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Plantation Forestry and Laboratory Work

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Department of Forestry and Environmental Science
School of Earth and Environmental Science



Uttarakhand Open University
Haldwani, Nainital (U.K.)

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Unit 1: Plantation

Unit Structure

1.0 Learning Objectives

1.1 Introduction

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1.3 Scope and impediments

1.3.1 Economic importance of plantation crops:

1.4 Plantation forests

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1.6 Maps

1.6.1 Characteristics of a map

1.6.2 Types of a Map

1.6.3 Map reading

1.6.4 Utility of forest maps

1.0 Learning Objectives

After completing this unit you shall be able to:

- Define Plantation forest
- Explain scope of plantation
- Explain plantation records and plan

1.1 Introduction

Due to the early abundance of natural forests, large scale plantation establishment only began in the 1960s (Szulecka et al. 2014). Pressure was increasing to reduce the deforestation rate of natural forests, which had become alarming. Plantation forests were, and continue to be, established to satisfy increasing global demand for timber products (FAO 2009, 2010, 2016), and they have the potential to supply the worlds entire wood needs (Fenning and Gershenson 2002; Siry et al. 2005). Modern industrial plantations are usually well managed, produce better quality wood, and have very high growth rates and short rotation lengths, and embrace tree improvement technology (Campinhos 1999). Plantation area increases over the last two decades have been coupled to forestry

industry internationalization and a shift of industrial plantations to the southern hemisphere (Korhonen et al. 2014), thus helping in reducing the pressure on primary forest, modified natural forest (FAO 2016). Due to government promotions and grants, plantation areas have increased in some European countries as well (Assirelli et al 2016).

1.2 Definitions

The term Plantation crops refers to those crops which are cultivated on an extensive scale in a large contiguous area, owned and managed by an Individual or a company. These plantation crops are high value commercial crops of greater economic importance and play a vital role in our Indian economy.

Definition: A group of commercial crops of perennial nature, cultivated extensively in tropical and subtropical situations which need employment of labour through out the year and the produces of which are usually consumed after processing.

Definition in traditional sense – Plantation crops are those which are cultivated on extensive scale like tea, coffee and rubber. Here the term plantation or estate is used synonymously. Estate or plantation means large scale agricultural unit usually of a single crop.

1.3 Scope and impediments

The Scope and impediments of plantations are as follows:

1) Expansion in non-traditional areas: As population and spice crops have restricted geographical distribution, the possibility of expansion in the traditional areas is limited. However, there is ample scope for expansion of area in non-traditional regions such as North Eastern States where there is irrigation potential. Due to the development of drip irrigation technology new area / non-traditional area under plantation crops is increasing.

2) Export potential: Plantation crops earn foreign exchange. Eg. coir based products, coir export and coffee. Main products and by-products not only have export prospects but also have considerable internal demand in several ancillary industries. The plantation crops accounts 27% of earning from export of total agricultural commodities and 4.8% of total export

3) Employment generation: Cultivation of plantation crops provides year round gainful employment on the farm and factories.

4) Crop diversification: These crops provide ample scope for diversification and thereby it creates sustainable agriculture.

1.3.1 Economic importance of plantation crops

- They contribute to national economy by way of export earnings.
- India is the leading country in the total production of certain plantation crops in the world.
- Plantation industry provides direct as well as indirect employment to many millions of people. For instance, tea industry offers direct employment to 10 lakhs and indirect employment to 10 lakh people, while-cashew processing factories alone provide employment to 3 lakhs people besides 2 lakhs farmers are employed in cashew cultivation.
- Plantation industry supports many by-product industries and also many rural industries.
- These crops help to conserve the soil and ecosystem. Tea planted in hill slopes and cashew in barrel and waste lands protect the land from soil erosion during the rainy season or due to heavy winds.

1.4 Plantation forests

Plantation forests can provide most goods and services that are provided by natural forests. These include timber, non timber forest products, protection of clean water and clean air, soil erosion control, biodiversity, esthetics, carbon sequestration, and climate control. Nonetheless, as the value of environmental services from natural forests is higher than that from forest plantations, the demand for conservation of natural forests is stronger. It is possible that a division of land, with some land specialized in timber production and other land in providing environmental services, would produce more forest-related goods and services to society. Because forest plantations grow much faster than natural forests, forest plantations are seen as an increasingly important source of timber supply. Should more forest plantations be developed, more natural forests might be saved.

In FRA 2000 "forest plantations" are defined as those forest stands established by planting or/and seeding in the process of afforestation or reforestation. They are either of

introduced or indigenous species which meet a minimum area requirement of 0.5 ha; tree crown cover of at least 10 percent of the land cover; and total height of adult trees above 5 m.

1.4.1 Types of the plantation

Types of the plantation are as follows:

Industrial Plantations: Industrial plantations are the “arable” crops of forestry; their principal objective is to grow a product, usually wood fiber, efficiently. The main purposes include fuel production—firewood and charcoal, pulpwood for paper and cardboard, panel products, sawn timber (lumber or sawnwood), and sometimes veneers. Commonly one plantation supplies several of these products in the course of a rotation. Of course there will always be other products, whether as other roundwood products such as posts and poles, or non-wood forest products, and benefits such as amenity or even biodiversity enhancement, where a plantation has been established on an impoverished site. But the dominant objective is to grow a commercial product. Industrial purpose dominates management in terms of species choice (usually only one), stocking density, thinning prescriptions, rotation length to maximize financial returns or grow crops to a particular market specification, and clear-cutting silvicultural systems for efficiency of harvest.

Social and Community Plantations and Woodlots :Planting trees is one way of compensating for loss of natural forests as a means of providing domestic products such as building poles, fencing materials, firewood and even leaves for livestock fodder. It was widely promoted in the 1970s and 1980s in countries of the African Sahel, in India, and elsewhere in usually the drier tropics, but was not always successful. Sometimes choice of species was poor, sometimes tenure and ownership of land, or even the planted trees, were unclear, but commonly the problems lay in a failure to involve the local community or village adequately in the decision-making process. Woodlots were foisted on communities rather than being their initiatives to help in local wood supply.

Tree planting for social and community needs are now embraced as part of rural development forestry, and are subject to participatory processes to place them firmly in local people’s control. In India, these are sometimes termed as “Communities of Protection,” in the Philippines they are termed community based forest management (CBFM), while in Ethiopia many planting projects begun as food-for-work initiatives during

the 1980s famine have become a village resource. Collectively these kinds of plantation projects often form part of joint forest management (JFM) initiatives.

Center for International Forestry Research (CIFOR), 2001 divided plantation types in following categories:

Plantation type and purpose	Characteristics
Industrial plantation: timber, biomass, food	Intensively managed forest stands established to Provide material for sale locally or outside the immediate region, by planting or/and seeding in the process of afforestation or reforestation. Individual stands or compartments are usually with even age class and regular spacing and of introduced species and/or of one or two indigenous species. Usually either large scale or contributing to one of a few large-scale industrial enterprises in the landscape.
Home and farm plantations: fuelwood, timber, fodder, orchards, forest gardens and other	Managed forest, established for subsistence or local sale by planting or/and seeding in the process of afforestation or reforestation, with even age class and regular spacing. Usually small scale and selling, if at all, in a dispersed market.
Agroforestry plantation: fuelwood, timber, fodder	Managed stands or assemblages of trees established in an agricultural matrix for subsistence or local sale and for their benefits on agricultural production; usually regular and wide spacing or row planting.
Environmental plantations: windbreaks, soil protection and erosion control, wildlife management, site reclamation or amenity	Managed forest stand, established primarily to provide environmental stabilization or amenity value, by planting or/and seeding in the process of afforestation or reforestation, usually with even age class and regular spacing.
Managed secondary forests with planting	Managed forest, where forest composition and productivity is maintained through additional planting or/and seeding.

Source: adopted from CIFOR, 2001

1.5 Planting plan

A planting plan is a construction document that shows the location, quantity, and other characteristics of vegetation to be planted in the landscape. It should be easy to read and understand. planting plan should include:

- A description of your objectives
- A map of the property and a site description

- Detailed plans for site preparation
- The number of trees required by species
- Planting arrangement and tree spacing
- Plans to control unwanted vegetation

1.5.1 Major objectives of planting plan

You may want to plant trees to:

- Improve the environment
- Increase the value of your property
- Provide a treed space for recreation
- Produce wood products such as lumber or fuel, or specialized crops like christmas trees or nuts
- Prevent soil erosion by wind or water
- Provide habitat and food for wildlife
- Conserve energy

1.5.2 Planting process

Planting plan includes the following steps:

- 1) **Choice of the species:** There are many broadleaf tree and shrub species available through MNR and private nurseries to help to meet your objectives.
 - To improve the availability of food for birds and other wildlife, fruit bearing shrubs should be planted.
 - For wildlife cover consider a plantation of cedar, spruce, or pine. These species will provide excellent cover for small animals such as rabbits in less than ten years, and winter cover for larger animals such as white-tailed deer in 30 to 40 years.
 - Valuable forest products such as veneer logs and sawlogs may also be produced from numerous hardwood species. But hardwoods are much more sensitive than conifers to competition from weeds and grasses. Be prepared to control all weeds before planting and for several years after planting.
 - Poplar, cedar, white spruce are good choices for windbreaks.

- 2) **Planting arrangement:** Planting trees in relatively straight, equally spaced rows provides tractor access for mowing, spraying or other operations. Allow a minimum of 2.4 m (8 ft) between rows. Trees of different species seldom grow at the same rate on the same site. Often one species will outgrow and eventually eliminate the other. If you wish to plant a mixture of species, plant each species in approximate squares or circles of no less than 20 trees. This will ensure that some trees in the centre of each cluster will not be overgrown by faster growing neighbors.
- 3) **Spacing:** If forest products are your primary objective, spacing and arrangement are critical to maximizing growth and yield of your trees. For example, you may wish to establish sugar maples in an orchard for the production of maple syrup. Such an orchard should be planted with 10 m (30 ft) between trees to encourage the development of deep, large crowns essential for maximum sap production.
- 4) Plant conifers for sawlog and pulp production in rows that are a minimum of 2.4 m (8 ft) apart. The trees should be planted within the row at 1.8 m (6 ft) spacing. This will result in a plantation of 2,300 trees per hectare (900 trees per acre). Hardwoods should be planted in rows 3 m (10 ft) apart, but with only 1.5 m (5 ft) between trees.
- 5) **Planning site description**
 - (i). **Map:** The best way to appreciate the site conditions is by making a thorough inspection of your planting site. A good first step is to prepare a sketch of your site. On the sketch, indicate the orientation of the site using a north arrow. Also show the location of the access routes, buildings and any relevant boundaries such as fences or edges of woodlots. Power line corridors and other areas which should not be planted should also be shown on your map. Note the lay of the land. Show any steep slopes or other obstacles that may be a problem for equipment.
 - (ii). **Soil characteristics:** Each tree species is adapted to a specific range of site conditions. To choose the appropriate species for your planting site you should be aware of the soil texture and drainage. To inspect your soil, use a shovel and sample the soil at different locations across your planting site. Trees cannot be successfully planted everywhere. Extremely shallow soils over bedrock are very

susceptible to drought, depriving trees of essential moisture. Soils that are flooded for prolonged periods deprive tree roots of oxygen. Avoid sites with less than 30 cm (1 ft) of soil over bedrock or sites where the year-round water table is very close to the surface.

(iii). Present vegetation: While inspecting the soil conditions on your site, also take note of the vegetation growing there. Take note of grasses, broadleaf weeds and woody shrubs that will compete with your trees for moisture, nutrients, light and space. Too much competition will reduce the growth of your seedlings or even cause them to die. Tall grass and weeds, weighted down by snow, can crush young seedlings. Thick vegetation is also ideal habitat for rodents that will feed on the bark of your seedlings during winter months.

(iv). Site preparation: Like vegetables in your garden, tree seedlings will benefit from the removal of competing weeds and preparation of the soil prior to planting. Refer to the Extension Note: Clearing the Way: Preparing the Site for Planting for help in planning appropriate site preparation for your site.

Your work has not done work accomplished after putting the trees in the ground. You should be prepared to inspect the plantation several times per season to check for weed and insect problems. In addition, you may have to spend some time controlling weeds around your new trees in order to ensure their survival.

1.5.3 Plantation records

In India, most of the state governments carry out surveys of plantations established in their state mainly to assess the survival percentage (in a few cases diameter and height growth are also measured) through their own monitoring and evaluation unit on peace meal basis. At national level only one survey has been carried out to assess the survival rate covering five representative states (Gujarat, Karnataka, Tamil Nadu, West Bengal & U.P. States: (IIP0 1989) (India has 25 states and 7 union territories). The results for some of the available studies are presented below.

The purpose of the survey was to provide an estimate of the survival rate of trees planted under different afforestation schemes in India during the last five years (from 1983–84 to 1987–88). National Wastelands Development Board, an organization under the Ministry of Environment, and Forests of the Government of India entrusted the task to an

autonomous body - the Indian Institute of Public Opinion. The survey was based on a sample of 10,000 interviews equally distributed among the five states and using a structured questionnaire designed to collect the necessary information. About 80% of the sample interviews were from individuals involved in agroforestry and 20% were from plantations raised by forest departments. In India about 50% of the plantations currently established are in the agroforestry environment and the remaining 50% were established by forest departments. Therefore, sample distribution was not proportional to the area. Based on the survey the following results were obtained:

Table 1. Results (survival percentage)

Location	All plantations	Only Agroforestry
Gujarat	63.64	43.67
Karnataka	79.39	61.60
Tamil Nadu	60.57	52.92
U.P.	60.69	70.42
West Bengal	67.56	69.88

Table 2: Derived Results

Location	Reported area (ha)	Net area (ha)	Success %
Gujarat	345,475	219,860	63.6
Karnataka	400,747	318,153	79.4
Tamil Nadu	255,410	154,676	60.6
U.P.	641,685	389,438	60.7
West Bengal	196,104	132,488	67.5
Total	1,839,421	1,214,615	66

- These five states cover about 37% of the total planted area in India during that period.
- Reported plantation area of the states concerned during 1985–86 to 1987–88 was extracted from the National Wasteland Development Board, Government of India report.

