination, but some workers report that untreated seeds better germination than those treated with cold, hot or boiling water. Soaking of seed in concentrated sulphuric acid gave 35% germination against 14% for untreated control in one experiment.

The species is indifferent to shade or open conditions in the nursery. In Assam however, open nursery beds are preferred. The germination time is 6-52 days, though, not infrequently seeds germinate in the second year. The seed should be sown in seed beds in drills about 25 cm part in March or April, and regularly watered; germination ordinarily takes place early in the rains though some of the seed may lie dormant until the second year, germinating at different times from March onwards. Planting out requires some care but it can be carried out satisfactory while the plants are still comparatively small (15-30 cm in height) during the first rains. Container planting is more satisfactory especially in arid localities, the seedlings being transferred to containers in the first rains and planted out in the second rains. Bamboo baskets or polythene bags may be used as containers.

20 *Casuarina equisetifolia* L.

ABOUT THE SPECIES

Casuarina equisetifolia L. belongs to the family Casuarinaceae. It has two distinct subspecies viz. ssp. *equisetifolia* and ssp. *incana*. The vernacular names are Beef wood (English), Kattadi (Malayalam), Savukku (Tamil) and Sarugudu (Telugu). *C. equisetifolia* has a wide distribution on tropical coastlines from Northern Australia (Queensland and Northern Territory) throughout Malesia, Melanesia and Polynesia, and northwards to the Kra Isthmus in South Thailand. It is also widely planted outside its natural distribution in India, East and South America, USA (Florida), Vietnam, South China and Middle East. It is a coastal species adapted to sandy and sandy loam soils. However, it also thrives well in the inland region with a variety of types. An evergreen tree with a conical crown and slender drooping branchlets commonly referred to as 'needles'. Trees are 6-35 m height. *Casuarina* is a nitrogen-fixing tree through symbiotic relationship with an actinomycete called Frankia. It fixes atmospheric nitrogen in special structures in the roots called nodules. It is necessary to ensure infection of Frankia in *Casuarina* seedlings for vigorous growth of seedlings as well as to increase their adaptability to planting conditions. *Casuarina* prefers sandy loam soils although it thrives well in all types of soil except highly clayey and water-logged areas. It responds well to irrigation and fertilizer application. The commonly followed rotation period is 4 years with irrigation and 6 years under rainfed conditions. Plantations with irrigation and fertilizer application yield 100 to 150 tonnes of air dried wood (up to 20 cm girth) per hectare (40 to 60 tonnes per acre) in 4 years. Under rainfed conditions an average yield of 75 to 100 tonnes per hectare is obtained in 6 years (30 to 40 tonnes per acre) depending upon soil quality and amount of rainfall during the cultivation period. An additional 5 to 7 tonnes of miscellaneous wood is produced per acre in the form of branches, tops and roots. At the time of harvest the average height of the tree is 12 m and girth is 25 cm. The best trees may measure 20 m height and 50 cm girth.

SEED COLLECTION AND PROCESSING

Casuarina seeds are small consisting 5 to 6 lakh seeds per kg. But about half of them may actually be immature seeds which usually do not germinate. Germination is generally about 30% and about 50000 to 100000 seedlings are obtained from one kg of seed depending upon source of seed and nursery efficiency.

SEEDLING PRODUCTION

Casuarina is a nitrogen-fixing tree through symbiotic relationship with an actinomycete called Frankia. It fixes atmospheric nitrogen in special structures in the roots called nodules. It is necessary to ensure infection of *Frankia* in *Casuarina* seedlings for vigorous growth of seedlings as well as to increase their adaptability to planting conditions. *Frankia* can easily be inoculated by adding top soil from *Casuarina* plantations to the mother beds. Alternatively it can be inoculated at the time of transplanting into secondary beds containers. Freshly collected nodules from *Casuarina* trees ground into a fine paste, dissolved in clean water and filtered make an inoculum. Roots of seedlings pricked from mother bed are first washed in water and then dipped in the inoculum about 30 minutes before transplanting.

SOWING OF SEEDS

Casuarina seeds are small and a kilogram has around 6 lakh seeds. But about half of them may actually be immature seeds which usually do not germinate. Germination is generally around 30% and up to 100,000 seedlings are obtained from a kg of seed depending upon source of seed and nursery efficiency. Seeds are sown in raised sand beds (called 'mother beds') of the size 10 x 1 metre. Generally no pretreatment is necessary for *Casuarina* seeds. In each bed about



250 g of seeds are evenly spread by mixing with fine sand. A thin layer of sand is applied over the seeds. The sand bed is covered with rice straw to prevent washing off of seedlings while watering. Water is provided through a rose can or a sprayer. A suitable repellent is applied along the periphery of the bed to prevent ants from removing the seeds.

GERMINATION AND TRANSPLANTING

Seeds start germinating from the 5th day and the straw is removed on the 7th day. They are grown in the mother beds for the next 3 to 4 weeks. The beds have to be kept moist by watering through rose can once or twice a day but water stagnation should be avoided to prevent fungal diseases. After 4 weeks when the seedlings attain 8 – 10 centimetres height they are transferred either to a secondary bed or polythene bags. Secondary beds are also of the same size as the mother beds but in addition to sand, farm manure and soil (2:1:1) are also added to increase nutrient availability and water holding capacity. They can be watered either through rose can or flood irrigation depending upon the size of the nursery. Again water stagnation should be avoided. Seedlings pricked from the primary beds are transplanted in the secondary bed at approximately 4 cm apart. Though it is a common practice to plant more than one seedling per planting point, it is strongly recommended to plant only one plant in a point to raise vigorous and healthy seedlings. Seedlings are grown in the secondary beds for 3 months to obtain a height of 30 to 45 cm and a collar diameter of 3 to 5 mm. Growing seedlings in polybags and root trainers is better than bare root seedlings especially for planting in rainfed areas. Seedlings raised in containers establish well in plantations and record vigorous growth in the first year. Polybags (size: 15 x 7 cm) filled with a potting mixture of sand, farm manure and soil in a ratio of 2:1:1 are suitable for raising *Casuarina* seedlings. Seedlings may attain plantable size within 2 months but can be maintained for another 4 to 6 months if planting is delayed.

VEGETATIVE PROPAGATION

Outstanding *Casuarina* trees can be propagated by rooting of young shoots ('sprigs'). Such plants produce uniform superior growth in plantations. Sprigs collected from selected trees are trimmed to 8-10 cm long and washed in a 5% solution of fungicide like Bavistin™. The lower portion of the shoot is treated with a rooting hormone, Indole butyric acid (commercial name: Seradix B™). The treated cuttings are placed in root trainers containing vermiculite or treated coir pith and kept in mist chamber or propagation chambers made of polythene sheets. Rooting occurs in 15 to 20 days and then transplanted into polybags or root trainers and grown in the same way as seedlings.

INOCULATION OF FRANKIA

Casuarina is a nitrogen-fixing tree through symbiotic relationship with an actinomycete called Frankia. It fixes atmospheric nitrogen in special structures in the roots called nodules. It is necessary to ensure infection of Frankia in *Casuarina* seedlings for vigorous growth as well as to increase their adaptability to planting conditions. Frankia can easily be inoculated by adding topsoil from *Casuarina* plantations to the mother beds. Alternatively it can be inoculated at the time of transplanting into secondary beds or containers. Freshly collected nodules from *Casuarina* trees are ground into a fine paste, dissolved in clean water and filtered to make an inoculum. Roots of seedlings pricked from mother beds are washed in water and then dipped in the inoculum for about 30 minutes before transplanting. Application of bio-fertilizers like phosphobacterium and *Glomus fasciculatum* also improve the seedling quality.

21 *Casuarina junghuhniana* Miq.

ABOUT THE SPECIES

Casuarina junghuhniana Miq. (Synonym *C. montana*) belongs to the family Casuarinaceae. There are two subspecies are recognized viz. ssp. *junghuhniana* and ssp. *Timorensis*. *C. junghuhniana* is native to Indonesia, East Timor and Wetar Islands. The subspecies *junghuhniana* is confined to medium elevation (1500-2200 msl) of Java and Bali Islands of Indonesia whereas ssp. *timorensis* occurs in the low elevations (0-600 msl) of Timor and Wetar Islands. The species has been widely cultivated outside its natural range especially in China and East Africa. It is a fast-growing species with adaptability to grow in a wide range of soil and climatic conditions. In India a single putative hybrid male clone commonly known as *C. junghuhniana* sourced from Thailand has been in cultivation since 1951. At present *C. junghuhniana* is cultivated in a limited area in the States of Andhra Pradesh, Puducherry and Tamil Nadu. The spacing between trees and rows is generally 1 m and such spacing accommodates 10000 plants per hectare. Since *C. junghuhniana* is faster growing than *C. equisetifolia* a wider spacing of 1.5 x 1.5 m is suggested. The usual practice of raising one intercrop of groundnut or black-gram adopted with *C. equisetifolia* plantations is also practiced for *C. junghuhniana* plantations during the first three months after establishing the plantation.

SEED COLLECTION AND PROCESSING

Seeds of *C. junghuhniana* are smaller than that of *C. equisetifolia* with around 18 lakh seeds per kg. Germination is ranging from 60 to 80% and about 4 to 5 lakh seedlings can be obtained from a kg of seed depending upon source of seed and nursery efficiency. Seeds are sown in raised sand beds (called 'mother beds') of the size 10 x 1 m. Generally no pre-treatment is necessary for *Casuarina* seeds. In each bed about 200 g of seeds are evenly spread by mixing with fine sand. They are overlaid with a thin layer of sand. The sand bed is covered with rice straw to prevent washing off of seedlings while watering. Water is provided through a rose can or a sprayer. BHC powder is applied along the periphery of the bed to prevent ants removing the seeds.

SEEDLING PRODUCTION

Seeds start germinating from the fifth day and the straw is removed on the seventh day. They are grown in the mother beds for 3 to 4 weeks. The beds have to be kept moist by watering through rose can but water stagnation should be avoided to prevent fungal diseases.

After 4 weeks when the seedlings attain 8-10 cm height they are transferred either to a secondary bed or polythene bags. Secondary beds are also of the same size as the mother beds but in addition to sand, farm manure and soil (2:1:1) are also added to increase nutrient availability and water holding capacity. They can be watered either through rose can or flood irrigation depending upon the size of the nursery. Again water stagnation should be avoided.

Seedlings pricked from the primary beds are transplanted in the secondary bed at approximately 4 cm apart. Though it is a common practice to plant more than one seedling per planting point, it is strongly recommended to plant only one plant in a point to raise vigorous healthy seedlings. Seedlings are grown in the secondary beds for 3 months to obtain a height of 30 to 45 cm and a collar diameter of 3 to 5 mm.

Growing seedlings in poly bags and root trainers is better than bare root seedlings especially for planting in rainfed areas. Seedlings raised in containers establish well in plantations and record vigorous growth in the first year. Poly bag size of 15



x 7 cm filled with a potting mixture of sand, soil and farm manure in a ratio of 2:1:1 are suitable for raising *Casuarina* seedlings. Seedling may attain plantable size within 2 months but may be maintained for another 4 to 6 months if planting is delayed.

VEGETATIVE PROPAGATION

Outstanding *Casuarina* trees can be propagated by rooting of young shoots ('sprigs'). Such plants produce uniform superior growth in plantations. Sprigs collected from selected trees are trimmed to 8-10 cm long and washed in a 5% solution of fungicide like Bavistin™. The lower portion of the shoot is treated with a rooting hormone, Indole butyric acid (commercial name: Seradix B™). The treated cuttings are placed in root trainers containing vermiculite or treated coir pith and kept in mist chamber or propagation chambers made of polythene sheets. Rooting occurs in 15 to 20 days and then transplanted into polybags or root trainers and grown in the same way as seedlings.

22 *Cedrus deodara* (Roxb. ex D. Don) G. Don

ABOUT THE SPECIES

Cedrus deodara (Deodar) is a majestic tree distributed in the Hindu Kush-Himalayan region across Afghanistan, Pakistan and India. Within India, it has been recorded in Jammu & Kashmir, Himachal Pradesh and Uttar Pradesh between an altitude range of 1200-3000 m. It is a large tree are found on deep, well-drained soils. It is tolerant to shade, but young trees are prone to injury from frosts and cold wind. It is a component of the temperate forest, usually on north-facing valley slopes, where rainfall ranges from less than 1000 mm per year up to 2500 mm per year, mostly in the form of winter snow. In these forests

It is the strongest Indian coniferous wood owing to its anti-fungal, insect-repellent and anti-bacterial properties. It is used as valuable construction material. The primary uses of deodar are for railway sleepers, beams, floor-boards, posts, door and window frames and shingles. It is also used for bridge construction, carriage and wagon building, furniture, packing cases, electric poles, battery separators and second grade pencils.

SEEDLING PRODUCTION

Cones are collected from standing trees during end September – October and placed in the sun till they open and break up. Seeds are extracted. Seed cannot be stored for long due to high oil content. Best practice is to sow seed before snowfall. One kg contains 7000-9000 seeds. Germination capacity and plant percent are 65-80 and 58 per cent respectively. Seed is sown in drills 10-15 cm apart or in polythene bags. The area is covered with thorny twigs to protect from birds. Germination takes place in spring. Seedlings from germination beds are pricked out in July of the same year. Seedlings are kept in the nursery with repeated shifting till they are 2½ to 3½ years old when 30-45 cm tall.

VEGETATIVE PROPAGATION

The species is not propagated through vegetative means.



23 *Dalbergia latifolia* Roxb.

ABOUT SPECIES

Dalbergia latifolia Roxb. is commonly known as Indian rosewood and belongs to the family Fabaceae. It is a large, deciduous or nearly evergreen tree, with a full rounded crown and a cylindrical and fairly straight bole, varying in size according to locality. The tree resembles *D. sissoo* slightly, but has denser and darker foliage. In its natural habitat, the absolute maximum shade temperature varies from 37.3 to 50.0°C and the absolute minimum from 0° to 15 °C. The mean annual rainfall varies from 750 to 5,000 mm, falling chiefly from May to September with a long intervening dry season. *Dalbergia latifolia* grows on a variety of geological formations, but it requires good drainage and attains its best development where the soil is deep and moist, it prefers good, deep loam or clayey soil, containing lime. It also grows fairly well on black cotton soil and adapts to poor, dry, stony soil but it does not reach large dimensions in such sites. Indian rosewood ranks among the finest woods for furniture and cabinet work. It is well known in Europe and America where its chief use is in the pianoforte manufacture. It is also a valuable decorative wood suitable for carving and ornamental ply-boards and veneers. It is especially useful for pattern making, calico-printing blocks, mathematical instruments and screws.

SEED COLLECTION AND STORAGE

The tree does not seed regularly or abundantly. Seed collection time varies with states. In West Bengal seeds can be collected from December to May, the best time for collection is February-March. The ripe dark brown pods are collected from the trees by lopping the branches. A precaution to be taken is to see that no unripe seed, characterized by colour of pods is collected. The pods are dried in the sun and broken. Extraction of clean seed is not necessary for sowings. The pods are usually stored in gunny bags until they are required. Seeds lose their viability appreciably when stored for one year or more. Seeds remain good for six months when stored in gunny bags or earthen pots and that they lose their viability after one year. Seeds insufficiently dried before storage usually lose viability in relatively short time. No pretreatment of seed is generally carried out in practice.

NURSERY TECHNIQUE

Seedlings are most commonly raised in containers i.e. polythene bags and root trainers. Seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds having porous sandy loam in drills, 22.5 cm apart or in longitudinal lines about 45 cm apart, according as the planting is to be done in the first or second rains. The time of sowing should be regulated in the different localities with reference to the commencement of the monsoon rains.

Watering is necessary, as also weeding and protection from the sun during the hot hottest period of the day. The plants will be ready for entire planting in June-July if the sowing is done in March-April. The seedlings may be kept in the nursery till the commencement of the second rains, in which case they may need thinning out during the cold season. They will be suitable for stump planting at the beginning of the second rains. In West Bengal the seed segments are dibbled in nursery bed at 7.5 x 7.5 cm spacing.

24 *Dalbergia sissoo*_Roxb.

Dalbergia sissoo (shisham, sissoo) is a medium to a large sized deciduous tree of family Papilionaceae, and attains a height up to 30 m (98 ft.). It is one of the most important timber species of India. Bark dark grey in colour. Flowers are yellowish white in color. Tree is a strong light-demander right from the seedling stage. The seedlings are comparatively sensitive to drought, but the tree in its natural state is drought-hardy. It is a tree of Tropical & Subtropical climate and grows throughout India except temperate climate. In the Himalayas, it ascends to up to 1500 m altitude. It thrives well in rainfall of 500-4500 mm. It grows well in a wide range of soil types, from pure sand and gravel to rich alluvial soil of riverbanks. It grows well in soil pH of 5.0 to 7.7 and tolerate some salinity, but growth is stunted on heavy clay soils.

It is one of the best known economic timber species in the country. Timber is used for furniture, wooden flooring, panelling, plywood, cabinets, ornamental turnery, tool handles, doors & windows etc. Sulphate pulp from wood is used in producing writing and printing paper. Sissoo leaves are used as fodder. It makes an excellent fuelwood. Shisham wood makes excellent charcoal for heating and cooking.

SEED COLLECTION & STORAGE

Fertile seeds are produced at the age of 3-4 years, but it is advisable to collect seeds from the middle aged vigorously growing trees having straight & clean boles. Seeds are collected from December to mid-February. Pods are dried in the sun for 3-4 days & stored after removing dead leaves, portions of twigs, etc. Dried seeds protected against moisture can be kept for at least one year without any loss of viability. 1 kg of seed is sufficient to raise nursery stock for planting 10 ha area. Germination capacity & Plant percent in sissoo are about 90 & 45 % respectively.

SEEDLING PROPAGATION

Shisham can be artificially propagated by direct sowing, entire transplanting, stump planting and other vegetative means. Stump planting is known to be the best method.

Treatment of shisham seed before sowing is not necessary, but soaking in water 12-24 hours accelerates germination. Seedlings are raised by trench & berm method. Nursery consists of trenches 30 cm wide & about 23 cm deep connected by water channels at both ends. The trenches usually are 60 cm apart from end to end. Trenching is completed in winter and sowings done at the end of February. Water is done both before sowing & after sowing. Inoculation with Rhizobium: Seedlings can be inoculated in the nursery. When the seedlings are about 5 cm tall they are transplanted into containers. For production of stumps, 12-16 months are required in the nursery.

Directly sowing is done in wet areas. Stump planting is practiced in irrigated plantations during spring.



25 *Delonix regia* (Boj) Rafin

ABOUT SPECIES

It is commonly known as Gulmohar in Hindi and belongs to the family Fabaceae. It is a fairly large deciduous ornamental tree with broad spreading umbrella-shaped crown of light feathery foliage, reaching a height of about 18 m in favourable situations. It is a native of Madagascar, but is apparently not found growing naturally there at present, it was introduced in India within the last one hundred and fifty years and is now widely grown as a garden and avenue tree, in both the dry and moist regions of tropical India upto Himalayan sub-mountain tract a far north-west as the Yamuna. It is also grown in the warmer and moist parts of Myanmar. It is unsuited to localities with heavy frost. It is a light demander. It does not grow well under shade and develops a lean and lanky stem and high spare crown. The tree is grown extensively for shade and ornament in avenues and gardens.

SEED COLLECTION AND PROCESSING

The large broad flat pods form in the rainy season they are green and flaccid when young. They harden, turning brown or almost black, in ripening and hang on the tree for a considerable time after ripening, often till the flowers of the following year, appear.

NURSERY TECHNIQUE

The seeds are sown in the unshaded nursery beds after pretreatment in September-October or late till April and seedling pricked out in containers. The seeds can be directly sown in the polythene bags, about 4-5 seeds per bags. Seedling watered and weeded regularly become plantable by the rainy season. The seedlings can be pricked out in nursery beds, seedlings with ball of earth are taken out, tied with thatch grass and planted out. Keeping the plants for more than nine months is not desirable, as they become too tall to handle. The trees can be propagated by cutting.

26 *Emblica officinalis* Gaertn.

Emblica officinalis is commonly found in deciduous forests in most part of the country except in the arid regions (Brandis, 1906). In the outer Himalayan ranges, it ascends up to an elevation of about 1400 m, but is not common to the west of the Ravi River (Troup, 1921). It is a characteristic tree in moist peninsular high level sal, moist peninsular low level sal, moist sal savannah, and dry savannah forest (Champion and Seth, 1968).

NURSERY TECHNOLOGY

Direct sowing is not very successful and the best method to raise this species is to plant out nursery raised seedlings (Seth et al., 1962). The seed is extracted by drying the ripe fruits in the sun until they dehisce and the seeds escape. The seed is dried before storage. About 65-90 seeds weigh one gram (Troup, 1921). The seed does not store well, the seed kept for one year at Dehradun failed to germinate (Troup, 1921).

The seedlings can be grown either in nursery beds or in polythene bags; in the former case the seedlings will have to be planted out with balls of earth. Plants of about 2cm collar diameter planted out with balls of earth are reported to have given good success in Uttar Pradesh both in survival and height. Sowing is done in March and the seedlings attain plantable size by the following July-August if these are regularly weeded and watered in the nursery. Planting is done in 30 cm³ pits dug in advance at a spacing of about 2.5 m x 2.5 m or 3 m x 3 m.



27 *Eucalyptus camaldulensis* Dehnh.

ABOUT THE SPECIES

Eucalyptus camaldulensis (synonym: *Eucalyptus rostrata*) is a common and widespread tree species, belongs to the family Myrtaceae. Commonly it is called as river red gum. The vernacular names are Thaila maram (Tamil), Jamail (Telugu) and 8afeda (Hindi). It is a widely distributed species in its natural habitat, latitudinal range is from 12°48'8" in the tropical north of the Northern Territory to 38°1'8" in cool temperate Victoria., Australia. It is perhaps the world's most widely planted tree in arid and semi-arid lands. India is one of the largest planters of eucalypts in the world with 8 million hectares of planted area. It is a best suitable tree species for the areas which receive rainfall from 250 to 600 mm at the same time it can also grow well in high rainfall areas which receives as high as 1250 mm. The altitudinal range is 30- 600 m. The success of *E. camaldulensis* as an exotic is attributed to its superiority to other trees in production of wood on infertile dry sites, its tolerance of extreme drought and high temperature. It also shows tolerance to periodic water logging and soil salinity, some tolerance of frost, addition to coppicing ability. This species occurs on red, black and sandy alluvial soils. It can also grow well in salt affected areas, except calcareous soils.