1.6 Maps

Map is a representation of the whole or part of the earth's surface in miniature. It is very useful. It is an outline, a plan or a diagram that can guide you in geographic place. The main objective is presentation of the information on forest resources of the country at state

and district level and to prepare forest cover maps on 1:50,000 scale. The first assessment in 1987 was done visually on 1:1 million scale. Thereafter, up to 1999 the assessment was done on 1:250,000 scale. On this scale, the country was covered by 363 top sheets of SOI. To enrich the information on forest cover and to make it more useful, assessment on 1:50,000 scale is desirable and has been taken up since the 2001 assessment for the forest cover assessment to be done on 1:50,000 scale, the quantum of work increase manifold as the country is covered by 5,200 sheets on this scale. However, the application of DIP reduces the time taken in interpretation significantly.

1.6.1 Characteristics of a map

- (i). All objects in the map are in the same relative position as on the ground.
- (ii). All angles between the lines drawn on the map are equal to the angles between corresponding lines on the ground.
- (iii). Each map has specific scale.
- (iv). Information in the map is depicted in the form of signs or symbol.

1.6.2 Types of a Map

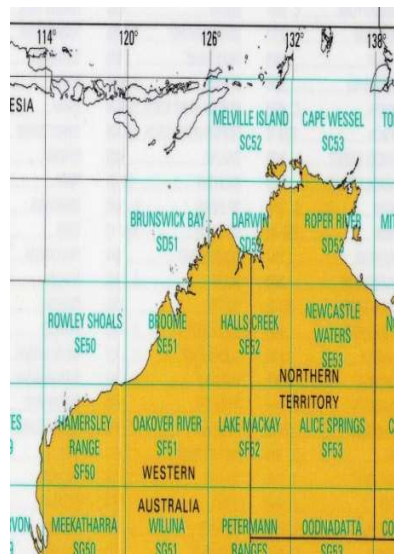
- There are many different types of maps, which are usually classified according to what they are attempting to show. However, it must be noted that there are many different ways to interpret the types of maps. One common point of view is that there are two main types of maps
- Those, which summaries the actual landscape (topographic and general reference maps), those, which describe/comment on specific features using the landscape as a background or for context (all other maps – usually called thematic maps).

Forest Survey of India assesses the forest cover mapping of the country on a two-year cycle using satellite data. The main objective is presentation of the information on forest resources of the country at state and district level and to prepare forest cover maps on 1:50,000 scale. First assessment of forest cover of the country was made in 1987 and thereafter eight more assessments have been made. District wise information on forest cover has been made available from the third assessment (i.e. from 1991) onwards.

(i). **General Reference (sometimes called planimetric maps):** These are simple maps showing important physical (natural and man-made) features in an area. Their main purpose is to summarise the landscape to aid discovery of locations. They are usually easy to read and understand. Most of the early mapping of the Earth falls into this group. Street and tourist maps are good examples of general reference maps.



(ii). **Topographic Maps:** Topographic Maps are a summary of the landscape and show important physical (natural and man-made) features in an area. The primary difference is that they show elevation in detail.



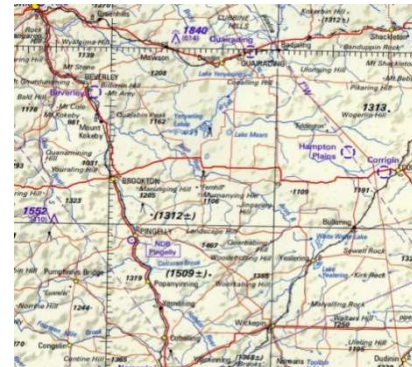
- They show elevation using contour lines.
- They have an emphasis on showing human settlement (roads, cities, buildings etc), but may include some thematic information such as vegetation or the boundaries of national parks
- They are typically produced by government agencies
- They have well defined standards (called specifications).
- They have very good location reference systems –i.e. Latitude and longitude, but may also have grid lines.

(iii). **Thematic maps:** These are maps which depict information on a particular topic or theme. The detail portrayed on a thematic map may be physical, statistical, measured, or interpreted, and



sometimes requires specialist knowledge by the map user. Weather, population density and geology maps are examples of thematic maps.

(iv). **Navigation Charts:** Navigation Charts combine aspects of topographic, general reference and thematic maps and are produced as navigation aids for ships, boats and aircraft. Specialist knowledge is usually required to read charts. These are also produced by government mapping agencies:



- Marine navigation charts are usually produced by a country's Navy and possibly also by civil defense bodies and/or port management authorities
- Air navigation charts are usually produced by a country's Airforce plus a civilian agency which is responsible for civilian air traffic control.

(v). **Cadastral Maps and Plans:** Cadastral mapping is one of the best known forms of mapping, because it is the mapping that shows all of the land parcels in relation to one another and to adjoining roads. It is also one of the most ancient forms of mapping – for example ancient Egyptians are known to have developed cadastral records so that land ownership could be re-established after the annual flooding of the Nile River.



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Till the fourth assessment interpretation of data for the entire country had been done visually. During fifth and sixth assessment interpretation of data for Madhya Pradesh and Maharashtra which comprises 28% forest cover of the country had been done digitally and for rest of the States/UTs, it had been done visually. In seventh assessment interpretation has been done digitally for thirteen states namely; Andhra Pradesh, Arunachal Pradesh, Assam, Delhi (UT), Himachal Pradesh, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, which comprises 63% of the forest

cover of the country. By eighth assessment the entire country was covered by digital assessment (Table 3).

Table 3. Assessment by FSI

Cycle of Assessment	Year	Data Period	Sensor	Spatial Resolution	Scale	Minimum Mapable Unit (ha)	Mode of Interpretation
First	1987	1981-83	LANDSAT-MSS	80 m	1:1 million	400	Visual
Second	1989	1985-87	LANDSAT-TM	30 m	1:250,000	25	Visual
Third	1991	1987-89	LANDSAT-TM	30 m	1:250,000	25	Visual
Fourth	1993	1989-91	LANDSAT-TM	30 m	1:250,000	25	visual
Fifth	1995	1991-93	IRS-1B LISSII	36.25 m	1:250,000	25	Visual & Digital
Sixth	1997	1993-95	IRS-1B LISSII	36.25 m	1:250,000	25	Visual & Digital
Seventh	1999	1996-98	IRS-1C/1D LISS III	23.5 m	1:250,000	25	Visual & Digital
Eighth	2001	2000	IRS-1C/1D LISS III	23.5	1:50,000	1	Digital
Ninth	2003	2002	IRS-1D LISS III	23.5 m	1:50,000	1	Digital
Tenth	2005	2004	IRS-1D LISS III	23.5 m	1:50,000	1	Digital
Eleventh	2009	2006	IRS-P6-LISS III	23.5 m	1:50,000	1	Digital
Twelfth	2011	2008-2009	IRS-P6-LISS III	23.5 m	1:50,000	1	Digital
Thirteen	2013	2010-11	IRS-P6-LISS III IRS-Resourcesat-2 LISS III	23.5 m	1:50,000	1	Digital
Fourteen	2015	2013-14	IRS P6 LISS III IRS-Resourcesat-2 LISS-III	23.5 m	1:50,000	1	Digital
Fifteen	2017	2015-16	IRS-Resourcesat-2 LISS-III	23.5 m	1:50,000	1	Digital
Sixteen	2019	2017-18	IRS-Resourcesat-2 LISS-III	23.5 m	1:50,000	1	Digital

1.6.3 Map reading

Map reading refers to the process of obtaining information from a map. The interpretation or reading of map needs following prerequisites:

- (i). Orientation of the map is known so that actual direction on the ground is predicted while traversing in a ground. It helps in finding of one's ground position on the map. It is required for determining directions of places, objects, etc.

(ii). Scale of the map is the ratio of a unit distance on the map to the corresponding distance on the ground. This helps in knowing the distance between the two points in ground.

(iii). Conventional signs depict the information of different objects in the map. If the map reader can't know signs properly, he will not get the correct information from the map.

The Survey of India (SOI) have standardised a set of conventional signs and symbols to be used in topographical maps.

Seven colours are commonly used in the maps of Survey of India.

Black - All writings on the map except grid numbers (names, abbreviation such as DB, RS, PO), river banks, broken ground, dry streams, surveyed trees, heights and their numbering, railway lines, telephone and telegraph lines, lines of latitude and longitude, all boundaries, any written amplification (such as 'open scrub', 'metalled road under construction', 'meter guage' are given in black.

- **Brown** - Contour lines, their numbering, form lines, sand features and barren rocky areas such as hills and dunes are represented in brown.
- **Blue** – Blue colour is used to show water features or water bodies (Rivers, Lakes, ponds, tanks, wells, etc.,)
- **Green** - Wooded and forested areas shown as green wash, orchards, scattered trees and scrubs shown by green symbols.
- **Yellow** - Cultivated areas are shown as yellow wash.
- **Red** - Grid lines (East and North) and their numbering; roads, cart track and foot path, settlements, huts and buildings are shown in red.
- **White patches** - Uncultivated land and glaciated and snow covered areas in mountains. (Figure 1)

1.6.4 Utility of forest maps

- Maps helps the undertaking a forest survey.
- It establishes a pattern of ground sampling.
- It helps the field staff to locate the areas selected for sampling.
- It act as a base maps for many other map preparations.
- It helps laying out a annual coupes.

- It helps identification of plantations inside the forests.
- It helps in laying out forest roads.

Roads, metalled : according to importance; distance stone	
Roads, unmetalled : according to importance; bridge	
Cart-track, Pack-track and pass. Foot-path with bridge	
Streams : with track in bed; undefined. Canal	
Dams: masonry or rock-filled; earthwork, Weir	
River dry with water channel; with islands and rocks. Tidal river	
Swamp, Reeds	
Wells : lined; unlined. Spring. Tanks : perennial: dry	
Embankments : road or rail	
Railway, broad gauge : double; single with station; under construction	
Railway other gauges : double; single with distance stone; under constrn. Light Railway or tramway, Telegraph line. Cutting with tunnel	
Contours, Cliffs	
Sand features (1) flate (2) sand hills (permanent) (3) dunes (shifting)	
Towns or Villages : inhabited ; deserted. Fort	
Huts : permanent; temporary. Tower Antiquities	
Temple. Chhatri. Church. Mosque. Idgah. Tomb. Graves.	
Lighthouse, Lightship. Buoys : lighted ; unlighted. Anchorage	
Mine. Vine on trellis. Grass. Scrub	
Palms : Palmyra; other. Plantain. Conifer. Bamboo. Other trees.	
Boundary, international	
Boundary, state : demarcated; undemarcated	
Boundary, district : subdivision, tahsil or taluk; forest	
Boundary, pillars : surveyed; unlocated; village trijunction	
Heights, triangulated : station; point; approximate	
Bench-mark : geodetic; teritary; canal	
Post office. Telegraph Office. Combined office. Police station.	
Bungalows; dak or travellers; inspection. Rest-house	
Circuit house. Camping ground.	
Forest : reserved: protected	

A number of methods have been used to show the relief features of the Earth's surface on maps, over the years. These methods include hachure, hill shading, layer tints, benchmarks and spot heights and contours. However, contours and spot heights are predominantly used to depict the relief of an area on all topographical maps.

Figure 1: different conventional signs and symbols

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UNIT 2: Seed Source and Seedling Establishment

Unit Structure

2.0 Learning objectives

2.1 Introduction

2.2 Seed biology

2.3 Importance and Characteristics of Seed Structures

2.4 Seed source

2.5 Stand and Seed Orchard

2.6 Seed Collection

2.7 Seed Extraction and Processing

2.8 Seed Storage and Testing

2.9 Seed Testing

2.10 Seed Germination

2.11 Germination Percentage and Tree Seedling Establishment

2.0 Learning objectives

After completing this unit you shall be able to:

- Define Seed biology
- Explain the process seed collection, extraction, storage and germination
- Explain seed orchard and establishment of seedling

2.1 Introduction

The quality of seed alone is known to account for at least 10-15% increase in the productivity (ICAR 1993). However, lack of quality seed continues to be one of the greatest impediments to bridging the vast yield gap. Therefore, to approach the potentially realizable yield of a cultivar, production and distribution of quality seed is essential. The good quality seed should have the following characters:

- Genetic purity, and uniformity and should conform to the standards of the particular cultivar.
- Disease free, viable seeds.
- Free from admixtures of other crop seeds, weeds and inert matter.
- Acceptable uniformity with respect to size, shape and colour.

Two principal groups of seed producing plants are Angiosperms and Gymnosperms.

(A) Gymnosperms: These are characterized by producing their seeds exposed i.e. not enclosed in a fruit. The term 'gymnosperms' means naked seed. These are represented in the north temperate regions by the pines, spruces, hemlocks, cedars and other evergreens. Many of them bear their seeds in cones and none of them has conspicuous flowers.

(B) Angiosperms: These have developed flowers and produce their seeds in an enclosed structure, which is called the fruit. The term 'angiosperm' means enclosed or hidden seed. The members of this group are very numerous and embrace all the well-known flowering plants. The angiosperms are further subdivided into monocotyledons and dicotyledons.

(i) Monocot seeds / Monocotyledons: The seeds of monocots are single seeded embedded in a fruit called caryopsis, utricle etc. The seed coat and fruit coats are fused as pericarp. The embryo is minute and confined to one end of the seed and is viable with $2n$ number of chromosomes.

The storage tissue is known as endosperm and is nonviable with $3n$ number of chromosomes and occupies the major portion of the seed. The embryo consists of radical and plumule which are enclosed in coleorhizae and coleoptiles respectively. The single cotyledon is known as scutellum. Aleuronic layer is a protein body, which remains at the periphery of the endosperm. It helps in absorption of water and releasing enzymes, which helps in germination. Monocot seeds are known as albuminous / endospermous seeds.

(ii) Dicot seeds / Dicotyledons: The dicot seeds consist of primary axis and a living storage tissue, the cotyledons which combine the embryo of the seed. This embryo is enclosed in the seed coat. Mostly dicots do not have endosperm which is fully utilized for the development of embryo. Sometimes they have well developed endosperm (castor, fenugreek) and mostly they are exendospermous or exalbuminous in nature (legumes). In some cases perisperm which is the remaining, unutilized portion of nucellus is also seen in dicot seed (eg) pepper.

2.2 Seed biology

Seed is defined as fertilized, matured ovule consisting of an embryonic plant together with a store of food, all surrounded by a protective coat. A **seed** (in some plants, referred to as a **kernel**) is a small embryonic plant enclosed in a covering called the seed coat, usually with some stored food. It is the product of the ripened ovule of gymnosperm and angiosperm plants which occurs after fertilization and some growth within the mother plant. The formation of the seed completes the process of reproduction in seed plants (started with the development of flowers and pollination), with the embryo developed from the zygote and the seed coat from the integuments of the ovule.

2.2.1 Components of Seed

(i) **Seed coat:** It is the outer covering of seed. It develops from the two integuments of ovule. Outer layer of the seed coat is known as the testa and is formed from the outer integument. The inner layer of the seed coat is called the tegmen and is formed from inner integument.

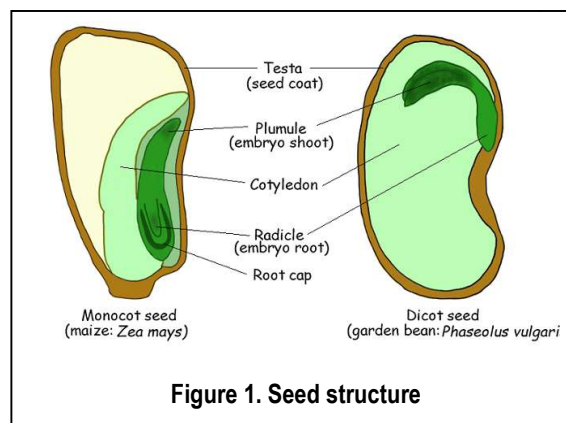


Figure 1. Seed structure

(ii) **Embryo:** It is the mature ovule consisting of an embryonic plant together with a store of food, all surrounded by a protective coat, which gives rise to a plant similar to that of its mother. It is a miniature plant consisting of plumule, radical and cotyledon. The plumule and radical without the cotyledon is known as primary axis.

(iii) **Radical:** Rudimentary root of a plant compressed in the embryo is the radicle which forms the primary root of the young seedlings. It is enclosed in a protective cover known as coleorrhiza.

(iv) **Plumule:** It is the first terminal bud of the plant compressed in the embryo and it gives rise to the first vegetative shoot of the plant. It is enclosed in a protective cover known as coleoptile.

- (v) **Cotyledon:** Cotyledons are the compressed seed leaves. A single cotyledon (Scutellum) is present in monocots while two cotyledons are present in dicots, hence they are named as monocots and dicots, respectively. In dicots they serve as storage tissue and are well developed, while scutellum is a very tiny structure in monocots.
- (vi) **Endosperm:** Endosperm develops from endosperm nucleus, which is formed by the fusion of two polar nuclei and one sperm nucleus. It stores food for the developing embryo.

2.2.2 Appendages of Seeds

Some seeds will have appendages that are attached to the seed coat. They vary with kind of seed. The appendages sometimes help in dispersal of seeds or in identification of genotypes. Some of the appendages are awn, hilum, caruncle, aril, hair and wings.

- (i) **Awn:** The thorns like projection at tip of the seeds. (e.g) paddy- the bract tip is elongated into the awn.
- (ii) **Hilum:** It is the scar mostly white in colour present on the lateral side of the seed. It represents attachment of the seed stalk to placenta of the fruit to mother plant e.g pulses.
- (iii) **Micropyle:** The point where the integuments meet at the nucellar apex is referred as micropyle.
- (iv) **Chalaza:** A region of integumentary origin and attachment opposite to micropyle is called chalaza.
- (v) **Raphe:** The area between the micropyle and chalaza is the raphe. The raphe may be visible on the seed coat of some species.
- (vi) **Caruncle:** It is the white spongy outgrowth of the outer integument in the region of the micropyle seen in some species e.g. castor, tapioca.
- (vii) **Aril:** It is the coloured flesh mass present on the outside of the seed e.g. nutmeg.
- (viii) **Hairs:** They are the minute thread like appendages present on the surface of the seed e.g. cotton.
- (ix) **Wings:** It is the papery structure attached to the side of the seed coat either to a specific side of the seed coat or to all sides e.g. moringa.

2.2.3 Parts of Normal Seedling

A seedling is categorized as normal only if it has the following essential parts:

- (i) **Root (Primary):** The part of the plant growing underground is known as root. The radicle of embryo develops into root. It grows straight and must be free from damages and decays.
- (ii) **Shoot:** The part of the plant growing above the ground is known as shoot. It develops from the plumule of the embryo.
- (iii) **Epicotyl:** The portion of the shoot above the cotyledons
- (iv) **Hypocotyl:** The region of shoot below the cotyledon and above the root.
- (v) **Coleoptile:** It is the cover that protects the plumule and helps in its emergence. It also helps in elongation of the cotyledons in monocot.
- (vi) **Coleorhiza:** It is the sheath which covers the radicle portion and it is the elongation of hypocotyl region.

2.3 Importance and Characteristics of Seed Structures

2.3.1 Carrier of new technology: The introduction of quality seeds of new varieties wisely combined with other inputs significantly increases the yield levels. In India cultivation of high yielding varieties increased the food production from 52 million to 180 million tons over a period of 40 years. Seed acts as a vehicle for the superior genes to reach farmers. It is also a carrier of bio technological innovations

2.3.2 A basic tool for secured food supply: Introduction of dwarf and high yielding varieties and hybrids of different crops increased the productivity and led to potential development.

2.3.3 The principal means to secure crop yields in less favorable production areas: The supply of good quality seeds of improved varieties suitable to these areas is one of the few important immediate contributions to secure higher crop yields.

2.3.4 A medium for rapid rehabilitation of agriculture in cases of natural disaster: Widespread floods and droughts in various parts of the country and elsewhere have focused attention on these recurrent crises and the accompanying threats of famine

and starvation. The establishment of National Seed Reserve Stocks should receive high priority for meeting such natural calamities.

2.4 Seed source

One of the most important aspects of forest and conservation seedlings is that they are always identified by seed origin, with both geographical location (township-range-section or longitude-latitude) and elevation specified. A seedzone is a geographic area that is relatively similar in climate and soil.

Unless progeny tests have shown otherwise, it is best to plant seedlings back into their zone of origin. Thus, most seedlings grown for forest and conservation purposes are ordered by species, stock type, and seed zone. When this seedling order is sown in the nursery, this information on species, seed zone, and elevation is included into a seed lot identification number. The seed lot number remains with this group of seedlings throughout their entire nursery tenure and is marked on the storage container when the seedlings are harvested for out-planting. The process is completed when the seedlings are planted back into the same general climatic region in which the seed was collected. The importance of proper source identification cannot be overstated. Seedlings perform best within their seed zone, and many plantings have failed because the stock was poorly adapted to the out-planting environment. If a lot of seedlings lose its source code, nurseries often destroy the seedlings rather than have them out-planted in the wrong environment.

2.5 Stand and Seed Orchard

Seed quality involves both genetic and the physiological quality of seeds. Good seed means that has both high physiological quality and genetic suitability. Methods for improvement of physiological qualities have been discussed in the previous sections. Genetic improvement of seed quality means the ability to produce trees that are best suited to the plantation sites and for the desired products. Genetic gains, wider adaptability and conservation of forest genetic resources are main aim of tree improvement programme. Genetic gains can be obtained from selection among species, provenance within species and/or trees within provenance. Some of the important points are mentioned below:

- The largest, cheapest and fastest gain in most tree improvement programmes can be obtained by use of already adapted and productive provenance of the desired species.
- Test plantings are the only sure method to determine the genetic quality and suitability of exotic species. Without analysing their result and to avoid failure or sub-standard performance, the safest rule is to use seeds of phenotypically selected stands or trees in local provenance of native species.
- Exotic tree species should be used only when the desired product cannot be obtained with native species at comparable cost.

2.5.1 Selection of Plus Trees

The first step in a tree improvement programme is the selection of plus tree in which best and promising phenotypes are identified. Immediate use of this selection process can be made by harvesting seeds from selected parent (plus trees) to get modest genetic gains especially for stem form and growth rate. One of the important effects of plus tree selection is to avoid the degradation of genetic quality which may occur when seeds are collected from short, branchy or easily climbed trees of poor quality. Culling out the undesirable trees and fertilizing the soil around the selected trees can encourage seed production in the selected stands. Local efforts can also be made to protect the seed from damage. In Arunachal Pradesh, State Forest Research Institute (SFRI) has identified nearly 800 plus trees of different species of commercial importance which are being used for creation of clonal seed orchards, germ plasm bank as well as for seed collection.

2.5.2 Selection Criteria

It varies from species to species and depends on the objectives of improvement programme i.e. whether for timber production, social forestry or NTFP purposes. Some of the important characteristics considered for selection of plus tree for timber purpose are as follows:

- Straight, cylindrical, non-forking, non-twisting bole, without buttress
- Fast growth, (maximum height and girth in comparison to neighbours)
- Narrow and minimum crown
- Thin branches with wide branch angles
- High wood density and long fibers

- Resistance to pests and diseases.

Selection is carried out in natural stands or preferably in plantations. Certain considerations of importance in the choice of the site for selection are mentioned below:

- Selection should be made from stands that are as pure in species composition as possible
- Selection should be concentrated on stands or plantations that are average or better in traits of interest,
- Selection works better in an even aged stand, since the age difference can be eliminated from the evaluation,
- Selection is best carried out in a mature stand i.e. Near to maximum height and girth, and
- Selection in natural forests where selective logging has taken place should be avoided since the best trees might have already been removed, leaving the poorer behind.

The plus trees should not be selected too close to each other, since closely growing trees may be genetically related, i.e. involving same parent (s). A thumb rule suggests selecting one tree per hectare or one per 1000 trees.

2.5.3 Seed Production Area (SPA)

These are developed from the existing stands of natural or plantation origin to meet the immediate requirement of quality seed in bulk on interim basis until the seed orchards come into production. It is a phenotypically superior stand made up of vigorously growing healthy trees upgraded by thinning to remove the inferior trees and are managed scientifically to cause abundant seed production. It is a short-term improvement programme used for immediate genetic gains. The main advantages are the availability of good quality seed from compact area of known provenance, ease of collection, maintenance and surety of sustained seed supply.

2.5.4 Seed Orchards

It is the plantation of genetically superior trees, isolated to reduce pollination from genetically inferior outside source, and managed intensively to produce regular and abundant seed crops of sound and easily harvested seeds. It is a long-term

programme coupled with progeny tests. The expected genetic gains from such orchards vary from 30% to 40%. These are of two types:

2.5.4.1 Seedling Seed Orchards (SSO)

These are raised from the seeds collected from plus trees and involve progeny testing. Culling is done to remove inferior families and trees, leaving only the best trees to cross-pollinate for seed production. It takes long time to come into seed production stage and genetic gain is also less than the parents. Generally it is raised for those species that are difficult to propagate through vegetative methods.

2.5.4.2. Clonal Seed Orchards (CSO)

These are developed by collection of the vegetative propagules (usually grafts) from the selected plus trees and grafted on the root-stocks. The clones are planted together systematically as per the design to form an orchard. The progeny tests of plus trees are simultaneously conducted for culling of inferior trees or clones.

The advantage of clonal seed orchard is that they come into flowering stage at very early age. The management and cultural operations like seed collection is very easy. The chances of crop failure are minimised. Further breeding and improvement programmes can be taken easily and germplasm of the selected individuals are preserved.

2.6 Seed Collection

It requires good planning in advance regarding deployment of trained staff, arrangement of transportation facilities, seed collection equipments, measures to ensure the safety of workers, packing and labeling material, and maintenance of the records, etc. The other important points are:

- Information about the location, time of flowering and fruiting,
- Information about the periodicity of seed crop,
- Prefer seeds of well-adapted local source to the un adapted sources of different places, avoid isolated trees of naturally cross pollinating species, since these are likely to be self-pollinated. Seeds from such trees are likely to be few or may have low viability and produce weak or malformed seedlings,
- Avoid stands of poorly formed, excessively flimsy, off-colour, abnormal or diseased trees,

- Change in latitude , humidity, temperature and attack of pests greatly affects the seed quality, yield and periodicity,
- Fruit ripening gets delayed due to rains and advanced due to high temperature and drought,
- Flowering and fruiting is earlier by 10-15 days in western parts of Arunachal Pradesh in comparison to the eastern parts.

In most of the tree species seed matures in a phased manner within a few weeks. At first, few seeds ripen and the number gradually increases till it reaches a peak (synchronized maturity) and then there is a gradual decrease. The mature seeds collected during the peak phase give more uniform germination and have greater longevity in storage than immature seeds.

2.6.1 Seed Periodicity

Most species do not produce abundant crops of seed annually. Good seed year occurs at intervals that are better thought of as sporadic rather than predictably periodic. The first essential requirement is an ill-defined state of physiological readiness for flowering and supply of nitrogen and phosphorus. Sometimes good seed crops follow years of total failure. In general, the more favourable the conditions of soil and climate for plant growth, the more frequent are good crops of seed.