When pulpwood is the principal objective, a spacing of 3 m x 2 m (1667 stems/ha) is often applied. Wider spacing of 4 m and 2 m (1250 stems/ha) or 5 m x 2 m (1000 stems/ha) are recommended when larger trees are required. For energy plantations, a spacing of 2 x 2 m is recommended. In India, *Eucalyptus* is managed through clear-felling system followed by coppice rotation to a maximum of three times. After three rotations, the below ground biomass is taken out and replanted with seedlings. For pulpwood depending on the fertility and availability of water, the rotation can fixed from 5 to 6 years. In Tamil Nadu, about 25-30 t/ha at a rotation of 6-7 years was realized through seed raised plantations during early 1990's. Introduction of clones increased the yield up to 60-70 t/ha in six years rotation.

SEED COLLECTION AND PROCESSING

Maturing fruit will turn from green to brownish-red when ripe. Temperature and seasonal conditions affects the time for seed collection. It produces heavy seed crop every 2-3 years. Generally after maturation capsules do not open immediately. Capsules opening are a slow process which takes 1-2 months period. Seeds are dispersed by water, ants and wind. For the purpose of establishment of plantation fruiting branches are clipped using pole pruners. Dry capsules are placed in a warm condition to release seeds quickly. Seeds are yellow or yellow-brown in colour, cuboid, smooth and can be difficult to distinguish from chaff. The number of seeds is approximately 700/g. The fruit measures approximately 4 - 6 mm. Germination is epigeal. Normally, the seeds show high germination percentages (more than 90%) without pretreatment. One gram seeds produced about 90-520 seedlings. Rapid and complete germination is achieved under moist, warm (32°C) conditions in the presence of light. The seeds can be stored for more than 10 years if they are placed in hermetic containers at a temperature of 3 to 5°C and a moisture content of 5.5 to 10 per cent. Seed stored at 25°C had a germination rate of 91 % after 5 years, and 87% after 10 years.

SEEDLING PRODUCTION

For all *Eucalypts*, the texture of the medium of germination must be fine. A fertile mixture of soils with sand in a proportion of 1:1 must be used. Seed should be sown under shade on a free-draining and sterilized medium and covered very sparingly with inert material (e.g. sand). Seeds must be sowed deep enough to prevent uncovering when watered, but they must not be too embedded. The germination period for this method ranges from 4 to 5 days. Smoke treatment has

been found to improve germination (Ralph, 2003). The seedlings are lifted from the mother bed when they are 5 to 7 cm in height and transplanted in poly bags. Alternatively, seeds can also be planted directly into bags using special devices, such as syringes, to place two to four seeds in each bag.

Shade cover is needed after transplanting till six weeks. Growth is fast under tropical conditions and plants could reach plantable size (30 cm) in four to five months. Seedlings require periodic watering in the first stages of development. Common mistakes in propagation are over-watering and associated disease problems, over-shading and allowing the germinants to become too large for easy transplanting leading to malformed tap roots or root curling in the pots. To prevent damping off, cupric fungicides should be applied. About 1-2 lakhs of seedlings can be obtained from 1 kg of seed in nurseries.

VEGETATIVE PROPAGATION

Eucalyptus hybrid can be propagated vegetatively by coppice shoot cuttings, epicormic shoots, lignotubers and semi hard wood cuttings.

- **Coppice Shoots**

Coppice shoots are the best juvenile material for mass propagation of Eucalyptus hybrid by cuttings. To obtain coppice shoots, the trees should be coppiced about 15 cm above the ground level in the month of February. The cut portion should be given antifungal treatment (1g red lead + 1g copper carbonate in 1 litre seed oil). The coppice shoots may be harvested after 6-8 weeks.

The coppice shoots are collected in the early hours of morning and made into bimodal leafy cuttings. The leaves are trimmed to half the original size and treated with talc preparation of 5000 ppm IBA. The base of the cuttings may be treated with 0.1% bavistin or any other suitable fungicide to prevent fungal attack. Treated cuttings are planted in plastic trays or root trainers filled with sterilized vermiculate, perlite or coarse sand. These are maintained under high humidity (RH 80%) in mist chamber and about 30°C temperature is adequate for quick rooting. The cuttings develop good rooting system within about 35 to 45 days. The rooted cuttings are transferred from plastic trays to polythene bags filled with soil and sand in 1:1 ratio. These are retained in the mist chamber for another week and subsequently shifted out for hardening. The rooted cuttings hardened under partial shade of trees or in the manipulated shade conditions under net house. Initially these are maintained under frequent misting but the frequency of misting is slowly reduced to nil over a period of 6 weeks. At the end of hardening period, the rooted cuttings are treated with 100 ppm N, 100 ppm P and 50 ppm K for boosting their growth. The stock is then handled in the routine way until planted out. The limitations in this method are that the tree has to be coppiced and very mature trees coppice very poorly.

- **Epicormic Shoots**

Very young epicormic shoots collected from near the basal region of the main stem are generally easy to root. These epicormic shoots should be collected in summer or rainy season. These are treated like the coppice shoots for making cuttings, rooting, hardening etc. Though these are comparatively lesser juvenile than coppice shoots, these can be used if coppicing of the tree is not possible due to any reason.

- **Semi Hardwood Cuttings**

Non-leafy semi hardwood cuttings of seedlings less than 1 year old can be rooted by treating with 100 ppm IBA by basal dip method or 5000 ppm IBA in talc preparation. Rainy season is the most suitable season for propagation by this method. This method has only limited applications.



28 *Gmelina arborea* Roxb.

ABOUT THE SPECIES

Gmelina arborea Roxb. belongs to the family Verbenaceae. It is a fast growing tree. It is commonly called as Gmelina and White beech (English), Melina (Spanish), Gmelina in Indonesia, Yemane in Philippines and Soh in Thailand. The other vernacular names are Gamhar, Khamara, Khumbhari, Sewan (Hindi), Bhadraparni, Gambhari, Gandhari, Kasmari, Krishnavrintaka, Sarvatobhadra (Sanskrit), Kumla, Kumalamaram, Ummithekku (Tamil), Gumartek, Gummadi (Telugu), Kumil, Kumbulu, Kumishu, Pokki (Malayalam) and Kulimavu, Kumbuda, Shivane (Kannada). *G. arborea* is found in India, Myanmar, Thailand, Laos, Cambodia, Vietnam and in southern provinces of China. It is also planted extensively in Sierra Leone, Nigeria, Malaysia, Sri Lanka, Bangladesh and Philippines. In India, it is distributed in Uttar Pradesh, Punjab, West Bengal, Assam, Andhra Pradesh, Orisa, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat and Madhya Pradesh. The species occurs naturally from latitudes 5° to 30° N and longitudes 70° to 110° E. Its altitudinal range is approximately 50 to 1300 m. *G. arborea* grows well on deep, loamy, clay loams, calcareous, and moist soils with optimum rainfall from 1800 to 2300 mm per annum and temperature ranges from 12 to 45°C. Planting is generally done at the onset of the rainy season and the spacing of the plantations depends on the objectives and the end uses. A spacing of 2 x 2 m is commonly used for plantation programs, and a spacing of 4.5 x 4.5 m is used for agroforestry. About 1111 Plants/ha will be maintained. Thinning has been practiced when it grows for heart wood plantation. Gmelina plantation has rotation ages of 5 to 7 years for pulp and paper products and 8 to 15 years for solid wood products. The growth of the species is remarkably fast and on a good site it can reach 20 m height in 5 years. The form of the tree is fairly good, with 6-9 m clear boles possible. It is also reported that some trees can reach 3 m with one year after planting and 20 m after 4.5 years. The average yield of Gmelina is approximately 21 m³/ha/yr. A lower value is found (7 m³/ha/yr) on poor sandy soil and the maximum of 50 m³/ha/yr on clay loams.

SEED COLLECTION AND PROCESSING

The fruits can be collected from the crown canopies or from the forest floor. Because fresh fruits are eagerly devoured by cattle, the seeds can also be collected from their excretion. However, collecting yellow fruits from the trees is recommended. The fermenting of fallen fruits on the ground may induce fungal attack that damages the seeds. Collecting ripe fruits from the trees ensures good seed quality from known sources. Tarpaulins or plastic sheets are placed under the trees to collect the mature fruits that fall when the branches are shaken. The fruits are soaked in cold water to facilitate seed extraction by hand or de-pulper. The number of seeds in one kilogram is 1,250 to 2,750. Fresh seeds can be stored in bags in a cool dry place for about 3 months without losing much viability. Fresh seeds show a 90 to 100 per cent germination rate. Seed storage behavior is orthodox. Seed viability can be maintained for several years in hermetic storage at 3°C with 7-10% moisture content.

Seed pretreatment: Seeds are soaked in water for one day before sowing. Floating seeds should be discarded because they have been aborted and nonviable. Germination can be improved through seed scarification with sand paper rubbing or acid treatment.

SEEDLING PRODUCTION

Seeds should be sown in germination beds with a mixture of sand and loam and covered with a thin layer of sand or compost. The seed sowing will be undertaken in the month of March- April. About 90 seeds are required for sowing of one

square meter area. Total seed rate is 14 kg per ha. Seeds germinate in 2-3 weeks and are ready for transplanting to poly bags when the first pair of leaves appears. Transplanting is done between June to July.

Poly bags of size 10 x 15 cm are generally used. Root pruning and hardening off of the seedlings are beneficial for maximum field survival. The bare-root seedlings should have a minimum base diameter of 1 cm with a well balanced shoot-root ratio. Seedlings are ready for planting in the field when they reach a height of 30-45 cm, usually in 6 months. For stump planting, stumps are prepared with seedlings of 7 -8 months with root collar diameter of 2.5 cm. Stump planting is not widely practiced due to high mortality (50% mortality is common).

GERMINATION

The germination of *Gmelina* seed is epigeous with the radicle emerging first and the cotyledons issuing shortly after. Depending on the position of the first germinating seed, the stone may be left in the ground or be pushed up, and the conditions for possible remaining seed to germinate may thus be more or less favourable. However, the germination is much depending upon conditions in the germination bed. Assuming optimal conditions, both temperature and light seem to affect germination. It was found that, the optimal temperature regime between a constant 31°C and a constant 36°C. Germination and storability of undried and dried seeds of *G. arborea* were evaluated at various storage temperatures. The freshly mature seeds (IMC $27.3 \pm 1.58\%$) showed 100% germination (excised seeds). Loss of germination was discernible if seeds were slowly dried below $11.3 \pm 0.4\%$ mc. In contrast rapid drying safely allowed dehydrating the seeds up to $3.4 \pm 0.14\%$ mc with still exhibiting 100% germination. The seed viability was reduced to minimal (5%) when slow dried for a period of 350 days to $5.6 \pm 0.6\%$ mc. Seeds are sowed in loosened soil and covered with fine soil or organic manure. Seed can also be dibbled directly into prepared containers with appropriate media, germination occurs 7 to 21 days after sowing. Young seedlings grow quickly and reach appropriate size for out planting in 2 to 3 months when they are about 40 to 45 cm high.

NURSERY TECHNIQUE

Seeds should be planted in germination beds with a mixture of sand and loam and covered with a thin layer of sand or compost. Seeds germinate in 2–3 weeks and are ready for transplanting to poly-bags when the first pair of leaves appears. A 10 x 15 cm poly-bag is widely used. Root pruning and hardening off of the seedlings are beneficial for maximum field survival. The bare-root seedlings should have a minimum base diameter of 1 cm with a well balanced shoot-root ratio. Seedlings are ready for planting in the field when they reach a height of 30–45 cm, usually in 6 months.

For stump planting, seeds should be sown at the rate of 90 seeds per square meter. Seedlings are usually ready for stump preparation in 7–8 months and should have a root collar diameter of at least 2.5 cm. The stem and roots of seedlings should be pruned back to 5 cm and 20 cm, respectively. Stump planting is not widely practiced due to high mortality (50% mortality is common).

Seeds are soaked in tap water for 1 day before sowing. Floating seeds should be discarded because they have been aborted, are nonviable, or both. Seeds are sowed in loosened soil and covered thinly (0.5 to 1.0 cm) with soil. Seeds can also be dibbled directly into prepared containers with appropriate media. Germination occurs 7 to 21 days after sowing. Young seedlings grow quickly and reach appropriate size for out planting in 2 to 3 months when they are about 40 to 45 cm high. Stump planting is also practiced. *G. arborea* coppices well after felling. Coppicing shoots are ready for rooted-cutting production when they are about 60 days old. A section of the half-leaf single node is commonly used for rooting with or without rooting hormone. However, treatment with rooting hormone may induce earlier and more vigorous rooting than untreated. *G. arborea* cuttings rooted well when the relative humidity is above 80 percent and the temperature is lower than 30 °C.

The seed sowing will be undertaken in the month of March- April and be transplanting in June to July. Hardening required for proper field establishment. Seedling should be hardened off with reduced watering and exposure to sunlight for 4 to 6



weeks before being out planted. 90 Seeds required for the sowing of per square meter area. Total seed rate is 14 kg per ha.

VEGETATIVE PROPAGATION

G. arborea can be vegetatively propagated by root cutting, stump planting, semi- hard wood cutting, mini cutting and half leaf single node cutting.. Particularly root cutting has been attempted. Stump planting also practiced. Semi-hard woodcutting and Mini cutting have been successfully employed. Stump planting is also practiced. A section of the half-leaf single node is commonly used for rooting with or without rooting hormone. However, treatment with rooting hormone may induce earlier and more vigorous rooting than untreated. *G. arborea* cuttings root well when the relative humidity is above 80 percent and the temperature is lower than 30°C. *G. arborea* coppices well after felling, coppicing shoots are ready for rooted cutting production when they are about 60 days old. The wedge-grafting method was also practiced.

- **Hardwood Cuttings**

The cuttings are collected lower and out portion of the canopy from healthy vigorous branches measuring 1-2 cm in diameter. The leaves and terminal soft portions are excised and treated with 5000 ppm IBA for by basal dip method. Rooting occurs in about 12 weeks, with 55 per cent.

- **Softwood Cuttings**

The branches representing the epicormic or coppice shoots are collected. Their upper soft wood portions are cut and made into 4 – 7 cm long bimodal leafy cuttings. The leaves are then trimmed to 1/3 of its size and treated with 5000 ppm IBA containing 0.1% bavistin or any other suitable fungicide. These cuttings are placed in 80% relative humidity and around 25 - 30°C temperature. The rooting takes place within 4 – 6 weeks. The hardwood rooted cuttings can be planted in the field directly.

- **Bud Sprouts**

Young bud sprouts, about 2-4 cm length with half open first pair of leaves are removed from the shoots during morning hours. The sprouts are treated with 2000 ppm IBA mixed with the fungicide planted in vermiculite or coarse sand based medium and placed in mist chamber. These sprouts will strike roots within 20-30 days. They are hardened before out planting. The per cent success is almost 100% when bud sprouts are used for propagation. Branch cuttings are collected from the lower one third of the crown. The length of the cuttings is approximately 20cm with thickness of 12 to 15 mm. Since rooting medium require proper drainage, sand, soil and silt in the ratio of 2:1:1 is used. Fungicide treatment is given as soil drench with bavistin 0.2 percent before planting. The base of the cutting is dipped in IBA 200 ppm. It is found to be effective and showed fifty percent rooting of cuttings. The rooted cuttings are transferred to hardening chamber and kept for 15-25 days. After hardening the cuttings are ready for field planting.

29 *Grewia optiva*

ABOUT THE SPECIES

It is a small to medium-sized, deciduous tree. It is distributed from Punjab to Bengal, ascending up to, an altitude of about 2,000 m in the hills of the Western Himalayas. It is often cultivated on boundaries of agricultural field of hilly farmers. It is very hardy and can grow in almost any situation. It is strong light-demander and can tolerate frost. It is an excellent pollarding quality against the lopping of branches for fodder collection by local people.

The bark yields a fiber of inferior quality, used for cordage and clothing. The branches are used for making baskets. The leaves are highly prized as green fodder for cattle, especially in winter. The tree is often planted in hedges and on field boundaries.

SEED COLLECTION

The seeds collected in the months of October-December.

NURSERY TECHNIQUES

Seedlings are most commonly raised in containers i.e. polythene bags and root trainers. Seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds.



30 *Hardwickia binata* Roxb.

ABOUT SPECIES

Hardwickia binata Roxb. is commonly known as Anjan and belongs to the family Fabaceae. It is a moderate to large-sized deciduous tree upto 36 m in height and 4 m in girth with a clear cylindrical bole of 12-15 m. *Hardwickia binata* is usually found in isolated blocks, often in fairly extensive gregarious patches or belts, in the drier parts of Central and Southern India, extending as far north as the Banda and Mirzapur Districts of Uttar Pradesh. *Hardwickia binata* thrives in a dry climate, characterized by a long period of drought, scanty to moderate rainfall, and intense heat during the hot season. In the cold season, frosts occur only in certain parts of its range particularly low lying places. It can stand a great deal of heat and, at all stages, a considerable amount of cold. The tree occurs on a variety of geological formations. Anjan requires while young regular supply of water, which it obtains from the soil through its long taproot and thus survives the long dry hot weather. After attaining the age of about 15 years, it can manage with very little soil moisture and is essentially a drought resistant species. The timber has a fairly extensive local use, where a very heavy hard wood is required, such as for naves of cartwheels, ploughshares, clod crushers, oil mills and machine bearings. It is also used for mine props to a limited extent, and for posts and beams. Heartwood posts are much in use. Anjan wood is an excellent fuel. The charcoal has been found suitable for produce gas. The leaves are much used for manure and cattle fodder.

SEED COLLECTION AND STORAGE

The small pale yellowish green flowers appear from July to September. The pod reaching full size in the cold season and ripening in the following April or May. The light winged pod commences falling early in May and are often carried to some distance from the parent tree by the strong winds which are prevalent in that season.

The light winged pods ripen in April or May and may be collected as soon as they ripen. The ripe pods are best collected by men ascending the trees with bags or baskets and pulling the pod off in handfuls. The pods may also be beaten off the trees with sticks on ground previously swept, or gathered after lopping the branches. The seed is liable to be eaten by birds and hence the necessity of collecting it immediately it is ripe. The pods may be dried in the sun days and then stored in gunny bags, bamboo baskets or sealed tins after removing dead leaves twigs and other foreign matter. The seed can be extracted from the pod by exposing them to the sun.

Fresh ripe seed has a high percentage of fertility and germinates readily with moderate moisture. There are recorded instances in which its seed remained fertile to some extent after one or two years storage.

NURSERY TECHNIQUE

Nursery work presents hardly any difficulty provided the basic conditions of overhead light and a sandy-loam soil are fulfilled. The species being hardy, elaborate soil working is not necessary. Seed may be sown in the nursery either in polythene bags or in beds at the commencement of the monsoon, or even earlier if facilities for watering are available. Soaking, in cold water for 24 hours prior to sowing gives satisfactory results. The seedlings are kept in the nursery for a year to attain plantable size.

31 *Leucaena leucocephala* (Lam) de Wit

ABOUT SPECIES

Leucaena leucocephala (Lam) de Wit, commonly known as subabul belongs to the family Fabaceae (subfamily Mimosoideae). This is an unarmed large evergreen shrubs or small tree, upto 9m in height. It is native to Middle America and tropical countries but now it is planted throughout the plains of India. It is). Several varieties and strains of *Leucaena* have been identified. Broadly these can be three classes i.e. Hawaiian type, Salvador type and Peru type. *Leucaena* grows under a wide variety of conditions through it is essentially warmth-loving and therefore restricted to tropical and shrub-tropical areas. It withstands large variation in rainfall, soil salinity and terrain condition. It grows best in regions with an annual rainfall between 600 -1700 mm, although it has been recorded to survive under rainfall as low as 225 mm a year. The plant has considerable salt tolerance and grows in exposed costal area often right down to the high water mark. Its mineral nutrient requirements are not very exacting. It regenerates and spreads rapidly from self sown seeds.

The plants flower and fruit at very early age, good crops of seed being produced by vigorous plants in the first or second year. The plant is useful for filling gaps in plantations, as wind -breaks and for checking soil erosion. It is grown in many countries as a shade and cover plant in tea, coffee, cocoa, rubber, cinchona, teak and sal plantations. It sheds its leaves regularly and enriches top soil with organic matter. It stands pruning and coppicing remarkably well under the normal condition. Leaves and twigs are rich in nitrogen and potassium salts and can be used for composting. The wood has been tried as a raw material for paper pulp, short fibred pulp is obtain by semi-chemical process. Powdered seeds make useful manure. It is a preferred leguminous species for afforestation, farm forestry, wind breaks fire breaks, ornamental planting and soil conservation in tropical countries.

SEED TREATMENT

It is generally raised by planting or sowing. *Leucaena* seeds weigh 20,000/kg. A well-grown seed tree on a suitable site produces approximately 40,000 seeds. The germination is low due to hard seed coat and seed treatment is recommended to enhance germination.

- Hot water : A volume of water equal to the amount of seed to be treated, is heated to about 80°C and the water is poured over the seed and the seeds are allowed to soaking for 12 hours in the cooling water.
- Acid treatment : Immersion in commercial grade sulphuric acid for 2-5 minutes followed by thorough washing is recommended. This method requires careful handling as there is a risk of injury both to the seed and the operator.

For maximum nitrogen fixation, it is recommended that the pretreated seeds be given a dressing with a suitable carrier of nitrogen fixing bacterium (*Rhizobium* strain). If this commercial preparation is not available, soil possessing native *Rhizobium* culture can be taken from under a healthy stand of *Leucaena* and mixed with the potting mixture.

NURSERY TECHNOLOGY

The nursery soil should be neutral to mildly alkaline. If the soil has pH of less than 6 then lime should be added to raise the pH to at least 7.5. It is raised in containers or in bed.



Two pretreated seeds are sown per container, which may be of polythene bag, bamboo pot etc. The container should have good soil having a pH near neutral. It is recommended that one gram of a complete fertilizer be added per container. If both seeds germinate, one seedling is transferred to another container.

If raising plant in nursery bed, seeds are sown 4 cm apart by drills in parallel rows, spaced 25 cm apart. Preferably, the seed beds should be trenched and filled with sand or humus, then bedded to provide adequate drainage and to minimize root damage when lifted for planting out.

32 *Madhuca longifolia* J.F.Gmel

ABOUT THE SPECIES

Madhuca longifolia J.F.Gmel. commonly known as Mahua, mahwa, mohwa, mohwra, Ilupai, honey tree, and butter tree is a medium-sized deciduous tree, which grows to a height of 16-20 m. It has a short, stout trunk, 80 cm in diameter. The crown is rounded with multiple branches. The bark is grey, vertically cracked and wrinkled, exfoliating in thin scales. The leaves are alternate and clustered at the end of branchlets. The leaf blade is simple, 10-25 cm long x 6-12 cm broad, oblong-shaped, rigid, thick and firm, woolly at the lower face and exuding a milky sap when broken. Young leaves are pinkish or reddish-brown. Flowers are borne on green or pink, furry bunches, each bunch consisting of 12 fragrant cream-coloured flowers. The flowers live for only one night and then fall to the ground. Pollinated flowers develop into a fleshy, greenish ovoid fruit containing 1-4 shiny, oily brown seeds. The seeds are 3-5 cm long, elliptical and flattened on one side.