2.6.2 Seed Crop Can Be Estimated By

- Flower count,
- Immature fruit and seed count,
- Fruit count on standing trees, some trees e.g., *Bombax ceiba*, *Delonix regia*, *Gmelina arborea*, *Pinus kesiya*, *Tectona grandis*, produce good seed crop every year,
- Dipterocarps like hollong and mekai bear irregular heavy seed crops at an interval of one to six years,
- Some species (e.g. *Eucalyptus*) produce heavy seed crops every year when grown in plantation, and — species like Teetasopa (*Michelia champaca*), Pines and Araucaria take one to two years from pollination to ripen their fruits.

The best seed producers are ordinarily dominant trees that have attained middle age and are healthy with reasonable good form. The likelihood that their seeds will be of acceptable genetic quality is greatest if similarly good trees are chosen. Unfortunately,

it is easier to gather seed from short or easily climbed and poor crowned trees, which should be avoided. It is always advisable to examine the seeds of a tree in the field before effort is expended in gathering more of them. Cutting a cross section to see that how many seeds are hollow, empty and immature can do this.

2.6.2 Methods of Seed Collection

The seed is usually collected by one of the following methods:

1) Collection of fallen seeds from the ground: Seeds can be collected from the ground i.e. collection of naturally fallen fruits/seeds or it can be collected directly from the trees. Large-sized fruits/ seeds e.g. *Ailanthus*, *Canarium*, *Dipterocarpus*, *Elaeocarpus*, *Gmelina*, *Quercus*, *Tectona*, etc. are easy to see and pick-up from the ground. It is easy and low cost method applicable to species having large seeds or fruits. However, there are certain drawbacks if seeds are collected from the ground:

- Chances of attack by fungi/insects/animals are more if not collected immediately. Seeds of legumes are more prone to insects,
- Chances of collection of non-viable, immature and empty seeds are more in case of seeds having short viability, and
- It is difficult to know the parentage of seed.
- Examples: Sal, Teak, Oaks, *Acrocarpus fraxinifolius*, *Trewia nudiflora*, *Gmelina arborea*

2) Collection of seed by lopping the branches or from freshly felled trees: This method is applied to species whose seed or fruit is either too small to be economically picked from the ground after falling as in case of *Terminalia myriocarpa*, *Betula* etc. or likely to be widely dispersed by wind as in case of *Dalbergia sissoo*, *Acacia catechu* etc.

3) Collection of seed from standing trees: Seeds which are likely to get damaged in falling with branches, or get dispersed, are collected by following methods :

- By using light weight poles for striking and shaking of branches,
- By using poles with knife and sickle for cutting the small branches.
- By climbing on the tree with the help of tree bicycle, rope-ladder, one-legged ladder, tree pruner, etc. And

- By using nets and other local materials.

Cones or fruits should be collected after the seeds have completed their development but before their dispersal. Most cones and some fruits mature when desiccation starts, if so, this is the most reliable indicator. It is very difficult to collect the fully mature seeds of *Acer laevigatum*, *Ailanthus grandis*, *Bombax ceiba*, *Oroxylum indicum*, *Ulmus lancifolium*, etc. because their samaroid fruits/winged seeds are liable to be blown over wide distances while plucking them

2.7 Seed Extraction and Processing

The method of seed extraction depends on the type and nature of fruits. The cones and dry fruits generally shed seeds if dried in open air or sunlight. Seeds from fleshy or pulpy fruits may be removed by macerating/crushing and washing, while the seeds borne in pods or husks can be extracted by thrashing. Other methods like drying of seeds under cover (e.g. *Abies*, *Cedrus*, *Dipterocarpus*, *Hopea*, *Quercus*, *Shorea*), thrashing, de-winging and picking by hand, etc. are used as per the morphology of seed/fruit. However, care should be taken during all these activities so that seeds are not damaged.

1) **Seed Cleaning:** It can be done by the following methods :

- Screen cleaning by using sieves of different pore sizes,
- Air separation/winnowing or by aspirators,
- De-winging reduces storage volume, make upgrading possible, sowing easier and removes pathogen,
- Empty seeds can be removed by liquid floatation, and
- Seed drier, seed grader, seed separator, seed blower, seed scarifier, sieves, etc. Are some of the useful equipments of seed processing.

2) **Seed Upgrading:** It reduces the chances of disease, quantity of the seed to be procured as well as its costs. It is done as follows :

- Remove weak and damaged seeds,
- Remove empty, immature, and discoloured seeds.

3) **Post-harvest Care:** The time between collection and extraction of seed is very important to maintain high germination and vigour. Some of the important points to be remembered during seed collection and storage are as follows :

- The freshly collected seed should not be exposed to sun except cones of conifers, *Alnus*, *Betula*, *Casurina*, capsules of *Eucalyptus* and *Toona*, etc. The sun's heat may kill the seeds,
- The safest drying method for delicate species like Dipterocarps, Deodar, Fir, Neem, Oak, Vitex, etc. Is to spread a thin layer of fruits in well ventilated rooms and stirring at regular intervals,
- Seeds should not be left in wet areas otherwise it will rot and die,
- The soft and fleshy seeds such as ash, Bonsum, Gamari, Leteku, Neem, etc. Should not be kept in heap or large sacks/bags immediately after harvest. They can be kept in small-untied perforated sacks or open basket after cleaning of pulp and drying of seeds. The large and closed sack generates much heat as well as thermophilic fungi that can kill the seeds.
- Seeds should be completely dried and labeled before putting them for storage under species-specific conditions,
- Fruit storage is advantageous in some species for after—ripening,
- Recalcitrant seeds deteriorate if their moisture content is reduced too much or too rapidly. Seeds can be categorized into following three groups on the basis of their harvesting and collection behavior:

2.8 Seed Storage and Testing

Seed storage is the preservation of viable seed until their sowing/requirement. It is essential to offset the uncertainty of seed production/availability during bad seed years. It delays deterioration, maintains viability and protects seed from rodent and insect damage. The longevity of seeds is a species-specific characteristic. The seed of most of the species can be stored at low temperature and low moisture content in sealed containers. It is important to dry the seed uniformly to prevent fluctuation in moisture content during storage. The moisture content of most of the seeds for storage ranges between 10 to 12 per cent. The respiration continues at low temperature, which is

necessary to keep the embryo alive. Polythene bags make good containers because they are impermeable to water but less so to oxygen and carbon dioxide. However, many species of moist tropical forests are so thoroughly adapted for germination that their seeds are almost impossible to store or even to transport. On the basis of storage behavior seeds can be divided into following broad categories :

2.8.1 Orthodox Seeds

Seeds, which can withstand drying down to low moisture content of around 5% to 10% and successfully stored at low or sub freezing temperature for long periods are known as orthodox seeds. For example, *Acacia*, *Anthocephalus*, *Betula*, *Duabanga*, *Eucalyptus*, *Fraxinus*, *Pinus*, and *Picea* etc.

2.8.2 Sub-Orthodox Seeds

Seeds of *Abies*, *Juglans*, *Salix* and *Poplar* lose viability within a few months in open air. These can be stored under same condition as true orthodox, but only for six months to a maximum of six years in some cases, loss of viability ranges from 0% to 34% when stored at -5°C to -20°C and moisture content between 5 to 10 per cent.

2.8.3 Temperate-Recalcitrant Seeds

Seeds are desiccation sensitive and can be dried to 35 to 50 per cent moisture content of fresh weight. Storage temperature varies from 3°C to -3°C e.g. *Acer*, *Aesculus* and *Quercus*.

2.8.4 Recalcitrant Seeds

Seeds which cannot tolerate drying below a relatively high moisture content (often in the range of 20% to 50% net basis) and which cannot be stored successfully for long periods, e.g. *Hollong*, *Mekai* and other dipterocarps, Cane, Champ, Neem, Rubber, and members of family Lauraceae, etc. Their seeds are sensitive to low temperature, chilling damage and death may occur if stored in low temperature. These are most difficult group to store even for short period.

2.9 Seed Testing

Seed testing is essential to assess the physical and biological aspects of seed. Seed tests are commonly done immediately after extraction and shortly before actual

sowing. It is also done periodically on seed lots kept in long storage. For small nurseries, common sense, clean hands, a clean working table and one good knife are sufficient for most seed testing tasks. Some of the common terms and methods have been described below :

- (i) **Seed Lot:** A seed lot is defined as a specified quantity of seeds of reasonably uniform quality from a particular geographic source.
- (ii) **Purity Test:** It determines what proportion of the seed sample by weight has pure seed and what proportion is other material. The four recognized components of a seed lot are pure seeds, other seeds, damaged seeds and inert matter such as seed wings, twigs, stone soil or other non-seed materials. The separation is done manually by placing seeds on a working table. The immature, shrivelled, cracked, and damaged seeds larger than one-half of the original seed-size, including those with internal insect damage and those starting to germinate, are designated as "pure" seeds.

Thus, if the initial weight of a seed sample is 50 gm and the pure portion weighed 40 gm, purity of the lot is:

$$40/50 \times 100 = 80\%$$

- (iii) **Seed Weight:** It is normally expressed for 1000 pure and full seeds. Factors affecting seed weight are size, moisture content and proportion of full seeds in the lot. It is generally calculated by taking 10 random samples of 100 seeds from a pure lot. If the difference between any two replicates exceeds 10% of the mean weight, additional replicates should be drawn. To convert number of seeds per kilogram following formula is applied:

$$\text{Number of seeds per Kg} = 10,00,000 / 1000 \text{ seed weight in gm.}$$

- (iv) **Seed Moisture Content:** Knowledge of seed moisture content is essential to determine the viability and storage conditions. Seeds of high moisture content cannot be stored and over drying can make them non-viable. It can be determined by drying of 10g sample in oven at 103°C for 17 hrs (or at 130°C for 1 to 4 hrs), weighing and calculating through the following formula.

$$\text{MC\%} = \frac{\text{Original wt. of seed} - \text{oven dry wt. of seed}}{\text{Original wt. of seed}} \times 100$$

(v) **TTZ Test:** Another simple test is tetrazolium (TTZ) staining test, which indicates the presence of live tissue. 1% solution of TTZ (2,3,5 - triphenyltetrazolium chloride) is applied to fully imbibed seeds, which have been cut opened lengthwise without damaging the embryo. The seeds are left overnight (18 to 24 hrs in the dark at 30° C). The live embryo, cotyledons and other tissue stain pink to red indicating that the seeds are viable. Comparatively larger seeds like *Albizia*, *Bauhinia*, *Phoebe goalparensis*, etc. can be conveniently tested in this way.

2.10 Seed Germination

After dispersal, a lot of seed is destroyed by insects, birds and rodents. The others germinate provided they are deposited on suitable soil. Germination of seed depends upon:

1. Internal factors
2. External factors

2.10.1 Internal factors

The internal factors are the factors pertaining to the seed itself. The following internal factors affect germination:

(i) **Permeability to water:** Moisture is very essential for germination; if the seed has a hard coat, it prevents moisture reaching the seed embryo and therefore prevents germination. Such seeds germinate only when the hard coat weathers due to exposure to sun and rain or when it has been partially eaten up by insects.

(ii) **Permeability to oxygen:** Oxygen is necessary for germination. Factors which inhibit moisture reaching the seed also prevent oxygen reaching it.

(iii) **Development of embryo:** The embryo should be fully developed at the time of seed fall. If it is not developed, the seed lies dormant till it is fully developed. A typical example of this is seen in *Fraxinus floribunda* in which the seeds lie dormant on the ground for the whole year.

(iv) **After Ripening:** Even if the embryo is fully developed, seeds, sometimes, do not germinate because the embryo is not chemically ready for germination. Such seeds germinate only when they have undergone a process of after-ripening. Delayed germination of *Juniperus macropoda* is due to after-ripening.

(v) Viability: Viability is defined as the “potential capacity of a seed to germinate”. Some seeds lose their viability soon while others retain their viability for a year or more. Thus, in case of seeds which lose their viability soon, if the environmental conditions are not favorable for germination at the time of their fall, they die. For example, under natural conditions salt seeds remain viable for about a week. If monsoon is delayed, most of the seeds that fall on dry ground die.

(vi) Size of seed-The size of seed, afflicts natural regeneration because while very minute seeds are washed away with the rain water, very big seeds do not get properly covered) Viability-Viability is defined as 'the potential capacity is a specific character and is described by the number of seeds gram or kilogram.

The size of the seeds varies not only from tree to tree in the same species but also on the same tree; some seeds are thin and poorly developed while others are thick. As a general rule, within the average size of the seed produced by the species, the thicker the seed, the better the germination.

(vii) Germination Capacity and germination Energy-All the seeds that fall to the ground do not germinate. As the percentage of seeds that germinate, affects natural regeneration, it is important to know the germination capacity and germination energy of the seeds of the species, germination capacity is defined as 'the percentage, by number, of seeds in a given sample that actually germinate, irrespective of time '.

Germination energy is defined as the percentage, by number, of seeds in a given sample that have germinated up to the time when the rate of germination (number of seeds germinating per day) reaches its peak (Holmes) '.

(viii) Plant percent: All the seedlings resulting from the germination of seeds do not survive long as many of them succumb to the adverse environmental factors. Therefore the number of plants that survive till the end of the growing season is an important factor affecting natural regeneration. This information is given by the term plant percent which is defined as 'percentage of the number of the seeds in a sample that develop into seedlings at the end of the first growing season.

2.10.2 External factors

External factors are the factors of environment which affect germination and these are:

(i) **Moisture:** An adequate quantity of moisture is very essential for germination. Moisture activates the dormant embryo and by softening the seed coat helps it to come out. Moisture is also necessary for dissolving the food material collected in the cotyledons and for translocating it in solution to the radical and the plumule.

(ii) **Air:** The germinating seeds require oxygen and this is supplied by air. Seeds buried in the deeper layers of the soil often remain dormant for want of oxygen, In the germinating seed, respiration is very rapid and therefore a constant supply of oxygen is very essential.

(iii) **Temperature:** Temperature is essential for germination but range of temperature within which seeds of various species germinate varies with species. The higher is temperature the better for germination within this range.

(iv) **Light:** Most species are indifferent to light conditions for their germination but some, e.g., *Cassia fistula*, *Albizia procera*, require light.

(v) **Seed bed:** It is necessary that the seed should be deposited on proper seed bed for germination. If the seed falls on sheet rock, boulder deposit, a thick layer of dry leaves or a dense ground cover, it will not germinate or even if it germinates, as often happens in the case of seeds deposited on thatched roofs, it does not survive. A light burning or shrub cutting is sometimes useful to provide a good seed bed in cases where thick layer of dry leaves and / or dense ground cover are the inhibiting factors. Even on a suitable seed bed, the depth of covering has a great influence on natural regeneration. While the seeds buried very deep in the soil, do not germinate for want of oxygen, and even if germinate, are not able to push the plumules through the soil, the seeds which are not properly covered do not germinate and this is so mostly with thick or large seeds like acorns .. Seeds which are covered with soil equal to about half their diameter germinate best, provided other factors are favorable.

2.11 Germination Percentage and Tree Seedling Establishment

Germination is a process by which seeds are actually induced to germinate and lead to subsequent growth of seedlings.

(i) **Germination percent:** Germination percent is an estimate of the viability of a population of seeds. Germination percent is the ratio between total numbers of

seed germinated to the total number of seed sown in all replications multiplies by 100. It is expressed in %.

$$\text{Seed germination (\%)} = \frac{\text{No. point of germinated seeds}}{\text{Total No. of seeds}} \times 100$$

- (ii) **Germination Capacity:** It is a measure of germination time course and is usually expressed as a percentage. Germination capacity will be always equal to or higher than germination percent.
- (iii) **Germination energy:** It is the per cent, by number, of seed in a given sample which germinate up to the time of peak germination. Where Peak germination is the highest number of germination in a particular day (William, 1985)

2.11.1 Seedling Establishment

Even if the germination is good it does not mean that the natural regeneration would be good because a large number of seedlings die at the end of rains or as a result of frost during winter or drought during summer.

Establishment is defined as the "development of a new crop, naturally or assisted, to a stage when the young regeneration, natural or artificial, is considered safe from normal adverse influences such as frost, drought or weeds and no longer needs special protection or tending operations other than cleaning, thinning and pruning.' The following factors affect establishment of seedlings:

- (i) **Development of roots:** For some time after germination, the seedlings depend upon the food reserves of the cotyledons but soon they have to depend on their own resources. For this it is essential that the seedling may develop a long tap root soon so that it reaches a depth where there is permanent moisture in the soil. Thus, in the species in which the development of root is fast, the seedling mortality is less.
- (ii) **Soil conditions:** The seedlings whose roots do not reach the mineral soil and remain only in the un-decomposed organic matter, die after the rains due to moisture deficiency. Soil aeration also plays an important role in seedling establishment. Soil aeration affects seedling establishment in two ways, viz.,
- Due to deficiency of air as is seen in case of teak whose seedlings die as a result of poor Soil aeration resulting from water logging.

- As a result of imbalance in the constituents of the soil air as is seen in case Of Sal whose seedlings start dying as soon as carbon dioxide/oxygen ratio reaches 2:8.
- (iii) **Light:** Light is a very important factor in seedling establishment but its requirement Varies from species to species and even in the same species according to climatic conditions and age. The requirement of light increases with age. The younger seedlings require comparatively lesser light but as they grow in age, they require more light.
- (iv) **Other climatic factors:** Extremely high or extremely low temperatures are both harmful for seedling establishment. In extremely high temperature, seedlings are killed due to isolation while in extremely low temperature they are killed by frost. For seedling establishment, only adequate rainfall is not essential but its proper seasonal distribution is also essential. Otherwise, the long dry season after the monsoonal rains, kills most of the seedlings.
- (v) **Condition of grass and other competing weed growth:** The effect of grass and other competing weed growth depends upon the nature of weed growth and the climatic conditions. The competing weed growth may be grass alone. a mixture of grass and shrubs or shrubs alone, The density of the weed growth has a great influence on establishment. A dense growth of grass is very harmful particularly when it forms dense mat-like roots and causes water logging For instance, very few species, including teak can survive in the dense growth of Imperata. In the dry and arid areas, a certain amount of weed growth is helpful in conserving moisture and affording a certain amount of shade to the seedlings.
- (vi) **Grazing, browsing and burning:** Light grazing and browsing is not harmful to seedling establishment but uncontrolled grazing and browsing completely destroy regeneration. Similarly, light or controlled burning is not harmful. On the other hand, it reduces the density of shrub growth and destroys the unrecompensed organic matter, and thus favors rapid growth in seedlings. Uncontrolled burning is, however, very injurious. The resistance to and the power of recovery from grazing and fire injuries vary with species and with age.
- (vii) **Drip:** Drip from the large leaves of species such as sal, teak is very harmful for seedling establishment because it removes soil from the roots of the tiny

seedlings in splash erosion thereby exposing the roots resulting in the death of plants.

(viii) Composition of the crop-The composition of the crop affects soil conditions and therefore affects the establishment. A mixed crop is believed to create more favorable condition for seedling establishment than pure crops.

(ix) Dying Back Of Seedlings: In some species, the shoot portion of seedlings keeps on dying year after year while the root remains alive. Every year the shoot dies back to produce whippy new shoots little or no bigger than the last year's shoot from the ground level results in keeping back the progress of the seedlings towards establishment. This continues for as many as 20 years or more with the result that the seedling does not develop a permanent shoot. As the root stock keeps on developing, it produces in some year with rare coincidence of absence of all adverse factors, a shoot that does not die and thereafter the shoot makes steady progress.

2.11.2 Seedling Establishment Period

The seedling establishment period is defined as the period which elapses between the initiation of natural regeneration and the time when it is considered safe from adverse influences such as frost, drought or weeds.

In short, the development of a forest of the desired species from seed under natural conditions depends upon the following conditions:

- Adequate and well distributed seed supply, ie, there should be not only adequate seed but that seed should be well disseminated over the whole regeneration area.
- Favorable conditions for the germination of seeds.
- Favorable conditions for the development and establishment of seedlings.
- Favorable conditions of under growth, ground cover and overhead canopies so that the seedlings receive not only adequate light but are also free from root competition.
- Protection against all kinds of injuries.
- Tending! during most part of the life span of crop
- Control over mixture

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UNIT 3: Nursery Management

Unit Structure

- 3.0 Learning objectives
 - 3.1 Introduction
 - 3.2 Objectives and importance of nursery
 - 3.3 Nursery works
 - 3.4 Methods of sowing
 - 3.5 Quality of seeds
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 - 3.7 Shading
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3.0 Learning objectives

After completing this unit you shall be able to:

- Define nursery and its importance
- Explain how nursery is prepared
- Explain different activities done for the establishment of the nursery
- Explain the process of fertilization and micro propagation

3.1 Introduction

The success of a plantation programme depends to a great extent on success of nursery. If we can produce good and healthy stock in a nursery, we can successfully cope up with the plantation target. At the same time we can supply stock to outside organizations and can earn a good name. If the produced seedlings are undersized or malnourished or short in number the cost of plantation will become very high.

The seedlings remain in the nursery for six month to one year or more during which they attain the necessary vigor to survive under the adverse conditions of planting site. The characteristics acquired during early development in the nursery are often a determining factor in deciding the fate of plantations. The planting stock which is under developed or infected with parasitic organisms are liable to fail after planting. The nursery that is producing one lakh seedlings per year is called "large nursery" whereas, the "small nursery" has capacity of 50,000 seedlings per year or even less.

"Forest nursery" is an area where plants are raised for eventual planting out; has ordinarily both seedlings and transplants (Anon., 1966). In a nursery the plants are raised for planting in the field. A good nursery contains nursery beds for root-shoots and polypots, inspection paths, perennial well or water source, irrigation systems, tractor, garage, stores or go down, recreational facilities and residential quarters for the staff. On the basis of the irrigation facilities the nurseries are called dry or wet:

(i) Dry Nursery

The dry nursery is a nursery maintained without any irrigation or artificial watering. The rab nurseries of Western Maharashtra, Karnataka and Gujarat come under this category. The rab or semi rab nurseries are made in the plantation areas on a small well burnt patch of land usually 0.01 to 0.05 ha. in extent mainly for supplying teak stumps for beating up of casualties. The seeds are sown in lines 45 cm. apart just before the onset of monsoon. Normally no elaborate beds are made, no fencing is made and no irrigation is provided as compared to other nurseries.

(ii) Wet Nursery

The wet nursery is the nursery maintained by irrigation or other artificial water during dry periods. The nurseries according to their use are of two types:

(a) Temporary and (b) Permanent

(a) Temporary Nurseries: Temporary nursery or field nursery is adjacent or near to the planting area and sometimes supplementary to permanent nursery to meet the planting needs of rising of seedlings for one or two years. It is no permanent and decentralized in nature and can be abandoned or shifted to other place. Sometimes it becomes a part of the planting area. It is also called "flying nurseries." The main advantage of a temporary nursery or field nursery is that it is economically cheap and more easily manageable. The plants have to be carried a short distance while planting

and there is less delay between lifting and planting. In spite of these advantages, the temporary nurseries should not be made unless their success is guaranteed. These nurseries should be made near the available water source e.g. stream or river. Temporary nurseries can have two types of problems:

- Where conditions are unfavorable the inspection may be difficult, the labor force may be scarce and scattered as a result of which plants can never be managed to become healthy. The supervision of temporary nursery is more difficult.
- Where conditions are favorable the good quality plants may be raised successfully but this is to be seen whether the spot of the nursery is far away from the main road. If it is so the path to the main road will become muddy, sticky and unpassable during rains as a result of which plants will be transported at a low speed and often late and this may become cause for failure of the plantation. This factor is important where the metallic and tarred roads have not been developed.
- The rab nursery or semi-rab nursery made generally for teak root-shoots is a kind of temporary nursery for small plantation area which also gives stock for causality replacement. If water source is not available the nursery is raised under dry conditions and is called dry nursery'.

(b) Permanent Nurseries: These nurseries are permanent in nature therefore should be centrally located so that production and supply of large number of seedlings could be effectively managed. It must have regular layout, roads, inspection paths, sowing beds, transplant beds, irrigation and drainage facilities, compost pit, store rooms for seeds and implements, labor hut, housing for staff, recreational and first aid facilities etc. The nursery should be well protected by fencing and it should be on the main road. In a forest division the number of permanent nurseries should be sufficient to meet the requirement of plantation targets.

3.2 Objectives and importance of nursery

- Seedlings and grafts are produced in nursery from which the fruit orchards and ornamental gardens can be established with minimum care, cost and maintenance

- The nursery planting materials are available at the beginning of the planting season. This saves the time, money and efforts of the farmers to raise seedlings.
- There is a wide scope for fruit orchards, ornamental, vegetable, and landscape gardens at public places, highways and co-operative housing societies
- It assures the production of genetically improved quality planting material
- It provides employment opportunities for technical, skilled, semi-skilled, unskilled labor.
- They are an important source supplying the seedlings for meeting the fruit, pulp and paper, fuel wood, timber and other demands of the industries

Objects of raising nursery:

- 1) To prepare healthy and vigorous stock
- 2) To prepare seedlings for distribution among the public
- 3) To raise tall and sturdy seedling to
 - a) Overcome the weeding competition at the planting site
 - b) To suit difficult site conditions such as roadside plantations
 - c) To supplement slow growth by intensive care in the nursery for reducing overall cost of plantations.
- 4) For introducing exotics species like tropical pines Eucalyptus, poplar so that their initial growth could be watched in nursery
- 5) Species which cannot be raised successfully by direct sowing, for them nursery raised seedlings perform better
- 6) To raise nursery seedlings for poor and barren sites this is the surest method for artificial regeneration
- 7) To supplement natural regeneration and direct sowing methods only healthy seedlings can assure uniform stocking. Replacement of causalities is always done by planting nursery raised seedlings

8) Species which do not seed each year or seeds which are difficult to store or of which viability erodes quickly nursery grown seedlings can ensure availability of stock in poor seed years.

Principal of Nursery Management:

- 1) Well grown seedlings that are reared and conditioned in the nursery will be in a better position to resist the extremes of field conditions
- 2) The nursery should be as far as possible near to the planting site and seedlings raised for about one or two years in a nursery are planted out
- 3) The site of the nursery should have good water supply and shade for some of the species
- 4) Hardening of the seedlings raised should be done before a planting by withholding irrigation and watering for a couple of days before planting
- 5) After transporting the seedlings to the site they should be allowed to recover from the shock of transport and a day is enough for this purpose.

3.3 Nursery works

Forests play an important role in the economy of the State. They meet our requirement of timber, fuel wood, fodder, paper pulp, sports goods, match wood, plywood, resin, packing cases, agricultural implements, other minor forest produce and medicinal plants. Owing to increasing pressure on forests due to enhanced grazing and other human interference, the natural regeneration on which we had depended a few decades ago is now very scarce. It has therefore, become necessary to restock them by planting suitable tree, shrub and grass species. Raising of plantation is a technical process which requires quality and healthy seedlings and nursery is a place where quality and healthy seedlings are grown. Nurseries can either be permanent or temporary depending upon duration and site of the plantation. The establishment of a nursery is a technical process.