Mahua is indigenous to India, Sri Lanka, Nepal and Myanmar. It is a frost resistant species that can grow in marginal areas of dry tropical and subtropical forests up to an altitude of 1200-1800 m. It can be found scattered in pastures, in crop fields in central India, and on rivers banks in semi-evergreen forests. It grows well where annual rainfall is between 500 mm to 1500 mm, and where temperatures are in the range of 2-46°C. *Mahua* does better on deep loamy or sandy-loam soils with good drainage, but it also occurs on shallow stony, clayey and calcareous soils.

The species is distributed in northern, central and southern part of peninsular India, Sri Lanka and Burma. Of the two varieties, var. *longifolia* is distributed in Sri Lanka, Southern India extending northwards to Maharashtra and Gujarat; var. *latifolia* is found in some parts of central and north India and Burma. It is common in dry mixed deciduous forests, dry Sal forest and dry teak forests. The tree grows on a wide variety of soils but thrives best on sandy soil. It also grows on shallow, bouldery, clayey and calcareous soils. The species is drought-resistant, strong light demander and readily suppressed under shade. It is not frost-hardy.

Mahua flowers, fruits and leaves are edible and used as vegetables in India and other Southern Asian countries. The sweet, fleshy flowers are eaten fresh or dried, powdered and cooked with flour, used as a sweetener or fermented to make alcohol. The fleshy outer coat of the fruit is used as a vegetable. In India, during periods of scarcity, a combination of Mahua flowers and Sal seeds (*Shorea robusta*) is boiled to prepare a substitute for grain staples. Mahua is an oil plant whose seeds yield between 35 and 47% oil. Mahua oil is used to make soaps and candles and is also used as a seed preservative against pests.

Oil produced in smallholder farms is of low quality and is mainly used as a ghee substitute or adulterant. *Mahua* oil is reported to have potential use in biodiesel production. In India, potential *Mahua* oil production could be up to 60 million t yr⁻¹. The oil cake resulting from oil extraction is used as a fertilizer, and could be used to control root-knot nematode and fungal infections because the high saponin content reduces nematodes and phytopathogenic fungi.

Mahua trees host *Antheraea paphia*, the tassar silkworm which produces silk traditionally used in making saris. *Mahua* is also used for its hard, strong, dense and reddish timber. *Mahua* flowers produce nectar that is very valuable to honey bees in periods of scarcity. *Mahua* is reported to have many applications in traditional medicine, and to provide several environmental benefits.



FRUIT AND SEED DESCRIPTION

Fruits are berries, ovoid, fleshy, turning yellowish green when ripe, 3-5 cm long, with prominent distal beak, 6 loci in ovary but usually only developing 1-4 seeds. Seeds: Seeds are large, 3-4 cm long with moderately hard testa, elliptical, flattened on one or two sides, brown and shining when mature. Approximately one kilogram seed contains around 420-670 seeds.

FLOWERING AND FRUITING HABIT

The flowers appear from March to May just before the new leaves flush. It takes about 32-35 days for complete development of visible flower bud to anthesis. The flowering varies with the local conditions. It shows a temporal sequence, starting from top portion to the lower branches and also from the more illuminated part to the shaded part of the tree. The plant produces abundant pollen which is shed in clouds when the flowers are disturbed. The freshly dehiscid pollen is sticky and becomes viable only after 2 days when dry. Pollination is anemophilic. The flowering *Mahua* is visited by monkeys, squirrels, birds. The fleshy scented corolla is an attractant to the predators.

Although the predators help in the dispersal of pollen grains they do not actually transfer pollen grains to the stigma. The elongated style projects out of the flower and beyond the reach of self-pollen and ensures better exposure of stigma to air currents. The seed setting is low even in hand pollination. Fruits ripen in May-July. The tree begins to bear fruits at the age of 8- 15 years and continues to do so for about 60 years. The tree shows pronounced periodicity with good seed years once or twice in every three years. 100-200 kg fruit per tree can be produced in cultivated areas whereas 20-50 kg fruit per tree can be collected from forest areas.

SEED COLLECTION

Fruits fall on the ground after maturation in the July (monsoon period) and seeds are liberated after decay of fleshy covering. Wild animals disperse the seeds by eating the fruits. The season for seed collection is short and in the absence of organized harvesting, a considerable portion of crop is lost. Maximum germination occurs when the seeds are fully mature. Fruits are then yellowish green in colour and seeds are brown with 40- 41% moisture content. The seeds may be collected after natural seed fall or by vigorous shaking of the branches.

PROCESSING AND HANDLING

Seeds are separated from the fruit flesh by rubbing the fruits manually and thorough washing.

DORMANCY AND PRETREATMENT

Germination percentage is high in fresh seeds (80-100%). Seeds have no dormancy and do not need any treatment for better germination.

STORAGE AND VIABILITY

Viability of *Mahua* seeds cannot be maintained in long-term storage. The freshly mature seeds are desiccation-sensitive (recalcitrant) and germination percentage starts to decline below 35% moisture content. Seeds are also chilling sensitive, damage may occur even at 15°C. High viability can be maintained up to 5 months by storing seeds at 28°C in sealed polythene bags with shedding moisture content of 40-41%. This method maintained about 82% germination percentage from initial 100%. The seeds may be treated by dressing with Bavistin 0.2% (fungicide) before storing.

PROCESSING AND HANDLING

Seeds are separated from the fruit flesh by rubbing the fruits manually and thorough washing. Dormancy and pre-treatment Germination percentage is high in fresh seeds (80- 100%). Seeds have no dormancy and do not need any treatment for better germination. Storage and viability of *Mahua* seeds cannot be maintained in long-term storage.

SOWING AND GERMINATION

The tree can be raised by direct sowing or planting out nursery-raised seedlings, the former method is preferred as the seedling develop long and delicate taproot that is difficult to handle during pricking or transplanting. Germination is hypogeal. In direct sowing seeds are sown in 1.5-2.5 cm depth of soil during June-July in well-prepared lines or patches. Nursery-raised seedlings are pricked out into deep containers (bamboo baskets, earthen pots or polythene bags) one month after germination. It can be successfully raised with agricultural crops like pulses and lucerne with 9 m spacing. Regular watering is necessary.

NURSERY TECHNIQUES

The soil of the nursery should be in nature, though *Mahua* can be grown in all types of soils. Collected fresh seeds will be sown in the polythene bags directly or baskets. Seeds are sown soon after collection in the nursery beds.

Ripped fruits are collected by shaking the branches. Fruits are rubbed and washed to, which however is soon lost on storage. Fungi and insects readily attach the seeds.

Fresh seeds are sown at a depth of about 1.5 to 2.5 cm. One-month-old seedlings are transplanted in nursery beds. Late transplanting gives poor results. Spacing in transplant beds is 30 x 15 cm; shading the seedling is necessary, one-year-old seedlings are used for planting in main field. Seedlings can also be containerized. In that case, one-month-old seedlings are pricked into containers. Shading is necessary.

PLANTING

Planting is one in 30 cm³ pits at a spacing of 4x4 m. planting of stumps is done in crow bar holes or 30 cm³ pits.

PLANTATION TECHNOLOGY

Before undertaking plantation, the site is cleared by cutting and burning all woody growth. Pits at a distance of 9x9 m or 10x10 m should be dug in summer. Pit size 30 cm³ is best for planting of *Mahua* in lateritic soil. However, pits of smaller sizes can also be used depending on the nature & soil thickness of the site.

BLOCK PLANTING

The trees can be raised by direct sowing or by planting of nursery raised seedlings. In direct sowing of 4 to 6 seeds are sown per pit, covering them with 15 to 25 mm soil in June or July or as soon as seeds are ripe. Before sowing the seed pit should be filled with mixture of soil, sand and farmyard manure (FYM) in the ratio of 3:2:1. After sowing, the pit should be watered, if monsoon rains are delayed. Direct sowing gives survival of 24 to 66%.



Mahua fruits



Mahua seeds



33 *Melia dubia* Cav.

ABOUT THE SPECIES

Melia dubia Cav. (Synonym: *Melia composita* Willd.) belongs to the family Meliaceae. The vernacular names are White Cedar (English); Bakain, derk (Hindi); Malai vembu (Tamil); Munnaitikaraka (Telugu); Malaveppu (Malayalam) and Hebbevu (Kannada). *M. dubia* is spread throughout tropical America, Mexico and Argentina. Caribbean islands, including Puerto Rico and also present in South America. In India, this species occurs in Sikkim Himalayas, Bengal, Upper Assam, Khasi hills, Hills of Orissa, N. Circars, Deccan and Western Ghats at an altitude of 1500-1800 m. Growing in the Himalayas up to 6000 ft. and even higher. The species is most competitive in relatively dry areas with less than 900 mm annual rainfall. It occurs from low land up to 1000 -1400 m. It prefers well-drained, deep, sandy loam soil, with pH 5.5 - 6.5. For raising plantations the area need to be cleared of ground vegetation, and staked into rows 2 m x 2 m apart. The seedlings are planted out in 30 cm x 30 cm x 30 cm pits. Seedlings of 6 months old are to be good for planting. Planting is done during the first monsoon season in June-July and casualties replaced after three months. For the first two years, two times weeding per year is necessary to boost the growth. *M. dubia* shows fast growth in the sapling stage and continues for 15-20 years, with mean annual increment of 4 to 5 cm. But the growth slows down before large dimensions are attained.

SEED COLLECTION AND PROCESSING

Seed collection can be done by collecting from the ground after natural fall or after shaking fruit bearing branches. The production of fruits is 10-15 kg per tree. Collection fruits should be separated as fully mature and not fully matured fractions. The latter should be after-ripened for some days under shaded and humid conditions. Stones from mature fruits may be extracted manually by rubbing with sand and then cleaning with running water. Larger quantities can be extracted by using mechanical equipment designed for de-pulping fleshy fruits, e.g. coffee de-pulper, adapted food processors. After extraction and cleaning in water, stones should be dried for some days until moisture content is about 15-10% (drying may be omitted or minimized if seeds are to be sown quickly after processing). When de-pulping fruits and disposing waste of fruits precautions must be taken to avoid any oral intake by humans and animals. Ingestion can cause acute poisoning and in extreme cases be fatal. There are 57,000 seeds /kg.

The seeds are semi recalcitrant. They should be kept in high moisture content (10-15%). Fresh stones (moisture content 22%) are kept in plastic and then stored in a tin can in a cold room with the temperature of 18-20°C, RH 70-80%. Using this treatment, the germination percentage of the seeds can be maintained up to 20-30% after 10-12 weeks in storage. To prevent fungal attack, seeds can be mixed with fungicide powder, for instance Dithane M-45 or Benlate. Seeds of *M. dubia* are hard and may take up to 3 months to germinate without pretreatment. Pretreatment should aim at breaking the physical barrier to water absorption and expansion of the embryo. Pretreatment can be done manually by cracking or cutting part of the endocarp, or by treatment with sulphuric acid (H₂SO₄). Acid treatment should be with high concentration acid for 40 minutes. Another study revealed that exposing the fruits to microwave energy for 7.5 min followed by seed pelletization with selected microbial consortia recorded the highest germination percentage of 68% over control. It is also reported that the higher germination percentage (44.67%) and other quality parameters viz., seedling length mean daily germination, seedling length and vigour index were recorded in cow dung treatment for 5 days. Similar observation was reported in another study that the highest germination percentage (34.3 %) was observed

in the soaking of seeds in cow dung slurry for seven days. Under complete aseptic conditions seeds showed highest germination of 61%. So high rate of germination seen under controlled conditions clearly indicate the role of light, temperature and nutrients on germination apart from hormones and morphometric characters.

SEEDLING PRODUCTION

Germination is epigeal. Sowing after pretreatment in plastic pots with the mixture sand and soil (1:1). Suitable practice is by burying the seeds into the media horizontally and then covered with fine sand. Stones contain more than one seed. The percentage of germination is low (14%). Karnataka Forest Department reported that, alternate soaking in cold and hot water for 20 days improves the germination percentage (70%). Transplanting medium may consist of a mixture of soil, sand and manure (7:2:1) and added 1 spoon of TSP or NPK in every 1 m³ of media. Transplanted seedlings are plantable in the field after 3-4 month.

VEGETATIVE PROPAGATION

Propagation by stem cutting, macro-rooting or root suckers are possible but is reportedly difficult. Vegetative propagation of branch cuttings with 4000 ppm IBA treatment was found to be promising (50 %). Another successful method of vegetative propagation reported was to take cuttings from six months-old seedlings. A cutting was taken from each seedling up to eight times at 5-8 day intervals. The success rate of rooting was 89%.

A protocol has been developed for micropropagation of *Melia dubia*. Murashige and Skoog (MS) medium supplemented with 6-benzyl amino purine (BAP) 0.5 mg/l along with gibberelic acid (GA3) 2.5 mg/l produced multiple shoots within 4-5 weeks. In vitro rooting was obtained on the half strength MS agar gelled medium supplemented with indole-3-butyric acid (IBA) 0.3 mg/l.



34 *Ougeinia oojeinensis* (Roxb.)

ABOUT SPECIES

Ougeinia oojeinensis (Roxb.) is known as Sandan in the trade circles and belongs to the family Fabaceae (subfamily Papilionoideae). It is generally a small or moderate-sized deciduous tree often with a crooked stem. In its natural habitat, the absolute maximum shade temperature varies from 37.5 to 47.5 °C and the absolute minimum from 2.5 to 15°C. The normal rainfall in its habitat ranges from 500 1900 mm; optimum rainfall appears to range from 750 to 1900 mm. It is common in the sub-Himalayan tracts between 300 and 1500 m elevation. In Siwaliks, bhabar and peninsular areas, it prefers hilly and undulating topography and generally tends to avoid areas with poor drainage. It is found on a variety of geological formations and soils including black cotton soil, red clay and gravel or boulder deposits, etc.. In Kumaon, it is a characteristic species on the limestone soils. Sandan is in great demand for shafts of carts, wheel-hubs, tool handles, axe helves, picker arms, bed legs, sugar crushers, agricultural implements and as posts and poles in constructional work. The leaves are highly valued and lopped as fodder for cattle. The bark is used to intoxicate fish.

SEED COLLECTION AND PROCESSING

The fruits are collected from standing trees in May-June. The tree does not seed abundantly every year. The fruits are dried in the sun, broken up into one-seeded fragments and stored for use. The seeds do not retain viability for long and should be sown in the year of collection.

One-seeded pod fragments should be soaked in water for 24 hours before sowing.

NURSERY TECHNIQUE

Seedlings are commonly raised in polythene bags and root trainers. One-seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds. One-seeded pod fragments, when sown in the nursery, take 10-30 days for germination. The small seedlings are tender to weed competition and may be lost completely if not properly weeded. As the seedlings are sensitive to damage of the taproots, only very young seedlings of small height should be utilized. If transplanting is to be done. Stump-planting is fairly successful and one-year-old plants may be suitable for this purpose.

35 *Picea Smithiana* Boiss

ABOUT THE SPECIES

Spruce (*Picea Smithiana* Boiss) and Silver fir (*Abies pindrow* Spach) commonly referred as high level conifers, cover extensive areas in the Northwest Himalayan States of Himachal Pradesh, Jammu & Kashmir and Uttarakhand, occupying about 31% of the total coniferous area and accounting for about 49% of the total growing stocks in these states. These forests are the very valuable resource and play an important role in the economy of these states, besides helping in soil and water conservation in the catchment areas of major rivers. These species extend throughout the western Himalaya from Afghanistan to Nepal chiefly at 2,100 to 3,600 m but sometimes descending below and up in cool ravines.

The natural regeneration in these forests is very scanty and following factors have been identified as the main hindrances affecting the natural regeneration of these species viz. thick layers of humus, poor seed production, lean seed years, dense weed growth, grazing, more litter fall and low decomposition rates. In the past, these forests had gained importance because of their extensive use in wood based industrial raw material for paper and pulp, matchwood, packing cases etc. Since, these forests could not be regenerated through natural regeneration, artificial regeneration is resorted to.

SEED COLLECTION, PROCESSING AND STORAGE

The time available for the harvesting of cones before seed fall is short (10-20 days) so the collection of sufficient quantity of seed is not always easy. The studies on maturity indices of cones of spruce show that cones mature during first fortnight of October under natural habitat, however, this time may vary depending upon the weather conditions. Therefore, the maturity of cones needs to be judged on the basis of specific gravity (0.97-0.99) of the cones, which can be determined by dividing green weight (g) of the cone by its volume (cc).

It becomes difficult to collect seed manually on the maturity dates, as most of the seed gets dispersed in the air from mature cones. Results of artificial ripening of cones revealed that the collection time can be successfully preponed to fifteen days of maturity date through their artificial ripening at room temperature. A simple method to judge the suitable time for cone collection is; by putting a cone in a water container, if it starts floating in the upper half of the water, cones collection of the species may be initiated. Harvested cones are kept for air drying for 1-3 weeks either in sun or at room temperature and then partially or wholly disintegrated cones are tumbled, shaken and screened to separate seeds. Due to low viability and infrequent seedling in Spruce, it has been recommended that seeds in sufficient quantity should be collected to tide over the lean seed years for raising plantations without fail. The number of seeds per kg is 63,000-65,000 in Spruce. It has also been found that storage of seeds in deep freezers/ low temperature walk-in cabinets improves the seed longevity. Therefore, seeds should be stored at low temperatures (below 10 °C). It can be stored for more than two years at low temperature of -10 °C to -12 °C.

PRE-SOWING TREATMENT

The seeds of Spruce are soaked in cold water for 48 hours before sowing in the nursery. Pre-sowing treatment of Spruce with cold water for 48 hours ensures elimination of seeds which keep on floating and hence, gives better germination percentage (80%).

NURSERY TECHNOLOGY

Spruce is a very slow growing species and require 3½ years respective in nursery to attain plantable size of 20-25 cm; out of this nursery period, 1½ years time is needed in germination beds and the remaining period in the transplanted



beds. Seedlings are raised in permanent nurseries located at the lower limit of natural zone of this species. In the past, low-level nurseries were tried to save time required for producing plan table stock but were subsequently given up, as these nurseries did not offer any advantage over the nurseries in the natural zone of these species. Moreover, it was also observed that the seedlings raised in low-level nurseries resulted into low survival percentage, when planted in the field. The location of the nursery in the natural zone of the species is an added advantage.

Traditionally, Spruce was sown in the month of July, sowing in the month of July was not successful as most of germinated seedling died due to damping off in moist season. While sowing during the months of November/ December, though successful but injury to the seedling due to late snowfall in the months of March/April result in their mortality. Hence, for good result, sowing of these species in the nursery beds is recommended after snowfall in the month/April. Sowing of spruce is done in 6-inch high raised beds. Before sowing formaline treatment of nursery beds against damping off is of utmost importance for controlling damping off. Damping off is most severe in excessively wet nurseries. For the treatment of 1 m² bed area, 250 cc. of formaline dissolved in about 4-5 liters of water is recommended to be sprinkled at least 15 days before sowing. The quantity of water added to the germination bed should be sufficient to penetrate/soak the soil at least up to 15 cm depth. Afterwards, the beds should be immediately covered with polythene sheet for percolation of formaline fumes into the soil. The polythene sheet is removed after two days of formaline application and the soil is raked to allow fumes to escape. During raking of the soil, it should be ensured that the untreated soil does not get mixed up with the treated topsoil. The beds are then left as such for about ten days before seed sowing to avoid toxic effect of formaline on seed. In a standard nursery, beds should have soil, sand and forest manure in the ratio of 1:1:1 respectively to produce quality seedlings of these species. Line sowing proved better than broadcast sowing for this species.

Spruce seed should be sown in 2-4 cm wide strips spaced 10 cm apart. Appropriate depth of 10 for Spruce has been found suitable for sowing. Seed should be covered with forest manure for better germination. Density of sowing depends upon the viability of seed, e.g. seed having 70-80 % germination, 40 g of soaked Spruce is sufficient for bed area per m². In nursery, germination is observed after 15-20 days of sowing. Though the germination will complete in a month time, but a few seedlings may emerge even after a month. Spruce need shade at early stages of their development. Shading in the germination beds provided with the help of net made up from wooden battens of 125 X 0.3 cm dimensions have been found suitable. The gap between two consecutive battens is to be kept approximately 0.7 cm. This type of shading permits about 30-40 percent direct sunlight on the beds. This arrangement prevents the seedlings from direct sunlight, which saves nearly 25 % of the seedlings which otherwise die during summer season, if this precaution is not adopted. These wooden battens can be rolled at the time of watering and when no shade is required. Agro shade net of 35:65 available these days may also be tried. Irrigation and weeding in nursery may be done as and when required. Transplanting of seedlings is necessary to encourage fibrous root development and to grow the seedlings into sturdy plants to withstand the planting shock, otherwise develop long tap root which results in ill health of seedlings. For these species only one transplanting (manually) is recommended in raised beds during raining season. Transplanting of Spruce done during August gives the best performance. One and half years aged seedlings Spruce are recommended to be transplanted in the month of August at a spacing 15 X 8 cm i.e., 84 plants/m² bed area. Spruce seedlings less than 7.5 cm in height should be culled at the time of transplanting, as the performance of these seedlings in transplanting beds have been found quite poor and ultimately it results into wastage of resources and time. The mean root length of Spruce seedlings at the time of transplanting is about 15-25 cm. Furrows for transplanting are not always dug sufficiently deep which results in the root coiling and consequent deformities of roots. Root pruning, leaving about 10 cm of root length intact, improves the growth and survival percentage of seedlings. Shading in transplanting beds is essential as well after transplanting particularly during summer months. Seedlings may also affected by cutworm attack in nursery which results into debarking of roots and stem as well. Application of Phorate @ 10 gm /m² has been recommended to control cutworm attack in these nurseries. Irrigation, weeding and hoeing is recommended as and when required.

VEGETATIVE PROPAGATION

Vegetative propagation of Spruce is not practised for raising of seedlings in the nursery for commercial planting.

36 *Pinus roxburghii* Roxb.

ABOUT THE SPECIES

Pinus roxburghii (chir pine) is a native of the inter-ranges and principal valleys of the Himalaya, beginning from Afganistan in the west and ending in Bhutan in the east it extends through Pakistan, India and Nepal. In India its forests are found in Jammu and Kashmir, Haryana, Himachal Pradesh, Uttar Pradesh, parts of Sikkim, West Bengal and Arunachal Pradesh. The total area under chir forests is estimated to be 8,90,000 hectares and occurs between 450 m to 2300 m altitude. Chir pine is the fastest growing among the conifers found in the Himalayas. The species is hardy, frugal in its soil requirements and adapted to degraded sites which are deficient in nutrients. It grows with ease both on deep soils which should be well drained as well as on skeletal soils.