3.3.1 Sites and area

Selection of site is of utmost importance because it has a significant bearing on the raising of seedlings. Therefore following points must be kept in mind while selecting a site for the establishment of a nursery.

a. Location: The site should be centrally located and easily accessible for transportation. Sites used earlier for agriculture should be avoided and preference to forest sites, where weed problem will be less and useful mycorrhizae will be available, should be accorded.

b. Water: Enough water should be available especially during summers. A natural source of water at a higher altitude is preferable but if there is no natural water source, ground water may be used. It is estimated that during peak summers 2000lts of water is required for 100000 seedlings.

c. Topography and drainage: The site should be almost flat with good drainage. This can be done by providing gentle slope and channels to drain out excess water from the nursery. In the hills northern aspect is desirable up to 1,200 m elevation and beyond it, 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.

d. Soil: The ideal forest nursery should have sandy loam to loamy texture. Sandy soils having pH between 5.5 and 8.0 moderate fertility, with a minimum of 2.5% organic matter may be given preference over heavy soils. The higher the organic matter content of the nursery soil, the better it is because it 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. Tree nurseries should be sited in a central location preferably close to areas targeted for land restoration activities. Assess if your nursery site meets some of the following conditions:

- Not heavily shaded with trees for proper light management and encourage air circulation
- Accessible throughout the year to facilitate efficient nursery operations
- Design should provide paths for ease nursery workers movements to potting and seedling production areas; also plan for kind of irrigation to be used for large nurseries
- The site should be well protected from strong winds, livestock and unauthorized people.

3.3.2 Size of nursery

The size of the nursery depends on

- (a) Area to be planted annually
- (b) The species to be planted
- (c) The time or in nursery
- (d) Whether plants are to be pricked out or not.
- (e) Area required for buildings, sheds, store, garage etc.
- (f) Requirement of roads, inspection paths, irrigation facilities etc.

As a rough estimate the area required for a nursery varies from 1.5 to 3.5% of area to be planted. The area is calculated on the basis of the above and a 50% increase made in the area so as to allow for inspection paths irrigation channels road etc. It should be 0.4 ha for every 1.00 lakh seedlings.

3.3.3 Protection of the Nursery Area

Forest nurseries are to be protected against outside influences such as grazing by domestic and wild animals. For this purpose: a) Erection of 1.5m height barbed wire fencing for temporary nursery. b) Erection of stone wall or cattle proof fence around permanent nursery. c) In arid areas planting of wind breaks, shelter belts to provide shelter. d) Protection against birds by placing thorny bushes on the bed.

3.3.4 Seed bed

After the main soil preparation has been done, the seed beds are made just before sowing. Beds should be laid in a systematic order. The long side of the bed should be towards the hottest sun i.e. in east west direction so that shading can be done if required. The beds should be 1.2m to 1.5m wide so that a labor or mali can reach up to the middle for weeding and other purpose. The standard beds are of size 12.2m x 1.2 (40ft x 4ft) raised 15 cm or more upto 30 cm above ground supported by bamboos, stones, planks etc. in wet areas. They are of sunken type (25 to 35 cm deep) in arid areas and hot places. Toe beds should be well dug, the soil thoroughly loosened and all lumps broken. Where the seedbeds are required the beds should be sunken below the general level of the path. This will facilitate irrigation and is beneficial in dry soils and well drained localities. In wet areas if the beds are not flat and raised above the ground level, the seeds will be washed off to the sides. In the hills nursery beds are

made after terracing the area. In Rajasthan the size of sunken beds are of size 10m x 1m x 0.30m. The beds should be serially numbered to maintain the record of planting stock.

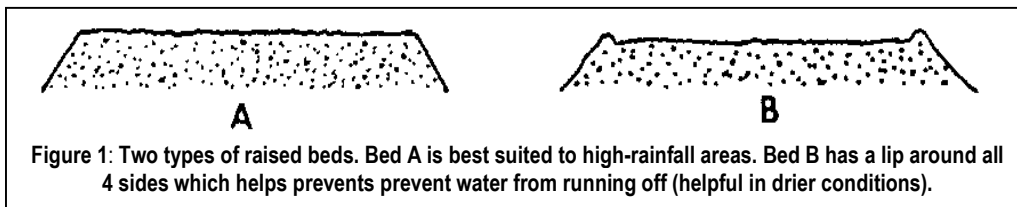
Depending on conditions the beds can be made of three types (i) raised beds (ii) sunken beds and (iii) level beds. In all these cases the soil should be well dug before making beds. The best type to use depends much more on the particular climate and soil conditions than on the crop.

(a) Flat / level Beds: Flat beds are used where water availability is adequate and there are no drainage problems. In some areas, crops like maize, sorghum, beans, and potatoes are started out on a flat bed; as the season progresses, soil is thrown into the crop row to mound up the plants; this is called "hilling-up" and is done to control in-row weeds, provide support, and improve drainage. (Potatoes are also hilled up to keep the developing tubers covered with soil.) Hilling-up only works with plants that have enough stem height and leaf clearance to tolerate partial burial.

(b) Raised Beds: Crops can also be grown on raised-up beds or ridges. They are especially advantageous for clayey soils under high rainfall or wherever else drainage is likely to be poor. They can also be used in many other situations. Where crops are furrow irrigated, raised beds or ridges are essential so that the water can flow down the furrows between them. Height of raised beds: Raised beds are usually 10-30 cm high. The best height depends mainly on soil texture and moisture considerations. For example, raised beds are often 20-30 cm high on clayey soils under high rainfall where poor drainage is likely to be a problem. On coarser-textured soil under the same conditions, bed height might be 15-20 cm. When raised beds are used in drier conditions, a bed height of 10 cm or less may be best to avoid excessive moisture loss due to evaporation from the exposed sides. Width of raised beds: Typically they are 100-130 cm wide. Raised beds may have several advantages:

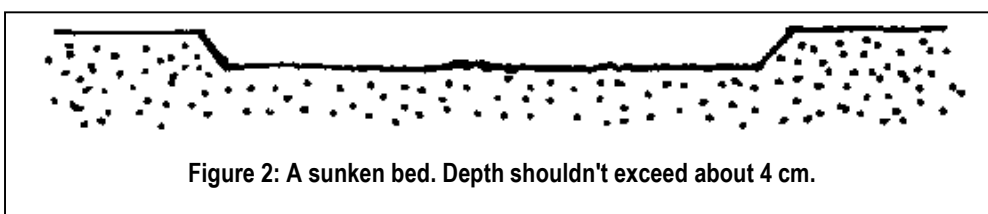
- Much better drainage compared with flat or sunken beds.
- They provide a double layer of topsoil, because they're made by dragging in topsoil from the surrounding alleyways. (Because of this, they're also likely to be looser than flat or sunken beds.)

- In temperate regions, raised beds warm up more quickly in the spring, which may benefit cold-sensitive crops and even permit earlier planting.
- Plants on raised beds are easier to reach when doing hand operations such as weeding and thinning.
- Raised beds usually aren't a good choice during the dry season, because they dry out more quickly than flat or sunken beds; also, water tends to run off them and be lost into the alley-ways. These disadvantages can be partly overcome by mulching the bed with straw or rice hulls, making a lip around the bed's edge to reduce run-off, and by reducing bed height to 10 cm or less (see Fig. 1).



(c) **Sunken Beds:** In dry regions, especially on sandy soils with low water-holding capacity, vegetables can be planted in sunken beds (i.e. shallow basins) about 100-130 cm wide and 2-5 cm below the surrounding soil level. Sunken beds conserve water much more effectively than raised beds for 2 reasons:

- Sunken beds don't have the exposed sides of raised beds from where considerable moisture can be lost by evaporation (Figure 2).
- None of the applied water is lost by runoff.



One disadvantage of sunken beds is that some topsoil is lost in the usual method of construction. (They're made by pulling off soil from the bed area and placing it in the surrounding alleyways). This probably won't affect crop growth, as long as the topsoil is of normal depth (at least 15 cm) and enough compost or manure is added. Here are 2 ways of building sunken beds without sacrificing topsoil:

- First take off the topsoil, and then replace it after removing enough subsoil to sink the bed enough.
- Make a "pseudo" sunken bed by mounding alleyway soil around the bed's borders. This will work well in clayey soil, but border dikes made of sandy soil may wash out when the bed is watered.

One variation of sunken beds is furrow planting in which crops like maize, sorghum, and beans are planted in the furrow bottom between two ridges where soil moisture is higher and less easily lost. Soil can then be thrown into the furrow as the season progresses to control weeds and improve drainage if rainfall increases.

3.4 Methods of sowing

Seed sowing is defined as placing the seed in soil to germinate and grow into plant, but planting is putting the plant to propagate in soil for growing plants. Propagate are seedlings, roots, tubers, leaves, or cuttings. Transplanting is a term that is used for planting the seedling grown into nursery to different field or pot for different purposes.

Seeds may be sown directly or they can be transplanted. For transplanting method, the seeds are sown in nursery and then the nursery is transplanted to field. The different methods of sowing are given below;

- (i) **Broadcasting:** Broadcasting is the most common and oldest methods of seed sowing, where the seeds are just spread on the soil. Then seeds may or may not be covered with soil. Broadcasting may be done manually with hands or through mechanical spreader.

Advantages of Manual Broadcasting

- Manual method is cheap.
- It takes less time than other methods.
- This method is suitable only for small seeded and crops where plant to plant distance is small or does not matter.

Disadvantages of Broadcasting

- In this method the Seed distribution is uneven.
- Some of the Seeds are not be covered by soil.
- The density and depth of seeds are uneven.

- The germination of seed is Non-uniform.
- Crop stand is affected by uneven distribution.

(ii) **Dibbling:** Planting procedure with dibbling. Dibbling is the process in which we place seeds in the holes or pits at equal predetermined distances and depths. This procedure is done by dibble, planter or manually.

Advantages of Dibbling

- Less seeds are required.
- Germination is rapid and uniform.
- Seedling vigor is good.

Disadvantages of Dibbling

- It is time consuming.
- More labor is required
- This method is costly.

(iii) **Drilling:** In this method the seed is dropped into holes, the seeds are then covered and compacted by soil. Drilling is done with the help of seed drill or seed-cum-fertilizer drill. Seeds are drilled continuously in a row or drilling can be done at distance which is set and rows can be made accordingly.

Advantages of Drilling

- The quantity of seed required is less.
- During drilling Manures, fertilizers and amendments can applied with seeds.

Disadvantages of Drilling

- More time consuming.
- More labor required.
- Cost is high.

(iv) **Sowing Behind Country Plough:** In this process, the seeds are placed into the furrows ploughed in the field either continuously or at specific distance manually by a man working behind plough. The depth of sowing depends on the depth of plough.

(v) **Planting:** Planting is the placing of seeds or propagules firmly in the soil for germination and growth.

(vi) **Transplanting:** Transplanting is the method in which planting of seedlings in main field after pulling out from the nursery. The seeds in common practice should be sown in beds by dibbling or drilling. Broadcasting method can be used for very small sized seeds like *Adina cordifolia*, *Eucalyptus*, etc. While broadcasting very small seeds are mixed with sand or soil or wood ash whereas medium and large sized seeds can be broadcast without any medium. Broadcasting does not give good seedlings therefore usually the seeds should not be broadcast. The seeds should be sown in beds in lines by dibbling or by drill method. The distance between the lines should be adjusted (a) according to the germination capacity of the seed and (b) whether entire transplants are to be used or only large root and shoot cuttings are needed.

The line sowing facilitates hoeing and weeding operations, at the same time plants can also be thinned out later if uniform germination is not obtained. The distance between lines should ordinarily be kept as 10 cm. Seed should not be sown too dense because it will show poor germination, greater mortality, poor growth of seedling and damping off at the time of weeding. The drill sowing can be performed by drill board or drilling drum or other such instruments which can be made locally with the help of battens etc.

The seeds should be covered with soil. The thickness of soil varies with the size and type of seed. The seeds can be covered by raking or by sifting of clean sand, fine subsoil or leaf mould. Seed beds should be surrounded by stone plan ks, brick walling or wire netting sunk below the ground for protection against mice. Very small seeds should be sown on the surface and only just covered with earth. Larger seeds are sown deeper but it is advisable to sow too shallow rather than too deep. A general thumb rule to which there are many exceptions is to cover the seed as deep as the smallest diameter of the seed. The soil cover after sowing is not compacted. In light soils the sowing is made deeper as compared to heavy soils. There is always an optimum depth of sowing for a combination of particular and soil which need to be determined by experiment.

3.5 Quality of seeds

- Healthy and vigorous seedlings are the bases for better crop growth and yield.
- Vigorous seedlings produced in the nursery will be able to withstand pest attack in the main field.

(A) Seeds intended for sowing should satisfy the following requirements:

- The seed should belong to the proper variety, which is proposed to be grown
- The seed should be clean and free from mixtures of other seeds.
- The seed should be mature, well developed and plump in size.
- The seed should be free from obvious signs of age or bad storage
- The seed should have a high germinating capacity.
- Before sowing, the seed should be treated with fungicides which protects the seed against soil-born fungi and also give a boost to the seedlings.

(B) Up gradation of seed quality using salt solution

- Ten liter of water is taken in a plastic bucket of 15 liter capacity and a good quality fresh egg is dropped in the water and the egg sinks in water and reaches the bottom.
- The commercial grade common salt is added little by little and dissolved in water. As the density of salt solution increases, the egg raise up.
- The addition of salt (Sodium chloride) is stopped when the surface of the egg is visible above the solution.
- To this salt solution add 10kg of seeds.
- The seeds with low density float on the surface of the solution.
- The seeds floating on the surface of the solution are removed.
- The seeds sunk in the solution are washed for 2-3 times in water and then used.

3.6 Time of sowing

The time of sowing seed depends on many factors such as seed ripening, stage of dormancy if any, rate of growth of the species in the locality and the size of plants

required at the time of planting. Generally sowing in polythene bags should be done in November or in February. The day temperature during sowing should be 20-30°C. For fast growing species like *Prosopis* the sowing can be done in March.

The conifer seeds are sown just before and after the snow but mostly in March. The best period for sowing teak seeds in nursery beds is April-May so that stumps can be prepared in the next planting season. Early sowing gives more seedlings and taller seedlings. Sowing for fir and deodar should be completed in Nov - Dec. so that damage due to snowfall is avoided. The aim should be to produce planting stock of desired size at the time of planting season. Planting undersized stock will result in failure of plantation. The seeds having short viability e.g. Neem, Sal, etc. should be sown in mother beds or polybags soon after collection.

3.7 Shading

The shading over nursery beds is provided to plants to give protection against sun, frost, hailstorm, rain, fast wind etc. The dark condition is congenial to plants therefore the shading by dry grasses i.e., munj grass, straw, bamboo sticks, chicks, bamboo mats, leaf matting, agro plastic nets (black or green), opaque polythene etc. is beneficial after sowing for many species. For large seeds ordinarily no shading is required. When sowings are made at the break of rains the moisture content of the beds will usually be correct. Shades protect the beds and seedlings from heavy rains, scorching sun light and fast winds. They should be slanting towards north - south. The shades should not leak in rainy season because leaky shades will mechanically damage and spoil the germination at patches where the dripping occurs. To protect, frost tender species the seedlings are provided with shades or it should be covered with needles, dry grass or straw during winter season. The covering is removed, after the soil temperature rises up in the morning and is covered again in the evening. Shading is necessary for plants before and after rainy season i.e. in the months of April, May, June and October. It will reduce evaporation and transpiration losses. Permanent nursery requires permanent support for spreading shades.

The shading can be 50 to 100% depending upon requirement of light. Gradually the shades are thinned as the plant growth advances. It makes the plant hardy. It should be removed totally one or two weeks before planting out. Sometimes, the undercutting

or root pruning is done with sharp blade through seed beds to control taproots and to reduce height growth. This is normally done at 8 to 10 cm depth.

3.8 Watering and damping off

3.8.1 Watering

Regular supply of water is a must for every nursery. Proper and judicious irrigation solves many problems in the nursery. In case of teak seeds if sown in April or at the time of onset of monsoon, it germinates badly. But if the teak seeds are soaked for 48 hours and then sown and watered daily the beds will be absolutely full of seedlings by June. Over irrigation as well as under irrigation is harmful for plants it increases the cost of seedlings. The soil or rooting medium must be soaked to its field capacity. There can be three methods of irrigation from the main supply of water.

(i) Flow or Flood Irrigation: This method should be used if cheap water is available. The sunken beds are flooded with water from time to time. But with small seeds this method cannot be used because fine sediment of earth settles and forms a crust over the whole bed. This crust can be broken provided seeds had been sown in lines. If the seeds have poor germination excessive weeds will come up and too much weeding would destroy young seedlings. If the seeds have been sown in polythene bags kept in sunken beds, the beds are flooded after initial overhead watering by rose-cans or atomizer. In arid areas or water scarcity areas the beds can be cemented so that water dose not percolates down.

(ii) Furrow Irrigation: The water can be supplied through furrows which alone are flooded. To do this 1.2m to 1.5m wide beds are sub-divided so that no point is more than one foot from a furrow. The great advantages of this method over flooding are that it uses less water and that no crust is formed over the bed. This method is widely used in Jaisalmer and other arid areas.

(iii) Overhead Irrigation: This is a common method in many parts of the country. It can be done by:

(a) Rose cans: Fine holed rose cans should be preferred because water through fine holes will not displace seeds or small seedlings. This is excellent method for small seeds like halduor, or small Eucalyptus whereas germination might fail if fine roses are not used. Economy of water is also maintained by rose cans.

(b) **Automizer:** The water comes out in the form of a mist and no damage is done to seeds or seedlings. The automizer should be used till the seedlings attain a height of 10 cm; later on other methods may be used.

(c) **Sprinkler systems:** Nowadays many types of sprinkler systems are available. They are made up of network of pipelines having holes or nozzles to discharge water under pressure. It can be of drip irrigation or rotating type. For a big size nursery the irrigation through a sprinkler system is done in parts instead of watering the whole nursery at a time. In all these cases this is to be remembered that too much watering should be avoided. The beds should be kept fresh but not wet. The mud puddles which are often seen are not desirable.

The irrigation should be done in the morning or preferably in the evening. Too much under watering creates superficial root system which cannot withstand drought when planted out. Even then to some extent plant before planting out in field should undergo "hardening off" by decreasing frequency of watering. During summer season a good growth of seedlings should be maintained by sufficient irrigation. Sample polypots should be checked to see whether the water has percolated down up to the bottom of the bag. Amount of water required for raising 1 lakh plants in dry areas during summer is 2000-3000 litre/day i.e. 20-30 c.c./ plant/ day. During winter months the requirement will be 10 c.c./plant/ day.

During summer if the soil temperature goes above 45°C. It may result in root collar damage and consequently killing the seedling. To prevent this damage, the soil surface should be cooled by watering. Polypots kept in cemented beds require 30% less watering as compared to normal earthen beds. The water requirement of polypot seedlings kept in shaded beds is reduced by 9.6% (Kaul and Ganguli, 1963). The Species such as teak, bamboo, Prosopis and Acacias, require little irrigation but many other species require more water.

The water for nursery should have pH between 5.5 to 7.5 and content of salts less than 400ppm beyond which sodium toxicity develops. "Calcium nitrate" is used to increase pH and "aluminium sulphate" (2.5 g per 100 litre of water) is used to decrease pH. The presence of sodium makes the soil toxic to plants and tip drying of leaves can be seen. This will also affect growth of plants ultimately.

3.8.2 Damping Off

The most common and dangerous parasites in nursery soils are damping-off fungi which is responsible for destruction of seedlings in their early period of growth. It is mainly disease of conifer seedlings but many broadleaved species may also be attacked. The plants in the nursery are often affected by "Damping-off" disease. The seedlings are affected by fungi belonging to *Phytophthora*, *Pythium*, *Rhizoctonia* and *Fusarium*. These fungi cause root-rotting and plants are dead ultimately. The destructive activity of damping-off fungi is sometimes supported by mites. The disease may also be initiated or promoted by nematodes. The loss due to damping-off is often very serious. The disease may destroy the entire nursery stock in one season and may be unimportant in other years. The mortality due to damping-off can occur at three stages namely (i) pre-emergence, (ii) post-emergence soon after germination and (iii) root-rot in older seedlings. They are more pronounced in heavy clayey soils with high level of moisture (under anaerobic condition) than in light soils. Mostly pines, indigenous as well as exotic pines in acidic soils are affected by the damping-off disease. The mortality in conifers goes as high as 75%.

In India, *R. solani* is the most important cause for damping-off in nurseries. *Pythium* and *Fusarium* are recorded less commonly (Reddy, 1969). Low light intensity increases the soil temperature, application of high nitrogen doses and addition of raw un-decomposed humus favor damping-off.

The affected seedlings topple over as though broken at the ground level or remain erect and dry up. The symptom of the disease is discolored and pinched stem. Sometimes the leaves of the seedling seem to be drying out, although the stem still appears to be healthy. The pre-emergence blight should not be confused with the poor viability of seeds. A watery appearing constriction of the stem at the ground is another symptom of disease. In post emergence damping off the succulent stem decays at the ground level which results in toppling over of the seedling or collar rot. In some cases there is extensive root decay and root rot becomes the conspicuous symptom of the disease syndrome.

The collar rot is caused by the species of *Pythium* and *Phytophthora* whereas root-rot is caused by the species of *Fusarium*, *Rhizoctonia*, *Cylindrocium* and *Sclerotium*. The fungus spreads rapidly in the tissues and the seedlings either wilt completely or

fall over on ground due to rotting of tissues at the base. Fungal attack on gucculent root tips in older seedlings may not be fatal and under favour conditions new roots develop and seedlings continue to live. The damping-off is favoured by high humidity, damp soil surface, heavy soil, cloudy weather, an excess of shade, dense stand of seedlings and alkaline condition of the soil.

The damping-off is controlled by :

(A) Proper selection of site: The site should be slightly acidic and loamy. If the soil is neutral or alkaline, it may be acidified by adding sulphur, aluminium sulphate, concentrated sulphuric acid or ammonium sulphate fertilizer.

- (i). Nursery soils should be maintained dry throughout. During sprouting watering should be kept to the minimum.
- (ii). Sowing density should be reduced and seedlings should be thinned to create better aeration.
- (iii). The porosity of soil should be improved by addition of sand. Deep ploughing in addition to insecticide application is necessary for controlling damping-off disease.

(B) Steaming: In this method steam is used for sterilization. It is made to pass through the nursery soil. The soil pathogens are killed due to high temperature:

- (i). By placing the nursery soil under running steam in an autoclave or closed container for few hours.
- (ii). The perforated pipes are laid through nursery beds and steam is allowed to pass through them.

(C) Use of chemicals: The following chemicals are used to disinfect the nursery soil:

- (i). **Formalin:** A solution of 38% formaldehyde diluted in water is prepared and 300 ml of formalin per sq. m. of seed bed is enough for controlling damping off. It should be applied 8-10 days before sowing of seed.
- (ii). **Methyl bromide:** It is applied 15-20 days in advance of sowing. After applying the beds are covered with thick polythene sheets.
- (iii). **Brassicol:** Fumigation with formalin is done in fir and spruce nurseries in Himachal Pradesh.

- (iv). Use of chemicals such as captan (0.2%), Thiride, Zineb, Cuman, Bavistin (0.1%) etc. The doses should be nearly 20 to 25gm per sq. yard of seed bed. Similarly drenching can be done by Dithane-45 and Enisan-0.1 and 0.05% respectively, on the day of sowing with three watering schedule. Bavistin (0.02%) solution is applied to the seedlings as foliar drench before the onset of monsoon on non-rainy day (Sharma and Mohan, 1986).
- (v). Overhead shade should be avoided on wet soils.

3.9 Weeding

Weeds are grasses and undesirable plants which hinder the growth of planted seedlings. They check the growth of seedlings by sharing moisture, nutrient and light. At the time of planting there may not be any weed but with the break of rains different seeds, root stocks and bamboo rhizomes come up and start competing with the seedling. Therefore their periodical removal is a must for the success of plantation. Weeding is a practice of eliminating and/or suppressing undesirable plants. The intensity and type of weeding to be carried out depends on nature of species, slope of area and likely competition of weeds with the seedlings. Weeds are either annual or perennial plants e.g. shrubs, herbs, climbers, grasses, rhizomes etc. It also acts as secondary host for insect-pests and disease-carrying organisms. Thus, the nursery area must be kept free from weeds. Hand weeding and hoeing are the most common practices to remove weeds. To control a large number of weed species, pre-emergence herbicides can also be sprayed just after the sowing of seeds. The weeds are eliminated mainly in two ways:

- (i). **By Uprooting:** In most areas if the weeds have not developed deep roots they are eliminated by uprooting. Re-occurrence of weed are not possible after uprooting. The additional advantage is that soil aeration is also improved. Care should be taken that no damage is caused to the seedlings while uprooting deep rooted weeds. If the seedlings are likely to be affected weeds should be removed by cutting. Some soil working e.g. scrapping, digging etc. is also necessary for good uprooting. For this khurpi or spade with small blade should be used.

(ii). **By Cutting:** Where uprooting is not possible or desirable the weeds are eliminated by cutting. The various implements like spade, sickle, axe, Khurpi etc. are used for this purpose.

The different types of weeding are:

- Circular/square weeding
- Strip weeding
- Complete weeding.

The following kinds of weeding are recommended for the plantations:

I year plantation:

- First weeding - circular or square weeding (July).
- Second weeding - strip weeding (Aug .- Sept.)
- Third weeding - strip weeding (Sept. - Oct.)

II year plantation:

- First weeding - strip weeding (July - Aug.)
- Second weeding - strip weeding (Sept. - Oct.)

III year plantation

- One circular weeding only (Aug.)

The time of weeding should depend on the condition of soil. However, the first weeding is very important and should be made early before the weeds try to suppress the young seedlings. The first weeding in the first year of plantation needs to be carried out early rather than late. Similarly the time of second and third weeding should be decided according to the conditions in the field. If the two weeding are timely and properly done, the third is seldom necessary but it may always be beneficial to the plants. The weeding in the second year depends on the success of the first year weeding. The first weeding in second year should be carried out early rather than late, to check the growth of weeds effectively. This can be done by arranging different gangs of labor for first year and second year plantations. If the same gang of labor is employed in the first year and second year work the success of second year works suffer.

The only one weeding in third year plantation should be done at the proper time. The cleaning operation should necessarily be accompanied with third weeding as many unwanted plants and tall weeds if not removed shall affect the availability of light to the plants. This is the last weeding made available to the plants and therefore, it should not be taken lightly. Its importance is seen at the time of first thinning operation. The first weeding in first year and second year of plantation needs to be carried out early rather than late. Weeds should not be allowed to suppress the plants. The amount of weeding to be done depends upon various factors such as:

- (i) **Soil Fertility:** In more fertile soils the weed growth is heavier.
- (ii) **Season:** The warm and wet conditions help in weed growth.
- (iii) **Size of Plants:** Taller the plants used for planting lesser will be the weed growth. When the plants are smaller more weeding is required.
- (iv) **Light Requirement of Species:** The shade bearer plants can tolerate certain heavy weed growth better than the light demander species.

It should be noted that certain amount of weed is necessary for soil conservation and protection from winds, sun, frost and drought. Weed help in retaining some moisture in the soil.