Chir pine yields a good quality oleo resin, which on stem distillation generates two industrially important products viz., turpentine oil (about 70%) and rosin (about 17%). Rosin is extensively used in many industries viz., soap, paper, paints and varnishes, Pinoleum, sealing waxes, oil cloth, inks and disinfectants. Turpentine is chiefly used in preparation of paints and varnishes, polishes, chemicals and pharmaceuticals. It is also used for dissolving fats, resin and for domestic purposes. It is a popular timber of North India, especially in hills and is used for various purposes including house building, as rafters, poles and posts, doors and windows, shingles, flooring blocks, packing boxes, boards, railway sleepers and in the manufacture of pulp and paper.

SEED COLLECTION AND PROCESSING

Mature cones are collected from healthy, well grown, twist free and self pruned trees during February/March. Smaller ripe cones may even be collected as early as December provided not less than 10 cm in length. One kg seed may be collected from about 150-200 cones (50 kg by weight) or roughly 5 trees. Seeds should be collected during good seed years. The cones are spread in a single layer either on tarpaulins or on cemented floor and are allowed to open. Cones are sometimes covered by a polythene sheet to permit fast drying and prevent them from absorbing moisture. The polythene sheet is removed once during the day to permit evaporation of the trapped condensed moisture. By this method during the month of March the cones take about 3-4 weeks to open. The seeds are separated and cleaned and to a kilogram about 8800 to 12300 seeds are found. The seed size influences germination and subsequent growth. It is, therefore, recommended that seeds be sown grade-wise to obtain a uniform planting stock. Germination of freshly collected seeds on an average is 80-90 per cent and decreases with storage.

SEEDLING PRODUCTION

Perforated polythene bags of 23 cm x 13 cm size and of 150 gauge are used for raising seedlings. Sieved soil is mixed with well decomposed farm yard manure (2:1 ratio). About one quintal of compost is required for filling 300 bags. One kg CAN (Calcium Ammonium Nitrate), 1.50 kg single superphosphate and 0.850 kg muriate of potash are added to one cubic meter of prepared soil and the mixture is sufficient to fill 1000 polythene bags.

Cleaned seeds are immersed in a container with water. Unsound seeds (about 10%) which float to the surface are rejected whereas the remaining seeds that settle down the container bottom are allowed to remain in water for 24 hours. Thereafter the seeds are mixed with fresh dung and wrapped in gunny bags to keep them moist. Seeds start sprouting



after 8-10 days when they are sown in prepared polythene bags. The seeds, which do not sprout within a week from the start of germination are rejected. This practice advances the growth period by about two weeks. Ungerminated water-soaked seeds can also be sown in polythene bag. Two seeds per bag are sown at a depth of about 15 mm. Seeds are normally sown before March as seedlings obtained from late sowing are not fit for planting in July. In many areas sowing is done in September-October to obtain plantable size seedlings for planting during the following monsoon. In areas where winter planting of the species is preferred, seeds are sown during March/April.

Mycorrhizal introduction is done in nurseries.. Soil from the top 15 cm layer in chir forest excluding litter is used as inoculum. The soil inoculum should be collected during and after rains when the percentage of viable mycorrhizae is high. The soil inoculum is thoroughly mixed with the potting mixture before filling polythene bags.

Polythene bags are covered with a thin layer of grasses/shrubs or with hail covers erected on bamboo/wooden posts to protect seedlings from direct insolation, birds and hail storms. Plants in polythene bags are shifted twice within the nursery to prevent their roots from striking the earth. The first shifting is done in May and second combined with grading is just before planting i.e. in the last week of June or beginning of July. Similarly, for plants raised for winter planting, shifting is done in August/September and later on shifting is combined with grading in December/January.

VEGETATIVE PROPAGATION

Vegetative propagation is not much used in this species. Air layering is more successful in the vegetative propagation of chir pine than grafting.

37 *Pinus wallichiana* A.B. Jacks.

ABOUT THE SPECIES

Pinus wallichiana (blue pine or kail) is a dense evergreen tree, found in the Himalayas, from Afghanistan to Tibet, and forms forests at altitudes of 1800-4300 m. The tree is distinguished by its clusters of long cylindrical hanging cones, and its needle-like blue-green leaves. Its wood is highly resinous, and is used for local construction, carpentry and making tea-chests. It is good as firewood, but the smoke is pungent due to the resins. The resin is of superior quality.

SEEDLING PRODUCTION

Cones are collected from trees during late September or October during good seed years that occur in alternate years. Cones are dried till they burst and seeds can be extracted. About 12,500 to 22,000 seeds weigh one kilogram. Dry seeds can be stored for 14-18 months. Germination capacity is 60-70 per cent and plant percent is 55-60.

Though it can be regenerated through direct sowing, seedlings are often raised in the nursery to attain assured success. Sowing in the nursery bed or in polythene bags is done at the break of monsoon rains. Germination begins in a fortnight. Transplanting is done in rainy season twice i.e. when seedlings are one and two years old. Three years old seedlings are planted out with ball of earth.

VEGETATIVE PROPAGATION

Vegetative propagation is not done in this species.



38 *Pithecellobium dulce* (Roxb) Benth.

ABOUT SPECIES

Pithecellobium dulce (Roxb) Benth., locally known as jangal jalebi in greater part of India, belongs to family Fabaceae (subfamily Mimosoideae). It is a genus of shrubs or small trees with bipinnate leaves with glands at base of pinnae and the leaflets and without terminal leaflets. It is a small to moderate sized evergreen tree, with small persistent stipular spines on the trunk and closely lenticellate branches.

The tree is indigenous to the hot regions of Mexico and now grows wild in south India. It is commonly cultivated as fuel wood tree and as a hedge plant in the warmer and drier parts of India in the plains, particularly in south India and to a smaller extent in central and N.W. India. In the plains of the Gangetic valley it is found almost everywhere and has run wild. It is artificially regenerated in the forest regions in the southern states.

It grows on a variety of soils e.g. pure sand as in East Coast, deep alluvial loam as in the Cauvery delta and gravelly and black cotton soil. It shows great adaptability and grows even on sandy soil with *Casuarina* in Nellore district. It can grow on poor soil, on waste lands and even with its roots in brackish water.

The timber is used for cart wheels and agricultural implements. It is also used for petty construction, packing cases, panelling of doors, etc. The leaves and twigs are used as fodder for goats. The pods are eaten by children, cattle and birds. It has a tendency to develop leaves on dwarf shoots and hence it is amiable to topiary. The seed contains 17% of a fatty oil, which is light coloured and as thick as castor oil. It yields a gum usually in spheroidal tears about 1.2 cm in diameter with deep reddish-brown colour, it is freely soluble in water.

SEED COLLECTION AND PROCESSING

Plants begin to yield viable seeds from an early age. The ripe pods are collected from the trees from April to July and are dried in the sun, till they dehisce. Unbroken pods are hammered to separate the seeds. They are cleaned and kept ready for use. It appears that the seeds do not store well. Hence it is desirable to sow them as soon as possible after collection. The number of plants that can be expected from a kilogram of seeds is 3,230.

SEED TREATMENT

Untreated seeds give the highest percentage of germination. Treatment with cold and hot water appreciably reduce the germination capacity and treatment with boiling water almost disrupts it.

NURSERY TECHNIQUES

Seed is sown soon after collection either in containers or in nursery beds in lines 13cm apart. Beds are watered daily in the beginning; less frequently later on. Seedlings are planted out to form a hedge or routine block plantation or strip plantation. Seedlings can also be raised in baskets or other containers.

39 *Pongamia pinnata* (L.) Pierre

ABOUT THE SPECIES

Pongamia pinnata (L.) Pierre (Synonyms: *Pongamia glabra* Vent. *Cytisus pinnatus* L. and *Derris indica* (Lam.) Bennet) belongs to the family Fabaceae. The vernacular names are Pongam (Tamil), Naktamala (Sanskrit), Karanja (Gujarati), Karamji (Konkani), Pongungu (Malayalam), Honge (Kannada), Karaja or Karanja (Marathi), Karanja (Hindi) and Indian Beech Tree (English). An Indo-malaysian species, a medium-sized sub-evergreen tree, common on alluvial and coastal situations from India to Fiji, from sea level to 1200 m. It is distributed in Australia, Florida, Hawaii, India, Malaysia, Oceania, Philippines, and Seychelles. Tree grows in full sun mostly found in banks of rivers and in ravine. Distributed in Himalaya India, Sri Lanka and South East Asia. It grows best in clay, loam, sand, slightly alkaline, acidic and well drained soil. It is highly drought resistant and moderately vaporizer salt tolerant. Pongam should be grown in full sun or partial shade on well-drained soil. Pongam is resistant to high winds and drought but is susceptible to freezing temperatures. Pongam will show nutritional deficiencies if grown on soil with a pH above 7.5. Trees coppice well and can also be pollarded. When planted as a shade or ornamental tree, pruning may be necessary to obtain a trunk of appropriate height. The spacing adopted in avenue planting is about 8 m between plants. In block plantings, the spacing can range from 2 x 2 m to 5 x 5 m. The lateral spread of roots in this species is about 9 m in 18 years which is higher than most other species. It also produces root suckers profusely. Growth of young trees is fairly slow. A growth of 1.3 m in height and 0.4 cm in diameter in 13 months was recorded in India. Trees reach adult height in 4 or 5 years, bearing pods at the age of 4-7 years. A single tree yield about 50 kg pod per tree at the age of 15 years. In general, Indian mills extract 24-27.5% oil using village crushers, and 18-22% through manual crushers.

SEED COLLECTION AND PROCESSING

Mature trees yield about 50 kg of pods and 8-24 kg of seeds annually. Direct sowing is common and most successful. Seeds require no pretreatment and germinate within 7 days to 1 month of sowing.

SEEDLING PRODUCTION

Germination is hypogeal and the radicle develops quickly before the plumule emerges. In the nursery, it can be planted at a close spacing, as young plants tolerate shade well; in India a spacing of 7.5 x 15 cm is recommended. Seedlings attain a height of 25-30 cm in their first growing season. Transplanting to the field should occur at the beginning of the next rainy season when seedlings are about 60 cm in height. Seedlings have large root systems and soil should be retained around the roots during transplanting. It is easily established by direct seeding or by planting nursery-raised seedlings or stump cuttings of 1-2 cm root-collar diameter.

The successful propagation methods of *P. pinnata* are comprised of through seeds, through cuttings, and through layering and grafting. The trees easily established by direct seedling or by planting nursery raised seedling or stump cuttings of 1 - 2 cm root - collar diameter. Propagation by branch cutting and root suckers is also possible. Fresh seeds yield high germination. Tree will yield about 10-5.0 kg of seeds. About 1500-1700 seeds weigh per kilogram. Seeds require no treatment before sowing and will remain viable from one year if stored inside the pod in containers free from pest and disease attack. Fresh seeds are sown directly in poly bags of 20 x 15 cm filled with soil, sand and FYM in the ratio of 2:1:1. Seeds germinate in 10-15 days. Seeds with unknown germination can be sown in mother beds and then transplanted into poly bags after germination at 30 - 40 days. This will help to overcome empty poly bags and get uniform



seedlings in nursery. Germination is hypogeal and the radicle develops quickly before the plumule emerges. In the nursery, it can be planted at a close spacing, as young plants tolerate shade well; in India a spacing of 7.5 x 15 cm is recommended. Seedlings attain a height of 25-30 cm in their first growing season. Transplanting to the field should occur at the beginning of the next rainy season when seedlings are about 60 cm in height. Seedlings have large root systems and soil should be retained around the roots during transplanting. It is easily established by direct seeding or by planting nursery-raised seedlings or stump cuttings of 1-2 cm root-collar diameter. Seedlings of six months to one year old are out planted in the main field into pits of 30 cm³ or 45 cm³ at 3m x 3m or 5m x 5m spacing. Application of FYM 5 kg, DAP 25 g per pit will enhance growth and early establishment.

VEGETATIVE PROPAGATION

The plus trees of *Pongamia* were selected based on height of the tree, GBH, crown area, number of pods in one foot branch, total pod yield, oil percentage and pest and disease incidences. The age of the selected trees is about 15 to 20 years. The trees which showed yield of 100 to 200kg pod/ tree and oil content 27 to 33% were short listed. Branch cuttings were collected from plus trees in the month of March/ September and the cuttings were treated with 0.1% with Bavistin as fungicide for few minutes, and then the basal end of cuttings were treated 800ppm of IBA. The cuttings were planted in sand bed in the mist chamber at 30 ± 2° C and 70 to 80% RH, and intermittent misting was given at regular intervals. Rooting occur within 30 days, and the rooted cuttings were shifted to polybags containing soil, sand and farm yard manure in the ratio of 2:1:1 and hardened in the shade house followed by open sun light hardening.

40 *Populus deltoides* Bartr.

Populus deltoides (poplar) is the most widely planted species of poplar in India. It was introduced in India in the late 1950s. It is planted in plains of North-West India, i.e., Western Uttar Pradesh, Punjab and Haryana and to some extent in the outer plains/ valleys of Uttarakhand and Himachal Pradesh. It was introduced on a significant scale in Bihar a decade ago. It constitutes the backbone of agroforestry in irrigated plains of Northern India.

It is planted in deep, fertile, irrigated, well-drained soil, sub-tropical climate; mostly above 28°N latitude. It is always planted in irrigated, agroforestry plantations; 60% plants in the country exist as block plantation and 40% plants as boundary plantation. Poplars can produce moderate quality veneer logs at short rotation period of 6 to 8 years achieving high productivity of 20-25 m³ha⁻¹yr⁻¹. Because poplars are deciduous, winter crops can be grown alongwith poplars throughout the rotation period. The major uses of poplar are plywood, board, match, paper, charcoal, etc. More than 30 uses of poplar are known in India. Before planting poplar, it is necessary to ensure its saleability in the local timber merchants or industries since its market is limited and price varies considerably. Major markets of poplar wood in north India are Yamunanagar and Ludhiana.

Poplar requires deep, fertile, sandy loam, well-irrigated land. The soil must be well drained; stagnation of water in the plantation can lead to toppling of even well-grown trees. Water logging for a week or more results into death of the plants. It is drought sensitive; hot dry summer frequently results into death of young plants unless they are provided frequent irrigation. In areas where weekly irrigation of trees (about 20 litre water per plant per week) is not possible during summer season, poplar trees should never be planted. Hence the species is grown in agricultural lands in conjunction with agricultural crops, except paddy.

SEEDLING PROPAGATION

The species is not commercially raised through seed.

VEGETATIVE PROPAGATION

Propagation is done through cuttings. Cuttings should be taken only from stems of one-year-old nursery plants.

SITE PREPARATION

A deep, sandy loam, well drained fertile plot of land is prepared for establishing poplar nursery. For this purpose, the nursery land is ploughed to 25-30 cm depth. Land is then levelled with a plank. The quantity of fertiliser depends upon site. As a general guideline, 25 tonne/ha FYM, 150 kg/ha urea, 200 kg/ha single super phosphate and 100 kg/ha muriate of potash are added to soil in Dehradun area. About 25 kg/ha zinc sulphate and 75 kg/ha Phorate (insecticide) are also added to the soil. Beds of about 5 metre width and 12 metre length are generally prepared.

PREPARATION OF CUTTINGS

Cuttings must be taken from stems of one-year-old plants raised in the nursery. Cuttings taken from branches of trees should never be used. Cuttings are taken from middle part of the stem within 1 to 3 cm diameter limit. Cuttings of 22 cm length and 1 to 3 cm diameter should be made. The cuttings should be immersed in clean water for 24 to 48 hours before planting. Pre-treatment with Bavistin (20 g per 100 litre water) for 2 hours and Emisan (250 g per 50 litre water) for 20 minutes should also be given to cuttings before planting.



PLANTING OF CUTTINGS

Best time of planting cuttings is February. The recommended spacing for planting of cuttings for production of entire transplants for planting out in field next year is 80 cm x 60 cm. When cuttings are planted solely for propagation purpose (i.e. production of cuttings for next year's propagation works), cuttings should be planted at a narrower spacing of 60 cm x 60cm. Cutting should be planted vertically and deep enough that only one bud is above the soil surface. Cuttings must be irrigated immediately after planting. In termite prone areas, Chlorpyrifos 20 EC should be added @ 4 litre/ha to the soil with irrigation water.

AFTERCARE

Cuttings sprout within 10 days of planting. In case of emergence of more than one shoot per cutting, only one shoot should be retained and the less vigorous shoot should be cut off close to the stem with a sharp tool. Weeds should be kept under control in the nursery. First weeding is necessary by the end of first month in nursery. Total 3-4 weedings are enough. Loosening of soil promotes growth of poplar plant. Poplar keeps producing branches in the nursery. Shoots longer than 15 cm should be removed from the stem by cutting off close to the stem. This operation is called pruning and it should be done every 30-45 days.

In July end, shoots and leaves from lower 1 m height of the stem should be removed by rubbing off with a gunny cloth.

Plants reach about 3 to 5 m height at the end of one year and are ready for outplanting.

41 *Prosopis juliflora* (Swartz) DC.

ABOUT SPECIES

Prosopis juliflora (Swartz) DC. belongs to the family Fabaceae and is commonly known as vilayati babul in Hindi and mesquite in English. It is small to medium-sized, semi-evergreen to evergreen, usually unarmed but sometimes armed tree, commonly attaining a height of 9-12 m and a girth of 90 cm. In favourable localities the tree is reported to attain upto 18m in height.

Prosopis juliflora is an acclimatised exotic in many parts of India chiefly Andhra Pradesh, Delhi, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh, its original home being North and South America. It is indigenous in western Texas and eastern New Mexico in United state and throughout most of Mexico, Central and South America and the West Indies. In India five forms of *Prosopis juliflora*, namely the *Argentine* form, the *Arid* form, the *Mexican* form, the *Peruvian* form and the *Australian* form are recognized. A hot dry climate with mild winters, less rainfall and clear atmosphere suits it the best. In areas where it is indigenous or has been naturalized the absolute maximum shade temperature varies from 46.6° to 45.6°C and the rainfall from 250 to 762mm. It can be grown in area of lower rainfall down to 70 mm per year but germination here on direct sowing is patchy. It does not tolerate heavy rainfall. Some varieties can withstand a few degrees of frost.

It can grow on a wide range of soils. It is at home on rocky hills, on sandy soil, shifting sand dunes on coastal sand. It attains its largest size in localities protected from wind and having water table not far below surface. It does not tolerate the water log situation. It grown on small hillocks and ridges, sometimes quite stony as well as on the plain ground.

The mesquite has a large and stout taproot which descends vertically sometimes to 12-15 m depth. It coppices fairly well. Coppice shoots have been observed to attain a height of 60 to 90 cm in one year. It pollards well and also produce root suckers. It is a strong light demander and can stand isolation and exposure particularly in its early stages. The moisture requirement of species is very low and it can be successfully grown even where the water table is lower than 30 m and the rainfall is only about 250 mm. In drought resistance no tree can perhaps equal *P. juliflora*. Frequent irrigation in early stages tend to make it bushy.

In Rajasthan it is used for agricultural implements, fence posts and for cheap furniture, such as stools, tables, benches and cots. It is also recommended for tool handles of all sorts, crushers and other uses where strength and hardness are important. It makes excellent fuel and produces valuable charcoal. The flowers are good source of honey. Its pods are sweet and succulent and are edible possessing high nutritive value. It also yields a gum which is used for adhesive purpose.

SEED COLLECTION AND PROCESSING

Prosopis juliflora particularly the Australian form, produces an abundant crop of pods twice every first from November to January and again from April to June. The plants fruit regularly every year and commence producing seed at the age of 2-4 years. The annual yield of pods from an average sized tree is 37 to 75 kg. Ripe pods must be collected from the ground or off the trees; from well-grown tree. They turn yellow when mature and fall to the ground. Birds, especially parrots and squirrels, relish unripe pods and thereby cause considerable damage. After collection, the pods should be spread in the sun for drying. When dry the pods can be broken into segments by beating with wooden beaters. Pounding also breaks



the pods into bits, each bit containing a seed. The one-seeded segments can be separated by winnowing. It is very difficult to extract the seed from these dry broken bits as the endocarp is hard and does not yield to mechanical pressure. The dried pods broken into segments or extracted seed can be stored in a dry place in container such as gunny bags or sealed tins. Seed to be used in the same year may even be heaped on a dry floor. Well dried seed or single-seeded segments protected against moisture may be stored, without serious loss of viability, up to two years.

The number of pods per unit weight shows considerable variation; it is the greatest in Arid form (about 550 pods per kg) and smallest in the Peruvian or Mexican form (about 266 pods per kg): The number of seeds per pod varies from 4 to 32. The number of cleaned seeds per kilogram is 32,000 to 35,200. The viability of the fresh seed is very high and lies between 86 and 90%. Storage with dry slaked lime, 45 kg of lime to 181 kg of seed, is stated to insect attack. Storage in bins with 5 cm layer of sand on top is stated to prevent entry of beetles.

SEED TREATMENTS

The seed is very hard with an impermeable seed coat and requires pretreatment to hasten germination. The outer covering of the pods softens with soaking and can be removed by hand prior to sowing. Segments with seeds encased in the inner pod lining can be utilized for sowing. The following treatments have been found successful:

- Soaking the one-seeded segments in cold water for 24 to 48 hours before sowing.
- Soaking in concentrated sulphuric acid for 15 to 30 minutes.
- Placing the seeds in boiling water and allowing them to cool as they soak for 24 hour.
- Coating the seed with cow-dung.
- Pounding the seed along with sand. It is said to give 87% germination against 50% of the untreated seeds.
- Shaking the seed in a tin-container for 10-15 minutes so that seeds get impacting treatment.
- This method is said to have given 97% germination.
- Feeding the seed to sheep, donkeys and goats and collecting and using seed found in the droppings.

NURSERY TECHNIQUES

Nursery work presents little difficulty provided basic conditions of complete overhead light, sandy loam soil, watering and adequate drainage are fulfilled. One-seeded segments of pods or extracts are sown in properly worked-up soil and lightly covered with earth. In North India, seed should be sown as early in the spring season as possible to have well-developed seedlings at the commencement of the monsoon. Late sowings naturally result in lesser growth. Seeds are usually sown in polythene bag or root trainer directly. Sowing can also be done in nursery beds. The nursery-beds are usually 90 to 120 cm in width, and maybe flush with the ground or slightly sunken. Seed is sown in drill about 23 cm apart. Where large plants of the second year are required, sowing may be done in lines longitudinally along the beds or furrows about 46 cm apart. Beds are watered at 3-4 days intervals till germination takes place, after which the interval of watering can be gradually increased. For optimum growth, the nursery-beds should be kept free of weeds as weed competition retards development of stock. Soil working after each watering is beneficial. About 28 g of seed are sufficient for sowing a line 27 m in length at an espacement of 2.5 cm. When the seedlings are 3 weeks old, they should be thinned to a spacing of 7 to 10 cm. A second thinning may be done to space them 15 to 20 cm apart when the plants are about 30 cm tall. Stock for planting out is ready by the beginning of the first year monsoon, i.e., at the age of 2-4 months. It becomes, suitable for preparing stumps at the age of 12-15 months.

Nowadays seeds are generally sown in polythene containers and the stock after watering and tending is planted out in the field when large enough. The containers for sowing are of 10 cm in diameter and 20 cm high. These are filled up with a mixture of farm yard manure and soil in the proportion of 1:3 in May. Seeds are sown in spring season. By the end of the rains, the seedlings are 20-30 cm high and are shifted to prevent root penetration in soil. Side by side sunken nursery beds are prepared and their bottom is covered with polythene sheet. Over these another batch of larger polythene containers of the diameter 20 cm and height 30 cm filled up with same kind of soil mix is arranged and the plants from smaller containers along with the soil-block with roots are transferred in larger containers. This operation is done in November. Throughout the hot season the container plants are watered and shifted. These are planted out next monsoon when about 1.5 m high. This practice is widely prevalent in Gujarat and Rajasthan.



42 *Prosopis cineraria* Druce

ABOUT SPECIES

Prosopis cineraria Druce is commonly known as khejri and belongs to the family Fabaceae. It is a small to moderate-sized thorny tree, with slender branches armed with conical thorns and with light blushing-green foliage. Owing to incessant lopping, it is often seen as a large shrub but when protected it grows into a tree with height upto 18m and girth upto 1.8 m. The tree occurs in the dry and arid regions of India. It is one of the chief indigenous trees of the plains of the Punjab, West Rajasthan and Gujarat and is common in Bundelkhand and the neighborhood of Delhi and Agra. In the larger area of its distribution, the climate is arid or semi-arid and is characterized by extremes of temperature, heat being a feature of the hot weather, while in the winter a little of frost may also be registered.

This is one of the most useful trees of desert areas in India, and largely planted by the people in cultivated areas. The wood is of constructional class, and is used for house-building, chiefly posts and scantlings, doors and windows, and for well-construction, water pipes, upright posts of Persian wheels, agricultural implements, and shafts, spokes, fellows and yokes of carts. It can also be used for small turning work and tool-handles. It is largely used as fuel in the Punjab and Rajasthan, the wood yielding excellent fuel with great heating power. The foliage is much lopped for fodder and it is rare to find in some parts of its range a tree which has not been lopped and mutilated. The green leaves are said to raise the milking capacity of the animals fed on them. The pods, called sangri or shanger, which contain a farinaceous pulp of a pleasant flavour resembling that of *Ceratonia siliqua*, are eaten green or dry, raw or cooked, especially in times of scarcity. The pods are also used as fodder for camels, cattle and goats. The bark which has a sweetish taste is also largely consumed in the form of flour during severe famines. In fact there is no part of the tree which is not used by the people and the tree is rightly called a saviour of desert. It is considered sacred by Hindus.

SEED COLLECTION AND STORAGE

The best time for collection of seed is June-July. The ripe pods may be collected by hand-plucking or by shaking the pod-bearing branches, or may be beaten off the tree with a stick after the ground has been swept clear. The pods should then be spread in the sun for drying. The pods may also be fed to Penned cattle, goats and sheep. The dung and droppings of these animals are collected and spread out to dry. The seed may be extracted from the dry pods or from the dried droppings of animals fed on the pods by beating with wooden beaters or crushing with hand. The seed may be removed from the husk and other impurities by winnowing, and can be stored in gunny bags which are kept in some cool dry place, somewhat raised above the ground-level. Seed is said to store well and probably will keep for several years. Average number of seed per kilogram is 26,100 to 28,200.

SEED TREATMENTS

Soaking in cold water for 24 hours prior to sowing slightly increases the germinative capacity. Treating seed with hot water is harmful.

NURSERY TECHNIQUES

Pretreated seed is sown in earth-filled polythene bags (30 cm long x 10 cm dia.), 2 seeds in each, one centimeter deep during June-July. Regular watering is done. Seedlings are regularly weeded. Only one seedling is retained per bag. One-year-old seedlings are planted out. Germination is not affected by shading after sowing. Germination is epigeous. Seedling growth is slow, seldom attaining 30 cm in a year under irrigated conditions.

P. cineraria can be raised by direct sowing as practised in Sind (Pakistan) Sowing may be done broadcasting in sandy areas, dibbling in pits or patches or in ploughed furrows.

43 *Pterocarpus marsupium* Roxb.

ABOUT THE SPECIES

Pterocarpus marsupium Roxb. belongs to the family Fabaceae (Papilionaceae). It is commonly known as Bijasal, Piasal, Vengai, Vegisa, Indian Kino tree or Malabar Kino tree. *Pterocarpus marsupium* is a moderate to large deciduous tree, up to 30 m, spreading branches and large, rounded crown. It is distributed in tropical moist and dry deciduous forests of Gujarat, Uttar Pradesh, Bihar, Odisha, West Bengal, Madhya Pradesh, Western Ghats, Karnataka, and parts of peninsular India, Sri Lanka and Nepal. The timber is moderately heavy, strong, durable and easy to saw. It is mostly used for constructional and furniture purposes next to teak and rosewood. The aqueous infusion of the wood is said to have anti-diabetic properties due to transfer of glycoside into water. The heartwood contains two glycosides i.e., marsupin and pterostilbene, which are reported to have better effect than metformin, a potent medicine for diabetes. The bark yields blood-red or ruby colored gum, known as kino or Malabar kino that is used for tanning, printing and dyeing industry.

P. marsupium is characteristic of deciduous types of forests and appears to grow on a variety of formations provided the drainage is good. It establishes well on both hilly or undulating areas and more on less flat ground. It prefers a soil with a fair proportion of sand and it is often found on red loams with certain percentage of clay. The tree grows in larger dimensions on exposed hill-sides, on rocky ground and shallow soil. It is gregarious where the forest growth is poor. In the peninsular it is common on gneiss, quartzite, shale, conglomerate, sand stone and laterites.

P. marsupium yields a high quality timber with high percentages of strength, stiffness, shock-resisting ability, hardness, retention of shape and shear. The timber is chiefly used for building purposes as doors, window frames, rafters, beams and posts and as a substitute for teak after suitable seasoning and treatment

SEED COLLECTION

To avoid loss to natural dispersal, collection must be done before natural shedding. The best collection time is when the pods turn in to brownish white and pod moisture content is about 20-25%, which generally occurs in last week of March. At this stage the seed color is light brown and moisture content is about 40-45%. Collection can be done by shaking the tree, lopping the branches and by plucking the pods. A tarpaulin sheet may be spread under the tree. After collection pods should be spread in shade in one layer or cement floor for drying till the moisture content remain constant.

PROCESSING AND STORAGE

Seeds are usually not extracted from pods due to hard seed cover, which is difficult in extraction of seeds without damage. However, for convenience in sowing, the wings can be clipped off the fruits with the help of scissor. The seeds are orthodox and remain viable, if dried up to 4-5% moisture content. Viability can be maintained up to one year at ambient temperature (with annual variation 15-35°C) if moisture content is below 10%. The seeds can be stored more than three years at low temperatures (15°C to -10°C) at 4-5% moisture content. It is better to store extracted seeds instead of pods.

NURSERY TECHNIQUE

Though the fruit coat is very hard, it is hygroscopic and seeds have no dormancy. Therefore no pre-treatment is required. However, germination capacity varies from 60 to 95% due to empty or malformed seeds, whereas extracted sound seeds give 100% germination. The best temperature for germination is 20°-30°C. The seed germinate both in light and dark conditions.



The tree can be propagated through direct sowing or by transplanting the nursery-raised seedlings. In direct sowing method, seeds are sown in lines 3 m apart or patches of 3m x 3m. Seeds are spread in one layer on the surface of the soil and a thin layer of sand or dry leaves are spread over them with the commencement of rains. Simultaneous sowing of field crops is beneficial as such crops provide protection against the hot sun. Planting design should leave about 0.6m wide strip for sowing *P. marsupium*. In patch sowing, pre-germinated seeds are sown in each patch. In nursery, seedlings are raised by sowing seeds in lines 20 cm apart. Germination starts in about a fortnight and generally completes in 8 weeks. One year old plants are transplanted in the following rainy season with ball of earth. Planting of older seedlings becomes difficult due to development of long tap root. Seedlings can also be raised in containers, such as polythene bags or bamboo baskets filled with pulverized and sieved soil mixed with compost.

NATURAL REGENERATION

Natural regeneration is good. Seeds are anemophilic, i.e. dispersed by wind or storm, to long distance even before full maturation drying, though it doesn't affect seed germination. In forest the tree regenerates by seeds. It also coppices fairly well.

SITE REQUIREMENTS

- | | | |
|-----------------------|---|--|
| Light | : | It is a moderate light-demander. Seeds can germinate both in light and dark condition. Seedlings and saplings can stand a fair amount of lateral shade, but growth is adversely affected in overhead shade. So gap is necessary for growth of the seedlings. |
| Temperature | : | Bija seed germinate best from 20-30°C during rains. Temperature more than 40°C after rain reduces germination and seedling growth. |
| Rainfall and humidity | : | The normal rainfall in its habitat varies from 750 to 3800 mm |
| Soil | : | The species grows best in well-drained sandy and sandy loam soil. Leaf litter favours germination. |

SPECIAL CONSIDERATION

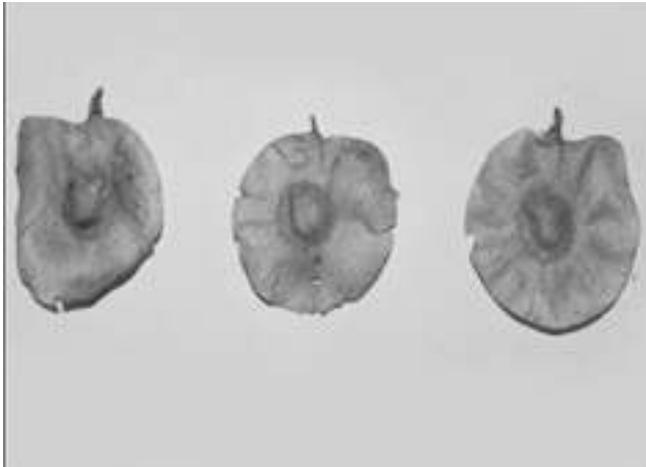
As seeds are dispersed during March (dry season), germination in early rain gets benefit of loose soil clear of grass and weeds. The seedlings are weeds tolerant. Seedlings should be protected from browsing cattle. Moist condition under partial shade favours survival of the seedlings. In general, 20-35°C temperature during rain, sandy to sandy-loam soil, partial shade (gap between trees), and protection from browsing by cattle ensures better regeneration in natural forest.

PLANTING TECHNIQUES

Land is made into fine tilth by ploughing and harvesting in April–May. Pits of appropriate size of 45 cm³ are dug at a spacing of 8m × 8m. About 25 kg FYM (farmyard manure), along with 200 g of nitrogen and 150 g of phosphorus, is mixed with soil of each pit as basal dose. The pits are refilled with this mixture after weathering of soil. Transplanting may either be done in July–August (monsoon season) when the plants are two-month-old or delayed till next June–July. A spacing of 8m × 8m is recommended, which accommodates about 160 plants per hectare. Gap filling in the field is done in September. When Bijasal is planted at a spacing of 8m × 8m, intercropping can be done with a number of species such as medicinal plants and vegetable crops. The species can also be raised as a pure crop at smaller spacing. The tree is harvested after 10–15 years for production of heartwood. Kino gum is collected through incision in the bark before logging of tree, and dried well in shade.

Grown as shade tree for coffee plantations, and often cultivated as a multipurpose tree in home gardens and as component of agroforestry systems in India. It provides a good bulk of leaves for green manure.

Pterocarpus marsupium



P. marsupium pods



P. marsupium seed

Wings are clipped off the bija seeds



Germinated seeds



Seedlings in the nursery beds



44 *Pterocarpus santalinus* L. f.

ABOUT THE SPECIES

Pterocarpus santalinus L.f. is an endangered species belonging to the family Fabaceae with the common names Red sanders, Almug, Red Sandalwood, and Saunders wood (English). The vernacular names are Lalchandan, Ragat chandan, Rakta chandana, (Sanskrit); Sensandanam, Sivappu chandanam (Tamil); Rakta gandhamu, Yerra chandanamu, Yerra sandanum (Telugu); Patrangam, Ratka chandanam, Raktashandanam, (Malayalam); Kempu gandha, Patrana, Rakta shandana (Kannada). The red sanders are endemic to the Eastern Ghats in South India and are found restricted to the middle and southern parts of the Eastern Ghats. It is found in a very localized and restricted distribution in the Cuddapah district of Andhra Pradesh with small populations in the neighboring districts of Kurnool, Nellore, Chittoor in AP and the hills of Chengalpet district of Tamil Nadu. Red sander is a light demander and will not tolerate overhead shade and therefore, requires abundant growing space for its crown development. It is more resistant to fire than many of its associates and at times even seedling and saplings escape serious damage by fires. In Andhra Pradesh the spacing adopted is 3 x 3 m while in of Tamil Nadu 2 x 2 m spacing is adopted. Regular thinning is necessary to promote the best growth to provide abundant space for its growth. The Kodur plantations (AP) of 1985 raised in rich alluvial soil showed for the first 18 years a mean crop height of 12.2 m, a mean GBH of 45.4 cm, average number of stems per ha of 1512 and MAI of 7.56 cm. In Chengalpet (TN), a 14 year old plantation showed an average height of 8 m and average girth of about 40 45 cm. The maximum height and girth were 12 m and 66 cm respectively. The heartwood formation starts at the age of 18 years when it has attained a GBH of 15 - 23 cm. A coppice shoots signs of forming heartwood at an age of 15 years, when it has attained a girth of 23 to 38 cm.

SEED COLLECTION AND PROCESSING

The pod set is only 3% under natural self-pollination. Pod maturity takes about 11 months after flower opening. The germinative capacity is as low as 10 - 12 % in Andhra Pradesh and 25 - 30 % in Tamil Nadu. The entire pods with wings as collected from the tree are used for regeneration purposes. The extracted seed has considerably less germinative capacity. The dry seeds weigh 900 - 1400 kg. Soaking the pods in cold water for 3 days enhances the germinative capacity to a large extent. Pods are also soaked in cow-dung slurry for 48 hours before sowing. 35° C is the optimum temperature for quick and maximum germination. Studies have shown that pods harvested and sown in March give better germination though the dry pods can be collected from the trees from April- June. It is evident from the observation that the pod given soaking in water 48h treatment showed better germination percentage as compared to acid scarification.

SEEDLING PRODUCTION

The seedlings were transplanted to polythene containers when they are 4-10 cm tall and kept under shade and watered daily. This process is continued till the period when the seedlings develop carrot roots and attain 20-25 cm height when they are fit for planting. Around 10-15 kg of pre-treated seed (seeds sown in cold water for 3 days or pods soaked in cow-dung slurry for 48 hrs before sowing) is sown in standard bed and is covered with a thin layer of earth, brushwood hay. Highest germination is obtained by sowing the seeds with flat side touching the ground. The bed is covered with dry leaves or straw and profusely watered. In Andhra Pradesh, it is reported that 7 -14% germination is obtained when 10-15

kg of pre-treated seeds are sown in standard mother beds, whereas in Orissa, seeds sown directly in the polythene containers showed 60% germination. Studies in Tamil Nadu revealed that stump planting gives the highest survival percentage (87%) as against 20% for direct sowing and 13% for entire transplanting.

VEGETATIVE PROPAGATION

An efficient protocol has been developed for the in vitro propagation of *Pterocarpus santalinus* L. using shoot tip explants. Multiple shoots were induced from shoot tip explants derived from 20 days old in vivo germinated seedlings on 1:1 ratio of sand and soil after treating with gibberellic acid (GA3). The highest frequency for shoot regeneration (83.3%) with maximum number of shoot buds (11) per explant was obtained on Murashige and Skoog (MS) medium supplemented with 1.0 mg/l of 6-benzylaminopurine (BAP) along with 0.1 mg/l of thidiazuron (TDZ) after 45 days of culture. The rooting medium is MS salts and 0.1 mg/l indole-3-butyric acid (IBA).

Micro-propagation of *Pterocarpus santalinus* using mature nodal explants: Combinations of serial transfer technique and incorporation of antioxidants (250mg/l l-ascorbic acid and 50 mg/l citric acid) into the culture medium helped to minimize medium browning and improve explant survival during shoot sprouting. About 70% of explants were sprouted on Murashige and Skoog (MS) liquid medium containing 4.4mM 6-benzyladenine (BA). The combination of 4.4mM BA and 2.2mM thidiazuron (TDZ) was found to be the most suitable growth regulator for obtaining the highest percentage of nodal segment sprouting (74%–75%). The best rooting response was achieved on solidified half-strength MS medium supplemented with 4.9mM indole-3-butyric acid (IBA). About 70% of the micropropagated plantlets were established successfully in 20-cm pots containing a mixture of soil and farmyard manure (4:1 ratio).



45 *Robinia pseudoacacia* Linn

ABOUT SPECIES

It is commonly known as black locust and belongs to the family Fabaceae (subfamily Papilionoideae). It is a medium sized deciduous tree, seldom exceeding 24-27 m in height and 1.8-3.6 m in girth. Robinia was introduced into India in the latter part of the last century about 1890 in the then Punjab. For many years afterwards, it had been cultivated indiscriminately there, in the hope that it would reforest bare hills. It has failed in the plains and lower hills but has succeeded in the higher hill now forming part of Himachal Pradesh. It favours a deep, rich, gravelly, well-drained loamy soil; but appears to be capable of growing on a wide range of soils, except wet, heavy and stiff ones. It seems to have special health and vigor on soils well supplied with lime. It grows particularly well in porous soils, especially on new embankments, spoil banks, loose hill sides, landslips, old alluvial flat lands and taluses, provided the situation is not too hot or dry.

Robinia is a strong light demander and possesses a fibrous root systems. The species coppices freely. It can fix the atmospheric nitrogen with help of bacteria in root nodules. It is used for tool handles, agricultural implements, gate and fence-posts, stakes and for other locations exposed to weather. It is particularly used in spokes of cart wheels in Kashmir. It is reported from Kashmir that well grown and older specimens are capable of yielding of good timber for furniture and turnery works. The leaves are an excellent nutritive fodder for cattle and the litter builds up the soil. The flowers provide nectar for honey bees. It is an invaluable species for soil conservations and anti-erosion measures, for road-side avenue planting and is eminently suitable for farm-forestry in the temperate zones of middle and western Himalayas.

SEED COLLECTION AND STORAGE

Abundant seed crops are produced every 1-2 years with light crops in intervening years. Trees begin to yield commercial quantities of seed from the age of 6 years, though stray plants 2 years old and 3-4 m. Seeds should preferably be collected from trees of good growth less than 25 years old. Pods are collected off the standing trees in September, October by hand-picking or stripping or beating on to a spread canvas. They are spread out in the sun to dry. The seeds are released by thrashing or flailing or by running them through a grain separator or macerator.

Chaff and light seeds are removed by winnowing. On an average, a middle-sized tree gives 6-12 kg seed. 100 kg of pods yield 15-33 kg of seeds. A kilogram of seeds contains 60,000 to 80,000 seeds. The seeds if stored in a cool dry place, retain their viability unimpaired for at least 3 to 4 years. Dry seeds are said to keep well for 10 years or more if placed in closed containers at 0.5 to 5°C.

NURSERY TECHNIQUES

This species is generally raised in the nursery in containers i.e. polythene bags and root trainers. Seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds. The nursery soil should preferably be fertile, well-drained loam or sandy loam. The seeds are sown in lines, 15 to 30 cm apart, at a depth of 6-12 mm.

46 *Santalum album* L.

ABOUT THE SPECIES

Santalum album L. belongs to the family Santalaceae, and is commonly known as White or East Indian Sandalwood. The generic name is derived from the Greek '*santalos*' meaning 'sandalwood', and the species name from the Latin '*albus*' meaning 'white', in allusion to the bark. The vernacular names are Indian Sandal wood (English), Safed Chandan (Hindi), Sandal, Chandanan (Malayalam) and Chandanam (Tamil). *S. album* is indigenous to the tropical belt of the Indian Peninsula, Eastern Indonesia and Northern Australia. It grows at an altitude of 600-1200 m, mean annual temperature of 2-38°C, mean annual rainfall is 450-3000 mm. *S. album* grows in a wide range of soils but is most common in sandy or rocky red soil zones. The species is not found on black soil but luxuriant growth is noticeable in moist soils such as garden loam and well-drained deep alluvium. In India, it usually grows on free draining red loams with a pH of 6.0-6.5 and occasionally on sandy soils associated with laterites. Spacing adopted for raising pure plantations is 3 x 3 m; 5 x 5 m. Plantations should strictly be protected from fire. Trees attain exploitable stage (over 15 cm diameter at breast height) in about 30 years, yielding about 50 kg of heartwood, and attain 25 cm dbh in 40 years; such a well-grown tree, including the roots, can yield over 250 kg of scented heartwood. Whole tree harvesting is employed, and both living and dead trees are utilized. Sandal is considered to be a slow growing tree. It grows at the rate of 5 cm girth or more per year under favourable soil and moisture conditions. The heartwood formation starts around ten years of age. The yield of the heartwood varies according to age and locality. As a rule of thumb, each tree adds 1 kg of heartwood to its weight each year after the age of 15 years. On deep rich soils in moist areas, trees grow luxuriantly but the heartwood formation is slow and the oil content is low, while the slower growing trees on difficult sites at elevations between 600-900 m and in rainfall zones of 500-1000 mm develop maximum heartwood with high oil content. A 40 year old tree attains a GBH of 44 cm and gives yield of 20 kg of heart wood.

SEED COLLECTION AND PROCESSING

Good seed is reported from trees over 20 years of age. Seed storage behavior is orthodox. The seeds are viable for 2 years when stored at room temperature (seed longevity declines rapidly at room temperature). However, some study showed that germination of 50% was achieved at the 7th week of storage and the germination rate was zero percent after 28 weeks of storage even under the GA3 treatment. The viability is reduced from 90-15% after 3 years of storage at 7°C with 30-45% relative humidity. Seeds tolerate desiccation to 2% moisture content, and no loss in viability is observed after 16 months hermetic storage at 4°C with 3-10% moisture content. On an average there are 4300-6800 seeds/kg. *Santalum album* seed has a minimum dormancy of 50 to 60 days, and untreated seed does not normally germinate for another 30 days or so. For 80 percent germination, about 7 months may be required. To speed up the germination, various pre-treatments have been tested. The most successful appear to be some form of scarification (removing or nicking the seed coat) or soaking in gibberellic acid (0.05 % GA3 solution for 24 hours). The results of the study conducted in Kerala also indicated that the highest germination percentage (74.33) was observed in treatment of soaking of seeds in 500 mg l-1 GA3 for 24 h.

SEEDLING PRODUCTION

Seed germination and early growth of the seedling in *Santalum album*, a semi-root parasite, is independent of the host but seedling establishment seems to be dependent on the establishment of host contact. Most natural seedlings of sandal



are found growing in the middle of thorny bushes, where the birds have dropped the seeds. *Lantana camara*, commonly found growing in scrub forests in areas suitable for sandal, acts as a good nurse to the seedlings in the early stages. Artificial propagation is easily done by directly dibbling freshly collected ripe seeds in worked up soil patches, with the onset of the monsoon. Seeds can be sown in polythene bags. Fresh seed has a dormancy period of 2 months. Manual scarification or gibberellic acid can break the dormancy. Germination starts within 8-14 days and the germination rate was 70%. Sandal seedlings attain a height of 15-20 cm by planting time and are planted out in the field along with the host plant. Seedling growth is rapid with 20-30 cm obtained at the end of the first year and 60-70 cm at the end of the second year. Root suckers are produced when roots are exposed or injured. The nursery Phase to raise sturdy 30 cm plants is usually 8 months. Primary host species are grown alongside the seedlings in each pot.

VEGETATIVE PROPAGATION

S. album has been propagated vegetatively by tissue culture, branch cuttings and cleft grafting. In general, vegetative propagation methods have not been successful.

47 *Sapindus mukorossii* Gaertn

ABOUT SPECIES

A fairly large handsome deciduous tree belongs to the family Sapindaceae. It is commonly known as reetha, ritha. The species attains a height of 12m, sometimes 20m and a girth of 1.8m. The tree is native to China and Japan and much cultivated in the North India, in the moister tracts along the foot of Himalayas from Ravi eastwards upto 1500 m elevation. The tree is also found wild in the valleys of the north-western Himalayas, Assam and West Bengal. The tree performs best in the moist regions receiving annual rainfall of 1750 mm. The species is very useful for afforesting eroded hill slopes in the Western Himalayas. The tree is extensively planted in Kumaon hills on the field bunds. It is a useful species for growing under agro-silvicultural systems. The timber is used locally for agricultural implements and making charcoal. The tree is mainly cultivated for ornamental and regarded as a cure for epilepsy. Seeds also act as a fish-poison; powdered seeds are considered insecticidal. Fruits contain saponins which can be extracted by boiling the powdered fruits. Soapnuts are used as detergents; also utilized for polishing jewellery, for washing and bleaching cardamoms. Saponin finds application as a textile auxiliary and also as an emulsifier in insecticides. Kernels contain a fixed oil which can be used for soap manufacture, and the exhausted cake as a filler and fertilizer.

SEEDLING PRODUCTION

It can be established by direct sowing, planting out nursery - raised seedlings.

SEED COLLECTION AND STORAGE

Ripe fruits are collected from the ground in January-February, dried in the sun and stored. Gentle cracking of the pericarp release the seeds. The seed retains vitality for one year and to a slight extent for two years. The seed weigh 770-840 per kg. The plant percent is 17 and about 135 seedlings are expected from a kg of seeds.

PRETREATMENT

Owing to hard covering of the seed and slow germination which may commence after three weeks and continues for two to three months; pre treatment of seed is necessary. The seed is filed flat at the "white line" end of the seed till the kernel just becomes visible. The filed seed is soaked in cold water for 24 hours, or buried in a slurry of cow-dung for 2-3 days.

NURSERY TECHNIQUE

Seedlings are most commonly raised in containers i.e. polythene bags and root trainers. Seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds. The germination of the treated seed starts within 10 days and is completed in 2-3 weeks. Germination of such seed is nearly 100 percent. The fresh and larger seeds give better results. Addition of compost in the nursery beds @ 11.11gm/seedling produce better seedlings. Nurseries are well irrigated and weeded. Transplanting can be done in the beds to contain size of tap root. It can also be raised by branch cuttings.

PLANTING TECHNIQUE

Plants reported to be raised by direct sowing show better development than transplants. However, direct sowing is unreliable because of the uncertainty of germination and low germination percent. In the nursery, seeds are sown in March-April. The beds are well watered and fertilized. The seedlings attain 15-20 cm height in the very first rains and are planted out entire at the break of rains. Planting is done in pits of 30 cm³ at a spacing of 5m X 5m to 8m x 8m in block planting. For avenue planting, larger-sized plants are used in pits 6m to 8m apart.



48 *Schleichera oleosa* (Lour.) Oken

ABOUT THE SPECIES

Schleichera oleosa (Lour.) Oken belonging to the family Sapindaceae. It is commonly known as Kusum, the lac tree, the gum lac tree. *Schleichera oleosa* is distributed sporadically from Sutlej eastwards up to Bihar, West Bengal, Central and Southern India. It grows usually at low altitudes, but can be found up to 900-1200 m. It is a medium-sized to large deciduous or nearly ever-green tree, up to 40 m in height, usually with a clean bole of about 6 m in length and a dense and spreading shady crown. It occurs in the tropical wet evergreen, tropical semi-evergreen, tropical moist deciduous and tropical dry deciduous forest. However, in general, it is sparsely distributed. The timber is suitable where hardness, bending strength and toughness are required. It is about 60 percent heavier than teak.

The bole, which is usually crooked and slightly buttressed, can be up to 2 m in diameter, but is usually less. It is a multipurpose tree, supplying food, medicine and a range of commodities for local use. It is occasionally cultivated throughout the tropics, especially in India. *S. oleosa* are tolerant of a range of soil types, so long as they are well drained, but grow best on deep, rich, acid soils that are rich in organic matter. It grows on rather dry to occasionally swampy locations on various, often rocky, gravelly or loamy, well drained, preferable slightly acid soil. It prefers a pH in the range 5.5 - 6.5, tolerates 5 - 7.8.

The treated timber is durable and is suitable for construction, cabinet-work, beams, and sleepers and for wagon building. Leaves, twigs and seed-cake are used as cattle-feed. The tree yields excellent fuel and charcoal. Oil extracted from the seed, called 'kusum oil' is a valuable component of true Macassar oil used in hairdressing, culinary, lighting and in traditional medicine. The tree is an important host for Lac-insect (*Laccifer lacca*) and the finest quality of Lac is obtained from this tree every second or third year called .

SEED HANDLING IN NURSERY:

Seed collection

Collection of ripe fruits starts in the month of July-August. The well ripened fruits are collected from the tree, since fallen seeds are generally damaged by insects or rodents. The best time for collection is when the color of the fruits turns to brownish green and pulp turns yellow and juicy. The moisture content of seed at this stage is as low as 20-25%. As the seeds are liable to be eaten by mammals, protection may be given by nets or guards to the seed bearing trees to avoid damages from wild and domestic animals. The easiest way of collection is to spread a tarpaulin sheet under the tree and by shaking the branches or tree collect the fresh fruits. On an average, a full grown tree yields about 28-37 kg of fruits in one season and a well grown tree can produce about 40 kg of fruits which yields 14-21 kg of de-pulped seed.

Seed Processing and handling

After collection, fruits/pods are sorted according to their maturity (colour). Green fruits with whitish colour seeds are discarded and brownish green fruits with brown seeds will be retained for cleaning. The fruit pulp must be removed before storage, either by hand or by de-pulper. Then the seeds are cleaned on wire mesh in running water. The cleaned seeds are then allowed to dry under sun and cleaned by seed blower or by winnowing to remove the inert materials. Under developed and small seeds are discarded which may invite foreign pathogens and will affect the good quality seeds too.

Seed Storage

The seeds can be stored for long period (more than one year) if stored at low temperature (-20 to 15°C) and at low moisture content (5-7%). The viability is short at ambient temperature (15-46°C) and if moisture content of seed is more than 7%, the viability will be reduced.

Seed Pretreatment before sowing

The seeds need pre-treatment for better and uniform germination. For optimum germination the seeds need to be clipped at the opposite end of the embryo and then soaked overnight in of GA3 with 500 ppm for uniform germination. The pre-treated seeds will give 80-85% germination. Germination starts after 15 days of sowing and completed in 30 days.

Seed Sowing

Freshly treated seeds are sown in thoroughly prepared mother beds in lines spaced about 3 m apart at a depth of 1 cm during the month of July. Seeds can also be sown in the shaded nursery beds or in polythene bags directly. However, nursery-bed raised seedlings notwithstanding the transplanting shock while transplanting to poly bags. Seed should be well covered with soil, as the exposed seed does not germinate. Germination is epigeal. Regular weeding and irrigation are necessary. Seedlings should be protected from livestock and other external enemies. Well grown seedling may be transplanted carefully to poly bags at the second rain without injuring the tap root. In case of long tap root, the same should be pruned down to 15-22 cm length. It is seen that 15-20% mortality may occur during transplanting process. The seedlings require protection from frost in their early stages.

NATURAL REGENERATION

Seed dispersal

Seeds are dispersed by birds, mammals and by natural shedding, therefore, increase in population of these animals favours dispersal.

Reproductive modes

In forest, the tree regenerates by root suckers in addition to through seeds also.

Light requirement

It is a shade-bearing tree. Seeds register better germination in dark (covered by soil). Under open forest (canopy covering 20-40 percent) the germination will be affected due to over light.

SITE REQUIREMENTS

Temperature

Kusum seed germinates best between 25 to 35° C. The temperature regime of its natural habitat varies between 35-47.5°C to 2.5-17.5°C.

Rainfall and humidity

The normal rainfall in its habitat varies from 750 to 2800 mm. The mean relative humidity varies from 40-80% in winter and 60-90% in rainy season.

Soil

The species grows best in well-drained sandy loam or loamy soil having sufficient sub-soil moisture. Lower slopes or undulating land is best for its regeneration as seed germinates best if covered by soil carried by rainwater.

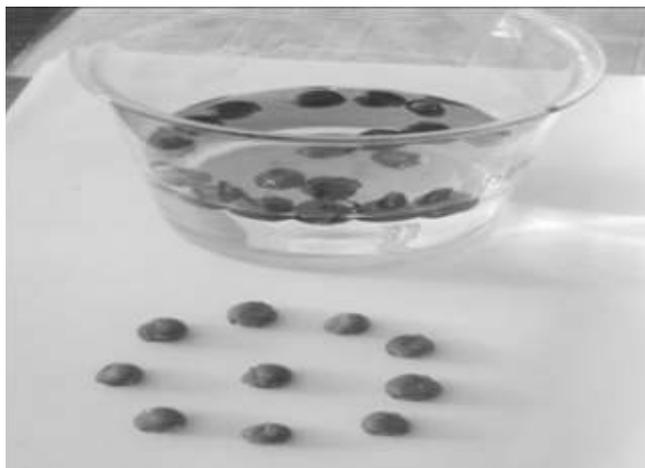


SPECIAL CONSIDERATION

Kusum seedlings need protection from browsing cattle's. Clearing of weeds is necessary and it assists the natural regeneration. Many Kusum seeds are dormant in the first year and germinate in the next year after dispersal through various means. In general, high rainfall, 20-35°C temperature during wet season, loamy or sandy loam soil, undulating lands, dense forest (canopy cover more than 40 percent), and protection from browsing animals will favour natural regeneration of this species.



S. oleosa seed



Scarification of *S. oleosa* seeds



S. oleosa seedlings in the nursery bed

49 *Sesbania grandiflora* Pers.

ABOUT SPECIES

Sesbania grandiflora Pers. is commonly known as agasthi and belongs to the family Fabaceae. It is commonly cultivated for green manure, fodder, as temporary shade and for wind-brake. It is a native of Malaysia and is now extensively grown in many parts of India such as Punjab, Delhi, West Bengal, Assam, South India and the Andamans, It prefers well-drained soil, but can grow on black-cotton soil. It is self-productive where the surface soil is loose and uneven. It cannot tolerate frost. Young pods and flowers are valued for food and leaves are good fodder and have medicinal properties. It is grown as a support for pepper and betel vines, as shade plant for coconut seedlings, as a green manure and as wind-break in banana fields. The wood is used for posts in huts and as a firewood.

SEED COLLECTION

Flowering takes place profusely from September-December and fruits during the hot season. The seeds ripen in April-May. The leaves turn bright yellow in colour before shedding. The seeds weigh 16,000 to a kilogram and are viable for more than one year under ordinary conditions of storage. The seeds should be collected from trees of best form.

NURSERY TECHNIQUE

Seedlings are most commonly raised in containers i.e. polythene bags and root trainers. Seeds are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds. Direct sowing in plantation site is also successful. Although the initial growth rate of bag plants is almost twice as high as that from direct sowing, the latter, with proper soil working and weeding can pick-up with the former by the end of first year and are often preferred on account of low cost. Sowings are done in the beginning of June, with outbreak of rains.



50 *Swietenia mahagoni* (L.) Jacq.

ABOUT THE SPECIES

Swietenia mahagoni commonly known as West Indian mahogany belongs to the family of Meliaceae. The vernacular names are small leaved, West Indian, Spanish or Cubanmahogany (English), caoba (Spanish), madeira (Bahamas) and coabilla (Cuba). *S. mahogany* is a humid zone species, with natural distribution in the Caribbean region (S. Florida, Bahamas, Antilles, Haiti and Jamaica). The species is over exploited in much of its natural area of distribution. It has been extensively planted mainly in Southern Asia (India, Sri Lanka and Bangladesh) and in the Pacific (Malaysia, Philippines Indonesia and Fiji), and has been introduced into cultivation in West Arica. Mahogany grows well on sites receiving mean annual rainfall of 1000-4000 mm with temperature of 15 - 35° C range. Mahogany appears to grow satisfactorily on a wide range of soils from clays to coarse sandy soils. Direct seedling is an effective means of establishing the plantation. 2 or 3 seeds are sown per mound at a depth of about 2 cm towards the end of dry season. This technique is done on drained soils. Thinning should be carried out on a 5-10 year cycle depending on growth rates. For plantations stocked at densities that are sufficient to encourage the development of acceptable tree form and timber quality, a rotation length of 30-50 years is anticipated depending on site quality. The yield tables provide evidence that mahogany plantations can be relatively protective for a hard wood species. If managed correctly the maximum mean annual increment for densely stocked plantation ranges between 10 and 25 m³ ha⁻¹ yr⁻¹ depending on site quality. Low density line plantings have a mean annual increment of only 4-8 m³ ha⁻¹ yr⁻¹.

SEED COLLECTION AND PROCESSING

The fruits are preferably collected from the trees just before they split open. Green as well as brown fruits may contain ripe seed. The centre of the fruit stalk turns brown as the fruit matures. Seeds are mature when they turn dark brown. Mature dry fruits or dry seeds collected from the forest floor can be stored for some days in sacks without significant deterioration, but since the fruits are bulky, pre-processing in the field is often desirable. Depending on maturity, the fruits will split open after 1-4 days of drying. The seeds are easily released by raking or gently shaking the fruits. Fruit parts (valves and columella) are removed by hand. The bulk can be further reduced by manual dewinging. After extraction, the seeds should be dried to a moisture content of approximately 6-7% for short term storage, or down to 4% for long term storage. Storage and viability: Seeds can be stored to several months. Storage at 15°C prolongs viability to 3-6 months. Cold storage (25°C) with 4-5% moisture content extends viability several years. The seeds must be stored in air-tight containers. Dormancy and pretreatment: Pretreatment is generally not necessary but if the seeds stored at low moisture content soaking in water for 12 hours can improve germination.

SEEDLING PRODUCTION

The seeds are sown in a bed of light sand in 3-7 cm deep furrows or holes or directly in containers. Germinating seeds should be under shade and kept moist. Seeds will germinate in 10-21 days. Germination is hypogenous. The seedlings are kept under shade until out planting. The seedlings can be planted in the field when they are about 50-100 cm tall. Soil type: Mahogany seeds have a high fatty content and require more oxygen during germination than starchy seeds. Germination may therefore be faster in well aerated soils. Soil moisture: Seeds requires an abundant supply of moisture. Germination may hence be faster, although soils should not become waterlogged due to risk of de-oxygenating the soils and damping off.

VEGETATIVE PROPAGATION

Mahogany may be propagated vegetatively. Stumps of seedlings and young trees are able to coppice, providing a source of new shoots suitable for propagation by leafy cuttings.

51 *Tamarindus indica* Linn.

ABOUT THE SPECIES

Tamarindus indica L. (Synonyms: *Tamarindus occidentalis* Gaertn. *Tamarindus officinalis* Hook.) belongs to the family Fabaceae. The vernacular names are Indian tamarind, ambli, amli, imli(Hindi), amalika (Sanskrit), tintiri, tintul, tetul (Bengali) chinch, chitz, amli (Marathi), chis, hunchi (Hyderabad), karanji, kamal, asam, hunse (Mysore), hunase, unsi, hulimara (Kannada), pulinje (Coorg), koya, tentuli (Uriya), chita, hitta, sitta (Gond), chinta (Telugu), puli, pulian (Tamil) and tetili (Assam). Most evidence however indicates that Central Africa is the origin of tamarind. Indigenous to the drier savannahs of tropical Africa, from Sudan, Ethiopia, Kenya and Tanzania, westward through Africa to Senegal. Seedlings or clones (grafts) are used for raising plantation. Spacing of 5 x 5 m or 6 x 6 m is followed. Growth of tamarind is normally fast in the early years. The juvenile phase generally lasts 4 to 5 years or perhaps longer. Growth slows down in later years. Mean plant height increases by about 60 cm annually. The average annual growth has been reported as 50 to 80 cm. Young trees should be pruned to allow 3 to 5 well-spaced branches to develop into the main scaffold structure of the tree. In the Philippines, young trees are pruned in the early stages of growth to train 2-3 lead branches and to remove the very low branches, thus developing a desirable frame. Bearing trees require very little pruning other than maintenance pruning to remove dead, weak and diseased branches and water sprouts. In closely planted orchards regular pruning is needed to rejuvenate fruiting wood and control the size of the trees. Trees will begin to bear from the fourth year with a pod yield of 40 kg/tree giving a net profit of Indian rupees 14,000 (US\$ 321.69) per acre. When the trees reach maximum bearing in 10 years, a yield of about 100 kg/tree could be harvested with a profit of 38,000 Indian rupees.

SEED COLLECTION AND PROCESSING

Tamarind is normally grown from seed and grafts. Seeds should be collected from high yielding trees with well-formed, rounded, fully ripe pods, although they may not come true to type due to outcrossing. Under natural conditions the seed pods fall from the trees and the seeds are released following decomposition of the pods.

SEEDLING PRODUCTION

The best medium for seed germination is sand or soil mixed with cow dung. Nursery potting mixture containing three parts of top soil, one part of sand and one part of compost, can be used for germinating tamarind seed. Seeds may be germinated in nursery beds or pots or polythene bags. When grown in nursery beds, the recommended spacing is 20 to 25 cm in both directions. The best germination results if the seeds are covered by 1.5 cm of loose sandy loam or a mixture of loam and sand. If the seeds are planted too deep seedling emergence is delayed and there may be some rotting due to poor aeration. Seeds may be sown in polythene nursery bags provided the bags are deep enough to accommodate the tap root without causing undue distortion. Bag raised seedlings should be planted before they get root bound. If there is a need to delay seed sowing, well dried seeds packed in a polythene bag, can be stored in a refrigerator for about a month. Seedlings grow rapidly in the early stages and produce a long tap root which may reach 30 cm or more within 2 months of germination. Seedlings should attain a height of at least 80 cm before being transplanted to the field at the beginning of the rainy season. Under normal conditions seedlings are large enough to be planted in the field within a year.

VEGETATIVE PROPAGATION

Vegetative propagation is preferable to seed propagation, as seed propagation does not produce true-to-type progenies. Vegetative propagation has the advantage of producing true-to-type progeny which can be taken from



selected, superior, mother trees. Selection through vegetative propagation is a rapid means of improving the quality of the produce to meet the varying demands of diverse commercial markets. Tamarind can be propagated vegetatively by stem cuttings, shield and patch budding or grafting on to seedling rootstocks and air layering or marcotting.

CUTTINGS

The easiest and the cheapest method of propagating tamarind is by stem cuttings. A technique using soft wood terminal cuttings has been developed, and the protocol standardised, by the Forest Research Station at Maddimadugu, Andhra Pradesh, India (Srivasuki *et al.*, 1990). Cuttings of shoots bearing new flushes of fully turgid leaves are collected in the morning. They are immediately dipped for 10 seconds in 1000 ppm of indole butyric acid (IBA), and in 50 % isopropyl alcohol, before being planted in polypropylene tubes containing vermiculite/perlite (1:1) and placed in a mist propagator with 70-80 % humidity. The terminal cuttings have an advantage over mid stem cuttings because there is only one cut end. This reduces the possibility of infection by disease causing organisms during or after the rooting phase.

Soft or semi-soft stem cuttings, 15-20 cm long, taken from 1-2 year old branches can also be rooted (Swaminath *et al.*, 1990). In this method, the cuttings are wrapped in moist cloth after removal from the trees to prevent moisture loss. They are then dipped in a rooting hormone, preferably IBA at 1000 ppm, and placed in a sand bed in a mist chamber. Bud initiation and root formation occurs after about 20 days and new leaves are formed after about 45 days.

BUDDING

Patch budding is normally practiced; for this method seedling rootstocks should be grown in raised beds and budded when they are 6-9 months old. This is a suitable method for large-scale multiplication of tamarind.

GRAFTING

Approach grafting is a very reliable method and up to 95 % success can be obtained (Swaminath and Ravindran, 1989). For veneer grafting, rootstocks about 6 months old and of uniform size should be selected. The scions should be defoliated before grafting. Veneer grafts are made 8 cm height on the root stock and immediately after, the stock is cut above the graft union. This method is reported to give about 50 % success.

For softwood grafting, the rootstock seedlings are defoliated and their tops cut off at 15 cm height immediately before grafting. A vertical downward cut is made in the centre of the cut stem to about 4 cm depth and the scion sticks are cut into wedge shapes, inserted into the stock and wrapped using 2 cm wide 200 gauge polyethylene ribbon. Soft wood grafting was shown to be the best grafting method in terms of successful unions and survival rates (Navaneetha *et al.*, 1990).

LAYERING

Layering is a widely practised propagation method for tamarind. In ground layering, a flexible branch is bent down and pegged to the ground, and the point of contact covered with soil. A small cut is made in the lower side of the stem where it touches the ground to impede sap circulation and encourage rooting. After 3-6 weeks, roots form at the point of contact with the soil and a new plant can be obtained by severing the branch above the place of rooting.

MICRO PROPAGATION

Tamarind may be propagated by tissue culture techniques. Shoot tips, cotyledons and cotyledonary nodes have been used successfully as explants for tamarind tissue culture. The explants were cultured in a MS medium supplemented with thidiazuron (TDZ) / IBA (indole butyric acid) or BA (butyric acid) / NAA and incubated at 28°C for 5 weeks under an 18 hour photoperiod. Although micro-propagation techniques have shown promise, none of them has reached the stage of commercialisation. Tissue culture protocols have yet to be developed and made available for use as an effective tool in the large-scale multiplication and propagation of selected tamarind cultivars.

52 *Tectona grandis* L. f.

ABOUT THE SPECIES

Teak (*Tectona grandis* L. f.) is one of the most valuable timber yielding species in the world, belongs to the family Verbenaceae. The vernacular names are Sagun (Hindi), Thekku (Malayalam), Sagwan (Marathi), Saguan (Kannada), Singuru (Oriya), Tekkumaram (Tamil) and Adaviteeku (Telugu). In other countries it is called as Kyun, Lyiu (Myanmar), Teck (French), Teca (Spanish), Mai Sak (Thailand), Djati (Indonesia) and Fati (Malasia). Teak occurs in natural forests in India, Myanmar, Laos People's Democratic Republic and Thailand. Teak grows well in deep, well-drained alluvial soils, fairly moist, warm, tropical climate with pH ranges from 6.5-7.5. Teak shows poor growth and form on dry sandy soil, shallow or hard pan soil, acidic, laterite, black cotton and waterlogged soils. Teak usually grows in the 800-2500 mm rainfall regime and from sea level to an altitude of about 1200 m. It occurs naturally over a wide range of rain fall i.e. very dry area in which the annual rainfall is less than 900 mm to the very moist areas with the annual rainfall of over 3,500 mm. In the Indian Peninsula, teak experiences maximum temperatures up to 48°C and minimum about 2°C in the dry zone of Central India while in the moist parts of the Southern India (west coast), the maximum and minimum temperatures of teak distribution ranges from 43°C and 13°C respectively. Teak is a light demanding species requiring relatively high light intensity, i.e. between 75 to 100 % of the full sunlight for better growth and development. Planting material consists of stumps, seedlings or tissue culture raised plants. In India stumps are generally used for raising plantation, and it is planted in closer spacing of 2 x 2 m to enhance initial height growth with straight and clean bole. Two mechanical and three silvicultural thinnings performed by the Forest Departments and Forest Development Corporations in India. The interval of thinning cycle is at age of 5, 10, 15, 20 and 30 for 60 year rotation, in Kerala and at ages 5, 8, 16, 20 for 40 year rotation in Maharashtra. After final thinning 150 to 170 trees per hectare are maintained. Generally teak plantations are raised in natural condition without any irrigation, and irrigation is followed only in farmlands. In India the protected irrigation in Maharashtra and the canal bank teak plantations in Tanjore, Tamil Nadu. The MAI of the Nilambur (Kerala) teak plantations ranges from 0.97 to 5.64 m³ ha⁻¹ year⁻¹, and the average productivity is 2.85 m³ ha⁻¹ year⁻¹ in 53 years rotation period.

SEED COLLECTION AND PROCESSING

The fruiting season of teak in India is mostly between Novembers to March. On an average a 40 year old tree produces about 3 kg fruits. The amount of fruit production depends on age of the stand, type of stand, location, edaphic and climatic factors and it is difficult to give exact figures about seed production. A teak fruit contains 4 seeds, but mostly filled with 1 or 2 seeds only. 1 kg of contains about 1,800–2,200 fruits. Teak seeds can be stored for up to two years at around 12 % moisture content and stored in airtight containers. Germination of teak is often poor and sporadic due to some degree of dormancy. Sowing is done directly in the field or in the nursery. Generally germination of teak seed is poor and the germination percentage varies from 30 to 50 % in moist teak and 5 to 10 % in dry teak in India. Optimum moisture content is required for effective germination. Grading of fruits according to size help in improving germination. Teak seed germination increases with increase in size of fruits. In general, moist teak possesses larger-sized fruits and higher seed filling than dry teak. Teak plants are very sensitive to shade, and when there is large variation in germination time, the later germinating seedlings can be shaded to death if they emerge under a large seedling.



SEEDLING PRODUCTION

Seed from dry and moist climates varies greatly in the ease with which it can germinate. Nearly all teak seed however, shows some degree of dormancy, making it difficult to germinate evenly and adequately. The main cause of delay in the germination of teak seed is the thick pericarp, which does not soften sufficiently for the embryo cells to open. Pretreatment of the seed is needed to break this dormancy. One method of achieving this is by alternate wetting and drying of the seed before sowing. Place the seed in a hessian bag and soak the bag in water, preferably in a running stream, for 12 hours. Then spread the seed out in the sun to dry for 12 hours. Repeated this for 10–14 days before sowing the seed into raised germination beds. Raise the beds about 50 cm above ground level by filling with a layer of 5 cm of gravel on the bottom, 35 cm of clean coarse sand in the centre and 10 cm of a 50/50 mixture of peat and coarse sand on the top. Push seeds into this top layer of sand and peat to cover them and water twice a day. It is important not to sow the seeds too deep, as this will hinder germination. Germination starts in 10–15 days after sowing, reaches its peak in 35–45 days and then decreases steadily to 80–90 days. In general, the proportion of the seed that germinates in the first year is about 35%. The un-germinated (but still viable) seeds will still maintain viability and germinate in the following year(s) when conditions are favourable. Such germination behaviour is due to dormancy. The real cause of teak seed dormancy is still unknown; however, three main factors are believed to influence seed dormancy: (1) seed structure, (2) seed maturity and (3) seed biochemistry. Seedlings can be pricked out into containers after germination and grown until they reach 30–40 cm in height. These seedlings should be planted into the field after the first rains. Tissue culture plantlets, although rather costly, have the benefit of superior genetic quality. The initial outlay may be high, but the final crop will be far superior to seedling or stumped stock.

VEGETATIVE PROPAGATION

Planting material can consist of seedlings, stumps or tissue culture. Another method is to plant prepared stumps. The stumps are the root and shoot cuttings. Teak root-shoot or stump is chiefly used as a planting material in Teak plantations. Teak is artificially propagated by stumps. The seedlings are left to grow in the germination beds until they reach about 15–20 mm in diameter, then they are prepared for planting by pruning off both the shoot and root. The teak root-shoot is prepared by cutting one year old healthy seedlings uprooted from the nursery into 15-20 cm root and 2.5 cm shoot portion with more than one cm thickness. Generally 25–50 mm of shoot is retained and about 150–200 mm of the root is left intact. This remaining material is known as a stump and is the most common planting method, because it can be stored for a period of time before planting, and gives more even height when planted in the field. The soil is pressed tightly around the stumps the holes are prepared in slightly slanting position and then planted in the month of June - July at the spacing 2 x 2m or 1.5 x 1.5 m. Tissue culture plantlets, although rather costly, have the benefit of superior genetic quality. The initial outlay may be high, but the final crop will be far superior to seedling or stumped stock.

CLONAL PROPAGATION

The superior teak trees were selected in the plantations based on tree height, GBH, clear bole height, tree form, branching pattern and less incidences of pest and diseases. Generally trees with height of 25 to 30 m with GBH more than 170 cm with clear bole were selected. The trees at the age of 40 to 60 years were selected. The selected trees were felled and the coppice shoots emerged 2 to 3 weeks after felling. Coppice shoots were collected from the selected trees dipped in a fungicide 0.1% aqueous Bavistin 2000 followed by 2000ppm IBA and then planted in root trainers filled with composted coir fibre as rooting media and kept in poly-tunnels at 80 to 90% RH with intermittent misting. The young spouts can also be used from the planted cuttings for rooting. Adventitious root formation occurred in the cuttings within 20 to 25 days after planting. The rooting percentage varies from 74 to 91% in different seasons. April / May was found to be the best month for rooting. The rooted cuttings will be shifted to polythene bags containing soil mixture and hardened and used for planting programme.

53 *Terminalia arjuna* (DC.) Wight & Arn.

ABOUT SPECIES

Terminalia arjuna (DC.) Wight & Arn (Synonym: *Pentaptera arjuna* Roxb. Ex DC.) is the medium to large size evergreen or nearly so riverine tree belongs to family Combretaceae. The vernacular names are Arjuna (Common name), White Murdah, Arjun (English), Kolamarutha / Marudu, Nirmatti, Vellamonda (Tamil), Arjuna, Arjun, Koho (Hindi), Arjuna, Arjunah, Kakubha, Kukubha (Sanskrit), Anjan (Marathi), Erumaddi, Tellamaddi, Tittumaddi (Telugu), Attumaruthu, and Nirmaruthu (Malayalam). It is widely distributed throughout the country including temperate regions of Himalaya except in arid regions. It is common along river streams, ravines and dry water courses in grasslands and forested areas in the sub-Himalayan tract, Peninsular India and Sri Lanka. It tends to be gregarious on flat clayey grounds along streams, while on shallow soils on hill slopes it grows in mixture with other species. It attains largest dimensions on deep rich alluvial soils. It grows in the temperature ranges from 20°C to 33°C, with mean annual rainfall varying from 1000 to 1500 mm. It requires soil pH of 5.0 to 7.0 with low soil salinity of 4 ds m⁻¹. Seedlings are ready for planting out when 2-3 months old with root ball of earth with shoot and root lengths of about 12.5 cm and 30 cm, respectively. Roots of older seedlings become too long for planting out conveniently, and are better made into stumps which also give good results. These are usually prepared from about 15 months old seedlings, and planted in the same manner as the seedlings. For roadside planting, about one year old plants are taken with root balls of earth and planted in the pits 60 cm³. In waterlogged areas, planting is done on central mounds instead of pits. When planted as an avenue tree for shade and ornament, trees are removed only when they become over-mature, unsound or badly damaged. Because of its deep rooting habit, Arjuna does not compete strongly for moisture with shallow-rooted annual crops, so it can grow well in near fields. It is cultivated on farmsteads mainly for feeding Tassar Silk worms and in some places for fodder value and tannin, as its outer bark can be removed for tannin extraction without damaging the tree. Information on growth of Arjuna is scarce and relates only to saplings. Under favourable conditions, seedlings attain a height of 45 cm in one year, and 2-3 m in 3 years. Growth of saplings and poles is fairly fast. Growth is stimulated by regular watering and loosening the soil. Yield of bark for tannin: An Arjuna tree yields 9-45 kg dry bark chips; bark grows again in 2 rainy seasons, hence the tree gives a regular yield of tannin on a 3-year cycle.

SEED COLLECTION AND PROCESSING

Trees start bearing fruits at 6-7 years. A good seed year comes roughly once in three years. Ripe fruits are collected in April to May from the trees, or from ground previously swept clean and stored well for about a year. Weight of fruits varies considerably depending on the source and time of collection. One kg contains about 175-450 fruits. Direct sowing: For direct sowing, the fruits are sown in June to July on the onset of monsoon rains, in a cultivated lines spaced 3.5 to 4.0 m apart. The seeds should be pretreated by soaking them in cool water for 48 hours. Alternatively, the seeds may be soaked in boiling water and allowed to cool. The seeds should remain soaked for 24 hours. The germination rate of pretreated seeds is up to 90%, while that of untreated seeds is 50%-60%.

SEEDLING PRODUCTION

Nursery sowing is done during April to May in lines 30 cm apart, with a spacing of about 5 cm between the fruits. Fruits are lightly covered about half buried in the ground. The fruits are pretreated by soaking in water for 48 hrs and put in shallow



pits until sprouting commences. Treatment with cooling boiled water for 72 to 90 hrs hastens the germination. 50-60 % germination is expected in untreated seeds while treated seeds gave 90% germination. Germination commences within 8 - 12 days of sowing. Germinated seeds may be transplanted in polybags with clay, manure, and sand in equal ratio. Alternatively, the pretreated fruits are directly put in polythene bags in April, with half of the fruit above the soil. Pre-germinated seeds are preferred to save time and ensure uniform germination. The seedlings are sensitive to drought during the germination stage as well as during the growth stage. The number of fruits per kg varies from about 200 to 1200, depending on the size of the fruits. Hence, about 4–10 kg of seeds may be required for raising 1 hectare of plantation at a spacing of 6 m × 6 m. In one study, it is recommended to use only medium and large size seeds for growing, because they do result in higher germination behaviour and seedling establishment.

VEGETATIVE PROPAGATION

In-Vitro Propagation: The shoot explant in MS media supplemented with Kin., 2,4-D and GA3 using the concentration from 1-5mg/L developed along with green calli. The nodal explants was also cultured on MS media supplemented with Thidiazuron (0.5, 1.0 and 2.0mg/L), BAP (2.0, 3.0 and 4.0mg/L), Kinetin (0.5 and 1.0mg/L), Riboflavin (0.5-1.0mg/L) and Bio. (0.1 and 0.5mg/L) resulted early bud breakage (6-8days) and shoot proliferation. In *T. arjuna* the regeneration process is very slow and it depends upon the explants. The percentage of responded explant was significant in callus and shoot proliferation. In another study, it is observed that mature leaf did not respond well; however, juvenile leaf gave good response. Out of various media combination tried, the explant showed callus induction on supplemented medium (MS media) contains 1mg/litre NAA along with 1mg/litre BAP. Callusing was observed after about 4-5 weeks of culture. However, NAA along with BAP was found most suitable for induction & proliferation of callus. It was found that even several repeating subculture of immature leaf explant did not reduce an ability of inducing callus.

54 *Terminalia belerica* Roxb.

Terminalia belerica (bahera) is common throughout the greater part of India except arid regions in western Rajasthan, Punjab and Haryana (Brandis, 1906). It grows scattered in the sub- Himalayan tract while in the Indian Peninsula, it grows chiefly moist valley. It is a characteristics tree of Himalayan sal and east Himalayan moist mixed deciduous forest (Champion and Seth, 1968).

NURSERY TECHNOLOGY

The ripe fruits are collected in March-April. The germinative capacity of the seed is generally low. Weevil attack appears to be partly responsible for this. The storage results, though variable, indicate that the seed keeps well up to about five months (Dent, 1948).

Sowing is done in June –July with the commencement of monsoon rains. The seed is soaked in water for 24 hours to soften the seed coat. Sowing is done in lines about 3m apart. The soil along the lines to be sown is worked well. The seeds are covered lightly. The lines should be kept weeded and bushes likely to shade the seedlings should also be cut. Germination takes about two months to complete. Shade is removed when the seedlings have established. The nursery beds are weeded regularly.



55 *Terminalia chebula* Retz

Terminalia chebula (harad) grows in the sub-Himalayan tract from the Sutlej eastward ascending up to about 1500 m elevation and also in deciduous forest of peninsular India (Brandis, 1906) and Madhya Pradesh (Haines, 1916).

NURSERY TECHNOLOGY

The period of flowering differs with the locality. In North India, it flowers from March to May and in the Himalayas valleys as late as June (Troup, 1921). In Madhya Pradesh, two distinct flowering periods, such as April -May and July - August is reported (Haines, 1916). The tree is a light demander, fire resistant and coppices fairly well (Troup, 1921).

Seed collected from the forest floor and not from the trees is recommended (Troup, 1921). Fruits attacked by insects are rejected. The seed stored well for at least a year and one or two year old seed germinates better than the fresh one (Dent, 1948). Sowing in nursery may be done in July. The fruit stones are sown after removing the hardened fleshy covering. Pre-sowing treatment of the fruit stones may be helpful and their soaking for 48 hours in cold water is recommended. One or two year old plant can be planted out with balls of earth. Planting is done in July–August in pits dug in advance.

56 *Thespesia populnea* (L.) Soland ex Correa

ABOUT THE SPECIES

Thespesia populnea (L.) Soland ex Correa belongs to the family Malvaceae and is commonly referred as Portia tree. The other vernacular names are Gajahanda, Paras-pipal, Parsippu, Bhendi (Hindi); Parisha Sanskrit; Puvarasam, Puvarassu, Poris, Purasia, Pursa, Porsung, Kallal, Karvarachu (Tamil); Gangareni, Gangarava, Gangaravi, Gangaregu, Galgaiovi (Telugu); Poovarasu, Sheelanthi, Pupparrutti, Chandamaram (Malayalam); Asha, Hurvarshi, Huvarsi, Bugari, Arasi and Hoovarasu (Kannada). The species has been planted throughout the tropics and it is naturalized in tropical climates throughout the world. It is a typical coastal species of South Asia, Mrica and the Pacific Islands. It is cultivated occasionally in Central and South America. In India, it is a common species in the coastal tracts of the Indian Peninsula and in mangrove swamps. It is especially common and perhaps wild in South Kanara, Malabar, deltas of Godavari and Mahanadi and in Cuttack. It is also found in the Sunderbans of West Bengal and in Andamans. It thrives well on sandy coastal soils, but also grown on volcanic soils, soils derived from limestone and rocky headlands. It does not grow well in upland acidic clays. It comes up in sands, sandy loams, loams, sandy clay loams, clays, clay loams and sandy clays. It tolerates occasional tidal inundation and saline soils. Preferred soil acidity 6.0 to 7.4. Once established it develops a deep root system and tolerate long periods of drought and it prefers full sun. It is cold sensitive, but can stand mild frosts. Since ancient times, the tree has been planted in home gardens. It is used to stabilize bunds of ponds for prawn cultivation. The species has been used as a living fence post also. It is an excellent windbreak in coastal areas due to its dense crown and tolerance to wind and salt spray. It is being used as a standard for pepper vines. It is regarded as a fast growing species having a height growth of 0.6 to 1.5 m per year in general for the first few years. At an age of 7 to 10 years, growth in height slows down. Stem diameter growth ranges from 1 to 3 cm per year.

SEED COLLECTION AND PROCESSING

Fruits are available nearly round the year. Fruits and seeds buoyant, adapted to long-distance dispersal by tides and ocean currents. 1 to 11 seeds per fruit have been reported. Fertile seeds/ fruit may range from 3 to 5. Germination percent varies from 65 to 80%. Germination begins about 8 days after sowing (may extend to 10 weeks) and the germination is epigeal. The number of seed weight is 6500 per kg. Reports are lacking on seed storage requirements. However, in general it is reported that short-term storage in sealed containers has not been detrimental. Seed may remain viable for 24 months. Refrigeration in sealed containers is recommended for long term storage. Germination can be hastened by nicking / sand paper rubbing followed by soaking the seeds overnight in cool water. Scarifying the seed coat for 20-60 minutes using 95% sulfuric acid followed by 24 hours soaking in tap water was also proved to improve germination.

SEEDLING PRODUCTION

T. populnea is usually propagated by seed, but propagation by stem or root cuttings or by air-layering is also possible. The seed pods are indehiscent, that is the seed pods do not open when mature. The capsules can be opened by hand and the seeds removed. The seeds should be scarified. This can be done using an emery board, sandpaper or nail clippers. Care must be taken to avoid damaging the inner part of the seed. The seeds do not require soaking, but soaking them overnight in warm water may hasten germination. The 1000-seed weight is 140–285 g. Seed storage behaviour is orthodox, retaining viability when dried and stored. Seeds may be sowed and lightly covered in fine sand, well-drained soil or potting mixture. Seeds are normally germinated in germination trays or beds and transplanted into nursery bags later. Around 1 to 1.5 kg of seeds can be used for standard bed. Germination can be difficult due to the hard seed coat, and is improved by scarification with a knife, sandpaper or with concentrated sulphuric acid for 20–60 minutes. Direct



sowing is generally practiced. For plants grown in a nursery, pots must be large enough to accommodate the taproot. Seeds may be pre-germinated before being planted in pots. Germination takes 14-28 days. The plants are normally ready for planting out in 12–16 weeks, but trees up to 3.5 m tall have been planted out successfully from containers.

Seeds may be sown and lightly covered in fine sand, well-drained soil or potting mixture. Seeds are normally germinated in germination trays or beds and transplanted into nursery bags later. Around 1 to 1.5 kg of seeds can be used for standard bed.

VEGETATIVE PROPAGATION

Cuttings are also good way to propagate *T. populnea*. Small cuttings, about 30 cm (1 ft) long will root easily. Although larger cuttings can also be used. Keep the top three or four leaves, apply some rooting hormone, if available. Plant in small container (transparent plastic is great as one can see the roots as they develop). The top can be covered with a transparent plastic bag to keep moisture in and prevent the leaves from desiccating. The cuttings should be protected from direct sun until it is well established. Rooting may take place within a month if conditions are favourable. Stump planting involves cutting back the stem to about 1 cm above the root collar before transplanting, thus allowing the roots to recover before new leaves develop. Wildlings are also collected and transplanted. For vegetative propagation small cuttings should be rooted in a nursery before planting out, but cuttings up to 2 m long have also been successfully planted directly in the field.

57 *Toona ciliata* M. Roem.

ABOUT THE SPECIES

Toona ciliata M. Roem. (synonym: *Cedrela toona* Roxb.) is a large deciduous tree of Meliaceae family having a spreading crown, usually attaining a height of 20-30 m and a girth of 2 to 3m; producing a clean bole upto 9-12 m under ideal forest conditions. It is a fast growing species. It is widely spread in Asia between 15° and 25° N, in India, Bangladesh, Burma, Thailand, Southern China, Indonesia, Malaysia and the Philippines at elevation upto 1500 m above sea level. It is cultivated to a fairly large scale in the plains, around agricultural fields in Uttarakhand and Himachal Pradesh and house compounds in Manipur. It is mainly a tree of sub-tropical climate. The annual rainfall varies from 1100 to 4000 mm. Toon is used for Grade I commercial plywood and Grade I Moisture Proof plywood. It is also used for furniture making, house construction, floors, boardings, panels of doors and windows and also for boats, masts, oars, toys, carvings, musical instruments etc. Bark is bitter, astringent, antiperiodic and used for infant dysentery. Leaves are lopped for fodder in many states.

SEEDLING PRODUCTION

It can be established by direct sowing, entire planting and stump planting.

SEED COLLECTION AND STORAGE

The trees seed abundantly every year. The seeds are collected in May from the trees as the seeds collected from the ground have low percentage of germination. The best time to collect seeds is when fruits turn yellow and a few start opening. The fruits are spread out in the sun for 3-4 days, dried until they start opening, rubbed or beaten with sticks for separation of seeds and winnowed to get clean seed. One kg of fruits give about 200 g of clean seed. The fresh seeds have high germination capacity ranging from 50 to 80 per cent. The seeds can be stored for one year as fresh as in air tight containers at 5°C.

NURSERY TECHNIQUE

Seedlings are most commonly raised in containers i.e. polythene bags and root trainers. Seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds for naked root planting. Seeds are sown thinly broadcast on the raised and shaded nursery beds soon after collection in the month of May. Seed sown under shade gives quick and higher germination. The seed maybe covered with fine earth, or river sand and in no case should be sown deep. The beds are covered with a thin layer of dry grass which should be removed as soon as germination starts. Germination commences in about 8 days and practically over within 15 days. The nursery beds maybe shaded till the seedlings are few centimetres high. No pricking out is necessary if planting is done in the first rains. The transplant should be spaced out at 15cm x 15cm. Watering should be done regularly after the monsoon ceases. The growth of root is faster in sunken beds, therefore, raised beds are preferred. Seedlings attain a height of 90 to 100 cm in 12-13 months when they can be planted out.

For direct sowing, seeds are sown directly in lines 1.8m apart or in thalis 1.8 X 1.8 m, line sowing being preferred to sowing in thalis. Better results are obtained by sowing the seeds without levelling the soil after hoeing as it helps to prevent the



seeds being washed away. As soon as the plants are 8 to 10 cm tall, they should be pricked out and evenly distributed in lines.

Planting entire, with or without a handful of earth around the roots, can be done during the first or second rounds. Cold weather planting when the plants are leafless is also successful. Planting is completed in August in pits 30 cm³ at a spacing of 2m x 2m.

Stump planting is better than either direct sowing or entire planting both from the view of survival rate and height growth. Usually, 1-2 year seedlings are used, keeping 8cm shoot portion and 25cm tap root. The optimum size of plants for preparation of stumps is 1.5 to 2.5cm diameter at collar level. They can be planted in pits of 30 cm³ in the monsoon or in lines cleared through low forest growth to provide the ample side shade. Stumps planted during the rains in July give 90-100% survival. The stumps are used to beat up the failures and fill up the blanks in plantation of other species. The spacing should not be wider than 1.8m x 1.8m due to its tendency to develop branchiness. Stumps should be planted as soon as they are prepared to get the best results.

58 *Ziziphus mauritiana* Lamk.

ABOUT SPECIES

It is commonly known as ber, beri in Hindi. It is a shrub, or sometime a moderate- sized almost evergreen tree which belongs to family Rhamnaceae. The species is found growing naturally in the hotter parts of northern and peninsular India and also in Deccan but absent from the very humid areas of North-East India. The tree is abundant in areas receiving 300-500mm rainfall. The tree spreads to about 1800 m elevation in the sub-Himalayas. The plant is hardy and can grow in dry tropical and sub tropical climates where most other trees fail. The timber is used for agricultural implements, boot and shoe-lasts, shafts, house posts and struts, axe and hoe handles, bedstead legs and poles etc. The fruit is edible and sacred to Hindus. It is used for making sherbat. It is rich source of vitamins and mineral salts. The leaves are lopped for fodder for cattle, goats and camels. Leaves are also used to feed silkworms. The plant is an important lac-host. The species can be planted for shelter belt purposes, sand binding and soil conservation works in arid areas. The branches are much used for fencing.

SEEDLING PRODUCTION

It can be established by direct sowing, planting out seedlings or stump.

SEED COLLECTION AND STORAGE

Young plants of 3years old are reported to fruit. The tree usually fruits well every year producing an abundant crop. The ripe fruits are collected in February-April from vigorously growing trees when they have turned yellow. Seeds are extracted after removal of pulp and dried in the sun before storage for further use in April or May. Seed collected from the floor contain a large number of non-viable seeds (50- 70%). Seed retains viability for at least two years if stored properly, infact the germination of seeds stored for 1-2 years is better than fresh seeds, perhaps due to after ripening. The seeds weigh 1760 to a kg. The germinative capacity and the plant percent is generally high between 31-95 and 27-82% respectively.

PRE TREATMENT OF SEED

After removal of edible fleshy part, the seed should be soaked in cold water for one or two days before sowing. Treatment of seed with conc. sulphuric acid for 45 minutes increases both the germination percentage and the speed of germination. All seeds may be immersed in 20% salt solution, and whatever float should be rejected.

NURSERY TECHNIQUE

Seedlings are most commonly raised in containers i.e. polythene bags and root trainers. Seeded sections of pods are sown either in containers or germination beds. Seedlings from germination beds are pricked out at stage of 2-3 pairs of leaves and transplanted in the containers. Only one seedling is allowed to grow per container. Alternatively, seeds are sown in raised in nursery beds. The treated seeds are sown in the nursery beds either broadcast or in drills 2.5cm apart, in lines 15cm apart in March-April. The seeds are covered with a depth of 2cm soil. The nursery beds should be fully exposed to the sun. Watering and weeding are carried out regularly. Germination takes place between one to two weeks.



The seedlings are ready for planting in the first rain. The seedling maybe transplanted in beds at the 4-leaf stage, spaced 20 X 15 cm until they attain plantable height.

For direct sowing, the thoroughly dried fruits are sown about a month before the commencement of rains, either broadcast or in ploughed or dug up lines. After sowing, the seeds are covered to a depth not exceeding 1-3cm. To ensure quick germination, pre treatment of seed may be done. When grown in conjunction with field crops, the line of seedlings should be kept free of the crops, as the seedlings cannot survive under shade.

For stump planting, the roots of one year old stock are pruned to a length of 2 to 25 cm and shoots to about 7.5cm. For planting seedlings, pits are dug well in advance. Farnyard manure, BHC 10% and fertilizer maybe added in the weathered soil. Plants give out numerous shoots from ground level which have to removed frequently. The plant will be ready for budding in the next season. The agricultural crops can also be grown for 2-3 years. The natural grown trees generally do not yield good fruits. Such trees can be top worked by budding with improved varieties. For top working, the trees are cut back in April-May. New shoots sprout from below the cut end. Strongest shoot alone is retained and others removed. The shoot is ready to receive the bud in July-August. The budding is done by 'T' method. After a year top worked trees start bearing fruits. For cultivating trees for fruit, spacing adopted is 10-12m each way.

VEGETATIVE PROPAGATION

Grafting and budding is practiced to grow improved fruit varieties.

TECHNICAL INFORMATION ON MAJOR PLANTATION SPECIES

Scientific name	Common name	fruit/seed collection time	nursery sowing	planting season	No. of seeds in 1kg	Seed longevity	Germination days	Plant percent
<i>Abies pindrow</i>	Fir, Silver fir	Sept-Nov	Oct-Nov	July	27,200	VSL	40	-
<i>Acacia auriculiformis</i>	Australian babul	Jan-April	March-April	June-July	30,800 to 42,800	MLL	30	59
<i>Acacia catechu</i>	Khair	Dec-March	March-April	July	40,000	MLL	30	45
<i>Acacia nilotica</i>	Babul	April-June	March	June-July	6600 to 11,600	VLL	30	25-75
<i>Acacia senegal</i>	Kumath, gum arabic tree	Feb-March	June-July	July	82,00 to 10,900	LL	30	50
<i>Acer caesium</i>	Maple	July-Oct	Feb-March	Dec-Jan	12,000	VSL	14-28	-
<i>Acrocarpus fraxinifolius</i>	Pink or Cedar tree	April-June	May-June	June-July	32000	MLL	4-21	14-21
<i>Adina cordifolia</i>	Haldu	Feb-June	May	Aug	1,000,000	LL	30	-
<i>Aegle marmelos</i>	Bel	March-May	May-June	July	5,300	SL	21	13
<i>Aesculus indica</i>	Horse chestnut	Sept-Oct	Oct-Nov	July	36	VSL	-	50-60
<i>Ailanthus excelsa</i> Roxb	Maharukh, ardu	May-June	June-July	July-Aug	9,500	VSL	45	20
<i>Albizia lebeck</i>	Siris	Jan-March	Feb-July	July	8,000-13,000	VLL	60	40
<i>Albizia procera</i>	Safed siris	Jan-April	May	July	21,786	VLL	21	51
<i>Anogeissus latifolia</i>	Axlewood (bakli)	March-May	April-May	July	135,800	MLL	15	-
<i>Anthocephalus kadamba</i>	Kadamb	Jan-Feb, Aug-Oct	Feb	June-July	9,32,142-27,21,400	LL	21	-
<i>Artocarpus heterophyllum</i>	Kathal	May-July	June-July	July	4350	SL	21	29
<i>Azadirachta indica</i>	Neem	June-Aug	July	July	3330	VSL	21	29
<i>Bambusa arundinaria</i>	Bans	Feb-July	April	July	75,000-10,05,000	LL	-	37
<i>Bauhinia purpurea</i>	Khairwal	Jan-May	Jan-May	July-Aug	4000-5000	MLL	30	80-95
<i>Bauhinia racemosa</i>	Jhinjhora	Dec-March	April-May	June-July	7000-9000	LL	21	23-70



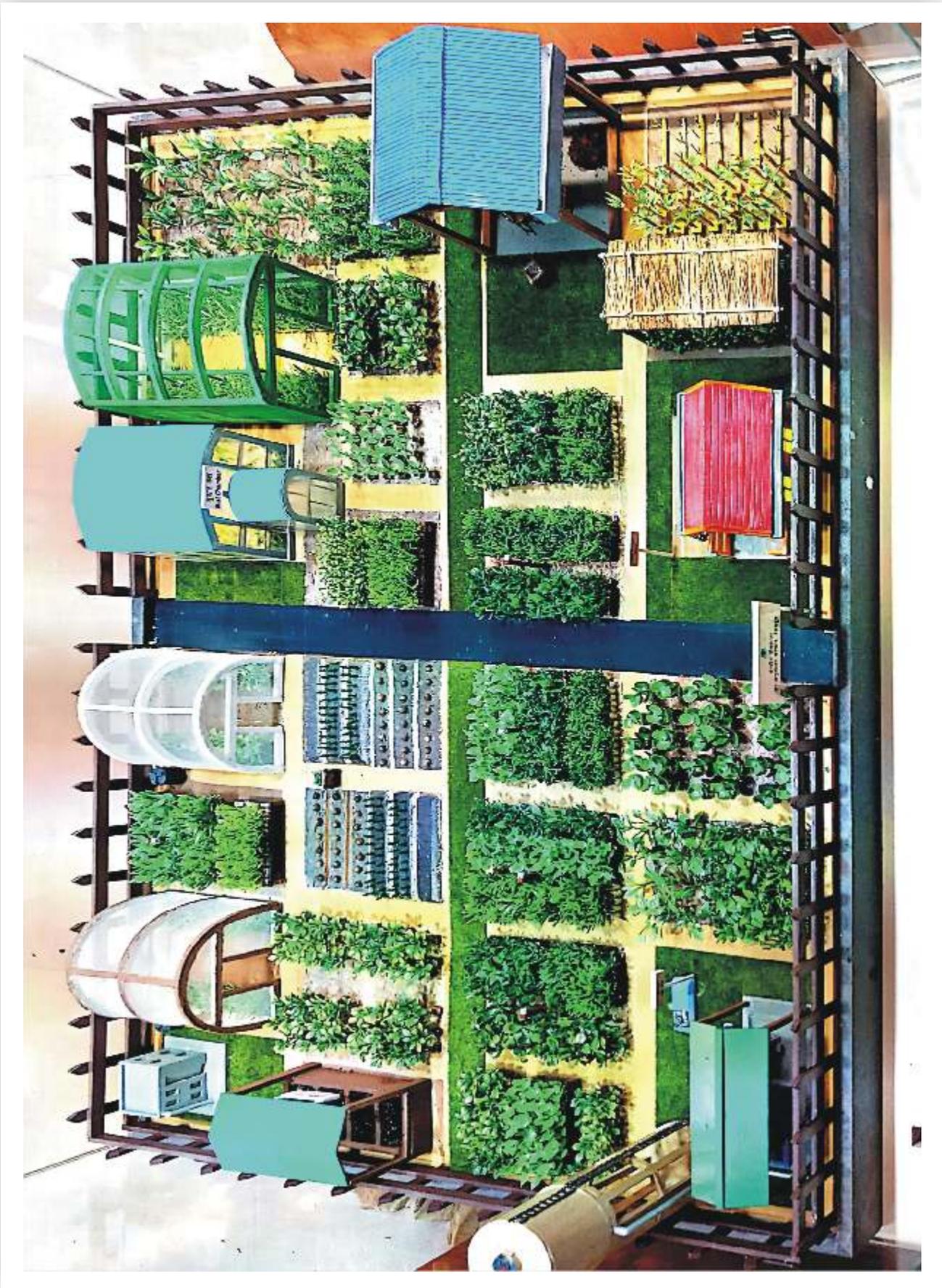
Bauhinia variegata L	Kachnar	May-June	May	June-July	2800-3520	MLL	30	78
Betula alhooides	Bhojpatra	Jan-March	Sept	June-July	1,38,75,000	MLL	56	-
Bombax ceiba L	Semul	March-May	May	Jan-Feb	21430-38500	MLL	25	Jun-31
Boswellia serrata	Salai,salgu	May-June	June	July	15000	-	6-15	45
Buchanania lanzan	Chironji,Char	April-May	May-June	July	4300-5300	LL	15-23	50
Butea monosperma	Dhak	May-July	May	July-Aug	9850-14790	MLL	15	52-80
Cassia fistula	Amaltas	March-April	March-April	May-June	6000-7090	VLL	10-20	12
Cassia javanica	Java Cassia	Dec-April	March-April	May-June	5460-6400	VLL	-	-
Casuarina equisetifolia L	Beaf wood (Sura)	June-Dec	Jan-Feb	June	760,000	LL	3-4	25
Cedrus deodara	Deodar	Oct-Nov	Nov-Dec	Oct, March	7000-9000	VSL	7-10	58
Celtis australis	Kharik	Oct-Dec	Oct-Nov	Sept-Oct	12000	LL	3-4	-
Chukrasia velutina	Chikrassi	Jan-Feb	Jan-Feb	June-July	100,000	MLL	7-10	58
Cupressus torulosa	Himalayan cyprus	April-July	June	July	2,017,86	MLL	90	-
Dalbergia latifolia	Rose wood	Jan-March	March-April	March-April	18500-40,000	S/MLL	21	30-40
Dalbergia sissoo	Shisham	Nov-March	March	July-Aug	53,000	MLL	10-15	65
Delonix regia	Gulmohar	April-June	Sept-Oct	April	2100-3245	VLL	6-30	19-30
Diospyros melanoxylon	Tendu	April-June	March-April	July	880-1410	MLL	90	40
Embelica officinalis	Amla	Nov-Feb	March	March	68000-89,000	SL	30	13
Eucalyptus citriodora	Kala tendu	May-Aug	July	July	786-895	SL	60	-
Eucalyptus tereticornis	Mysore gum	Oct-Nov	Sept-Oct	July-Aug	367,400	VLL	5-15	-
Garuga pinnata	Kharpat	July-Oct	July	Aug-sept	4,000-5,000	MLL	-	-
Grevillea robusta	Silver oak	June	Nov-Dec	July	100,000	LL	22	-
Hardwickia binnata	Anjan	April-May	May-June	July	3,900	MLL	28	31
Juglans regia	Akhrot	Sept-Oct	Nov	Nov-Dec	50-100	SL	35-50	-
Lagerstroemia speciosa	Jarul	Jan-Feb	Feb-March	July	120,000	LL	10-30	-

<i>Madhuca latifolia</i>	Mahua	June-August	July-Aug	July	450	VSL	15	80
<i>Mangifera indica</i>	Aam	April-July	June-July	July	10-237	VSL	30	80
<i>Melia azaderach</i>	Bakain	Jan-Feb	Feb-May	July	759-917	LL	20-40	50
<i>Michaelia champaca</i>	Champa	Aug-Sep	Sept-Oct	June, July, Dec, Jan	15,000	VSL	60	
<i>Moringa oleifera</i>	Sanjna	April-June	June-july	July-Aug	8000-9000	SL	20-30	80
<i>Morus alba</i>	Shahtoot, mulberry	May-June	June	July	4,28,000-4,65,000	VLL	45	-
<i>Ougeinia oojenensis</i>	Sandan	May-June	May-June	July-Aug	28,000-33,000	VSL	30	5-26
<i>Picea smithiana</i>	Spruce	Oct-Nov	Oct-Nov		6300	LL	21	40-70
<i>Pinus roxburghii</i>	Chirpine	Feb-April	April-May	Aug	8,800-12,300	VLL	10-15	65
<i>Pinus wallichiana</i>	Kail, blue pine	Sep-Nov	March-April	July-Aug	19,240	LL	24-27	55-80
<i>Pithecellobium dulce</i>	Jangli jalebi	April	Feb-March	July-Aug	6,700	-	35	50
<i>Pongamia pinnata</i>	Karanj	March-May	July-Aug	June-July	800-1500	SL	30	33
<i>Populus ciliata</i>	Pahadi pipal	June	Aug-Dec	Oct-Feb	1,500,000	VSL	50	-
<i>Populus deltoides</i>	Poplar	June-Aug	June-July	Aug	25000	VLL	-	-
<i>Prosopis cineraria</i>	Sangri, khejri	June - Aug	March	July	27000	VLL	14	25 - 45
<i>Prosopis juliflora</i>	Vilayati babul	May-June & Sep-Dec			12500-30000	VLL	14	87
<i>Pterocarpus marsupium</i>	Bijasal	Dec-April	June	June-July	1590-1940	MLL	56	36
<i>Pterocarpus santalinus</i>	Red sandalwood, Red sanders	Feb-March	May-June	July	1000	MLL	35	-
<i>Quercus dilatata</i>	Moru oak	Sep-Oct	Sep or March	July-Aug	50-60	LL	-	-
<i>Quercus semecarpifolia</i>	Kharsu oak	June-August	July	Aug	90	VSL	-	-
<i>Rubinia pseudoacacia</i>	Kikar, Black locust tree	Sept-Oct	April-May	July	30,000-50,000	VLL	30	-
<i>Santalum album</i>	Chandan	May-Aug & Oct-Dec	Feb-March	July-Aug	7000-10,000	MLL	90	39



Sapindus mukorossi	Reetha, Soap nut	Nov-Jan	March-April	June-July	770-840	VLL	21-90	17
Saraca asoca	Ashok	Sept	Oct	-	-	VSL	-	-
Schleichera oleosa	Kusum, lac tree	July-Aug	June-July	July-Aug	1500-2200	SL	10-90	-
Sesbania grandiflora	Agasthi,bak	April-May	June	July	16000	MLL	15	85
Shorea robusta	Sal	May-July	July-Aug	June-Aug	575-1000(fruits)	VSL	10-28	86
Swietenia macrophylla	Mahogany	Dec-March	March-April	July	2,150	SL	90	-
Syzgium cumini	Jamun	June	June-July	July	1,200	VSL	30	56
Tamarindus indica	Chinch,imili	March-April	April	July	1800	LL	15-20	70
Tectona grandis	Sag,Sagaun,Teak	Nov-Jan	April	July-Aug	1850-3100	LL	16	35-58
Terminalia alata	Larel	Feb-May	April-May	June-July	40-70	LL	25	38
Terminalia arjuna	Arjun	Feb-May	April-May	June-July	775	MLL	12-13	30
Terminalia bellerica	Beheda, Myrobalan	Nov-Feb	March-April	June-July	40-50	LL	30-60	52
Terminalia catappa	Indian badam	June	June-July	July-Aug	18	LL	13	20
Terminalia chebula	Hirda	Jan-March & Dec-May	June-July	July	141-220	LL	90	18
Toona ciliata	Toon	April-June	June-July	July	550,000	SL	10-15	-
Ziziphus mauritiana	Bor	Dec-March	April-May	July	1240-1760	LL	7	27-82

PLATE - 1



Gmelina Plantations (2 years old)

PLATE - 2



Mist Chamber during Misting Operation



Poly Houses



Plants inside a Shade House during Hardening Process

PLATE - 3



Greenhouse having system for control over Temperature, Moisture, Humidity and Air Circulation

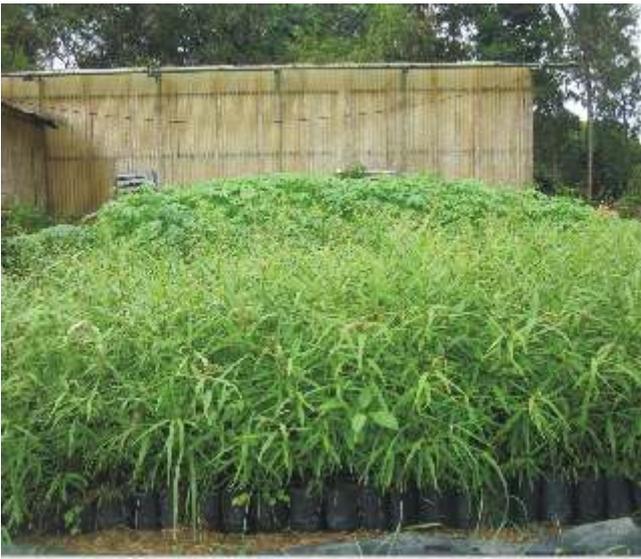


Mother Bed Chamber to Produce Cuttings for Mass Vegetative Multiplication



Net House

PLATE - 4



Seedlings in Polythene Bags



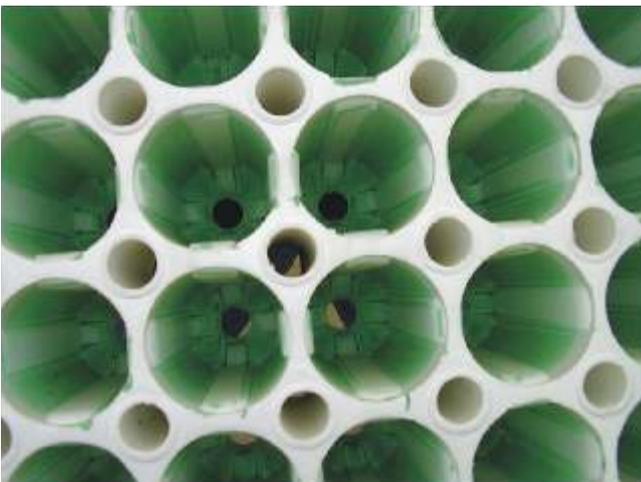
Bigger Containers for Growing Tall Plants



Seedlings in tray-type Root Trainers on Stands



Cup-type individual Root Trainers Placed in Stand



Inside view of a Root Trainer



Fibrous Root system of a seedling from Root Trainer interwoven with Potting Mixture

PLATE - 5



Potting Mixture with Component Sand, Soil and FYM in background



Seedlings from direct sowing in Root Trainer



Germination Box with seedlings ready for pricking out



Seedlings transplanted into Polythene Bags

PLATE - 6



Cuttings planted in vermiculite media in mist chamber for root induction



Culm cuttings of bamboo in open nursery bed



Air layering operation



Air layered shoots severed from mother shoot after successful root induction

PLATE - 7



Preparation of cuttings of poplar in a commercial nursery



Tools for layout of a commercial nursery of poplar



One-year-old entire transplants of poplar for outplanting



View inside commercial nursery of eucalypt



Commercial production of seedlings of *Melia dubia*



A research nursery with wide variety of tree species

PLATE - 8



Seedlings of *Terminalia arjuna*



Seedlings of *Grevillea robusta*



Clonal stock of *Salix alba*



Clonal stock of *Dendrocalamus strictus*



Seedlings of *Dillenia indica*



Seedlings of *Pterospermum acerifolium*



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