3.10 Soil working and transplanting

Loosening of soil or soil working must follow after each weeding. Soil working eliminates any root stock of weeds remaining around the plant. Weeding and soil working can be carried out simultaneously if small spade is being used. The soil working is done in an area of one metre diameter (circular) or in 1m x 1m area (square). Square pattern of soil working more costly but is more effective in conserving moisture. Soil working improves growth of several species e.g. poplars, eucalyptus, teak, etc. (FAO, 1980) The soil working boosts up immensely the growth of teak plants in the initial years particularly in lateritic soil where hard crust is formed on the surface after the water has dried up. Soil working improves rate of infiltration, removes compaction, improves soil aeration, improves soil structure, reduces water loss from the soil, removes weeds and general hygiene of the plantation area is improved. Soil moisture evaporates through the capillaries having less than 0.5mm in diameter

formed in the soil. Soil working breaks the capillary and water is stopped from evaporation.

Transplanting: The seedlings of different species remain in nursery for varying periods of time. Eucalyptus for example remains in nursery for short period, and hence can be planted out in the field directly from germination beds. This gives rise to compact bushy root system instead of long tap root in the plants. The bushy root is very much desirable in any planting stock and ensures good success in survival of plants when planted out. The operation of shifting plants from mother beds or germination beds to transplant beds is known as pricking out, lining out or transplanting. Pricked out plants are known as transplants and those which are not pricked out are known as seedlings. The pricking out should be done when the seedlings are of 4-6 cm size. It is a very delicate operation and requires care and skill. The best season for lining out is February and March. The seedlings if allowed to remain in the germination beds for a longer time, develop elongated tap-root. This makes it difficult to plant them out in field. After removing from germination beds, the seedlings can either be transferred to transplant beds at a wider spacing or to planting containers or polythene bags. Pricking out operation is performed as below:

The mother beds and also transplant beds or polypots should be thoroughly watered one day before picking out. The seedlings should be uprooted with a short stick under 100 percent shade condition and should be planted in transplant beds or polypots under shade. Alternatively dig a small trench at one end of germination bed. The first row of seedlings is first pushed into the trench along with a mound of soil with the help of shovel. This dislodges the plant from nursery beds without damaging root system. These seedlings are then transplanted with the help of transplanting board usually 3m or 2m in length or by manual method. If necessary, the young taproot may be cut with a sharp knife to about 1/3 of its length. It is best to make crow-bar holes where the seedlings are to be transplanted or the transplant beds should be well dug to a depth of 30 cm. Transplanting should be avoided on sunny days. The pricked out seedlings should be placed on a flat tin which has a filling of moist sack, moss or soil. It should not be placed in pots of water. After pricking out the seedlings should be planted within one hour. After transplantation watering is done to make soil compact and to be in full contact with the roots. For the seeds that can be directly sown in polybags pricking out is not required.

3.11 Plant containers

Plant containers are defined as the containers in which plants raised from seed or into which they are transferred from seed bed for the purpose of planting out later. Generally, plant containers are used to develop seedlings from seed or transfer seeds in different germination conditions. Some of the important containers (Fig. 3) which are commonly used in forest nurseries are given below:

- (i). **Baskets:** These are made up of bamboo strips or *Tamarix*. They are light to carry, easily available and can be buried in the soil along with the plant. They are also used for transporting plants from the nursery to plantation site. In a year the basket will decompose.
- (ii). **Dona:** Dona is made up of leaves which are larger in size like *Bauhinia vahalii*, *Tectona grandis*, *Ficus bengalensis*, *Diospyros melanoxylon* or *Shorea robusta* etc. They are filled with soil, sparingly manured with tank silt and or cow dung manure and placed either in sunken or shaded beds or on ground under the shade of a large crowned trees. In order to prevent excessive growth of tap root, they are generally placed on a layer of leaves.
- (iii). **Earthen pots:** In areas where clayey soils are available containers from soil are prepared. They are made of burnt porous clay in various sizes to provide requisite amount of soil and root space to different kinds and sizes of plants. They have straight sides and are made wider at the top than at the bottom to hold the greatest bulk of compost. Caked earthen pots with bottoms intact or bottomless based are used, the latter can be placed in the pits along with plants, whereas the former has to be broken. Earthen pots are heavy, fragile and expensive. They are rarely used now.
- (iv). **Brick containers:** These are prepared by mixing clay, farm yard manure and sand in 1: 1: 1 ratio. A paste is made which is put in a mold and dried. A hole is kept on the top to sow seed. Brick containers are used in drier and less fertile area. The seedling which comes out of the seed can take nutrient from the brick and get established. However, it is heavy and expensive.
- (v). **Tubes:** Bamboos, metals or plastics are used for making tubes. They are made in such a way that they can break open in two equal halves. Bamboo tubes can

be made by cutting it into two halves and removing the nodes. The two parts is tied with wire. The soil is filled in it and seed sown. At the time of planting the wire is opened and the column of soil along with plant is sown. The tube can then again be used. Though initial cost is high but, it can be reused, which lowering the cost. Tubes are available of following sizes:

Tube pot sizes	Height (cm)	Diameter (cm)	Cost per pot (Rs.)
Tube pot	20	13	15.00
¼ size pot	18	22	15.00
½ size pot	20	27	30.00
¾ size pot	25	32	50.00
Full size pot	35	35	65.00
Tube size pots	35	50	90.00

- (vi). **Polythene bags:** Polythene bags have revolutionized the nursery production. It is being cheap, easily available, durable and light to carry. They are available in different gauge 150, 200 or 250 and sizes 10 x15 cm, 10 x 20 cm, 10 x 23 cm, 15 x 20 cm, 20 x 40 cm etc. These are available with or without bottom for dry as well as high rainfall areas, respectively. Prior to filling of the polybags they should be perforated from many sides to allow aeration of roots. Small, medium and big sized bags are available, which are widely used in place of pots. Small polythene bags with holes punched in the bottom for drainage and filled with a porous rooting medium are used for propagation of cuttings like Jasmines, Duranta, and Crotons etc., in the mist chamber. Sometimes, young seedlings which are raised in the nursery are subsequently transplanted in these polythene bags and may be kept their till they attain required growth for transplanting.
- (vii). **Root Trainers:** In all the above mentioned containers a problem of root coiling is observed. This condition is not good for survival of seedlings when out planted in field. To overcome this, root trainers were designed. These can be cubical, cylindrical or of any desired shape. These are usually made up of black plastic. The basic principle is to make the walls corrugated which will not allow coiling of roots. They are available either singly or in a form of tray having 20 or 30 holes. These are easy to carry and can be heaped one over the other when not in use. Experiments shows that root trainers results in fibrous root system of plant which results better survival of plants in field.

(viii). **Clay pots:** clay pots provide a healthy environment for most plants. The porosity of clay allows air and moisture to penetrate the sides of the pot. This moisture and air is utilized by the fine roots located at the edge of the soil ball. Clay pots also act like a wick to remove excess moisture from the potting soil. This can be looked at as both an advantage and a disadvantage depending upon watering conditions.

(ix). **Plastic pots:** Plastic pots are lightweight, strong and flexible. Plastic does not have the wicking action that clay has making them an excellent choice for moisture-loving plants or for those gardeners who water infrequently. Plastic pots are made of inert materials and are considered safe for growing plants. Many are made of recyclable plastic so disposal is environmentally friendly when the pot is no longer usable (unglazed clay pots are fully recyclable as well). Plastic pots generally have thinner walls than their clay counterparts offering roots little if any insulation from temperature change. Black plastic can actually act as a solar collector, heating up the potting medium to plant damaging levels.

(x). **Root Maker Containers** These unique containers have staggered walls and a staggered bottom that prevent root circling and direct roots toward the holes in the walls and the bottom of the container. The containers were among the first to use side “air slits” to air prune plant roots and are available in many sizes of single containers that are either square or round. Smaller volume Root Maker cavities are joined together in blocks.



Figure 3: Different kinds of plant containers used in nursery

3.12 Fertilization

Plant is nature’s gift as they provide us with the food, oxygen, shelter, clothing, etc. They are also known as universal or primary producers. Like all other living things,

plant respire, grow, develop, excrete and reproduce. All higher plants reproduce by fertilization. Fertilization in flowering plants was discovered by Ralph B. Strasburger in the year 1884.

3.12.1. What is Fertilization?

In plants, fertilization is a process of sexual reproduction, which occurs after pollination and germination. Fertilization can be defined as the fusion of the male gametes (pollen) with the female gametes (ovum) to form a diploid zygote. It is a physicochemical process which occurs after the pollination of the carpel. The complete series of this process takes place in the zygote to develop into a seed. In the fertilization process, flowers play a significant role as they are the reproductive structures of angiosperms (flowering plants). The method of fertilization in plants occurs when gametes in haploid conditions fuse to produce a diploid zygote.

In the course of fertilization, male gametes get transferred into the female reproductive organs through pollinators (honey bees, birds, bats, butterflies, flower beetles) and the final product will be the formation of the embryo in a seed.

3.12.2. Fertilization Process

In flowers, the pollen grain germinates after the pollination of the carpel and grows into the style by creating the pathway for the pollen grain to move down to the ovary.

The pollen tube opens into the ovule through the micropyle and bursts into the embryo sac. Here, the male nucleus unites with the nucleus of an egg inside the ovule forming a diploid zygote, which later swells up and develops into a fruit.

(A) Post Fertilization: Post-fertilization is a series of events that takes place after fertilization to develop a seed from an ovule and a fruit from an ovary. The following events occur in the post-fertilization.

- (i). Endosperm development
- (ii). Embryogeny

(i). **Endosperm:** The endosperm is a type of tissue, which is present in the seeds of flowering plants during the time of fertilization. Reserve food materials fill in the cells of endosperm tissue. It provides nutrition to the developing embryo in the form of starch. Endosperm development is classified into three types. These are as follows:

- Nuclear endosperm formation: In this process, the primary nucleus of endosperm undergoes a nuclear division repeatedly to produce free nuclei without wall formation.
- Cellular endosperm formation: During nuclear division, the formation of cell wall occurs and it leads to the cellular endosperm formation.
- Helobial endosperm formation: It is an intermediate type of endosperm formation between cellular and nuclear type endosperm formation.
- During seed maturation or in the mature seed, the developing embryo may either utilize the endosperm completely or it is used by seed during seed germination.

(ii). **Embryogeny:** Embryogeny is defined as the process of growth and development of an embryo from a zygote in the flowering plants. Embryo development stages are the same in both monocot and dicot plants. In dicot plant embryo, an embryonal axis and two cotyledons are present. Two parts are present in the embryonal axis. These are as follows:

- **Epicotyl:** It is located above the cotyledon level.
- **Hypocotyl:** It is located below the cotyledon level.

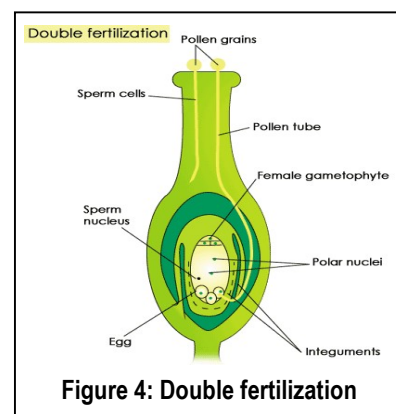
A monocot plant embryo consists of only one cotyledon. The cotyledon is termed as scutellum in the grass family. Root cap of grass is covered with an undifferentiated sheath which is called as coleorrhiza. A portion of the embryonic axis, which is located above the scutellum is called epicotyl. Epicotyl consists of shoot apex and coleoptiles.

3.12.3 Types of Fertilization

Fertilization process can be grouped into three types and are classified mainly based on the entry of the pollen tube into the ovule.

- (a) **Porogamy:** It is the common type of fertilization carried out in all **angiosperms** or flowering plants. In this type of fertilization, the pollen tube enters the ovule through the micropyle.
- (b) **Chalazogamy:** This type of fertilization is carried out on all Casuarina species of plants. In this condition, the pollen tube enters the ovule through the pollen tube.

- (c) **Mesogamy:** This type of fertilization is seen in all Cucurbit plants, such as pumpkin, ridge gourds, bitter gourd and other gourd plants. In this type of fertilization, the pollen tube enters the ovule through its middle part or through the integuments of the ovule.
- (d) **Double Fertilization:** Double fertilization is a process of fertilization characterized by the fusion of a female gametophyte with two male gametes. In this mechanism, one sperm cell fuses with the egg-producing zygote, and the other fuses with the two polar nuclei to make the endosperm. All angiosperm plants undergo double fertilization process.
- (e) Fertilization in plants occurs when haploid gametes meet to create a diploid zygote, which develops into an embryo. In gymnosperms (conifers) and angiosperms (flowering plants), the meeting of the gametes occurs in the following way: male gametes are enclosed in pollen grains and are carried by wind or insects to the female reproductive organs. The final product of fertilization--the embryo--is encased in a seed. For this reason, these two types of tracheophytes are termed seed plants.
- (f) **Gymnosperm Fertilization:** The female gametophyte contains several archegonia, where the egg cells originate and develop. The gametophyte itself is surrounded by layers of sporangia and integument; all of these elements comprise an ovule, which is found on the surface of a female cone. Fertilization occurs when pollen grains (male gametophytes) are carried by the wind to the open end of an ovule, which contains the eggs, or female gametophyte. There, the pollen grain develops an outgrowth called a pollen tube, which eventually penetrates to the egg cell within one of the archegonia. The sperm cells within the pollen tube then vie to fertilize the egg. Once fertilization has occurred, the embryo develops within the female gametophyte, and the ovule becomes the seed, complete with a food source (the gametophyte tissue) and a seed coat (the integument). This embryo, which will



eventually become a new sporophyte, consists of two embryonic leaves, the epicotyl and hypocotyl.

(g) Angiosperm Fertilization: The female reproductive organ of angiosperms is the pistil, located in the middle of the flower. As in gymnosperms, the male gametophyte is the pollen grain. In order for fertilization to occur in most flowering plants, insects or other animals must transport the pollen to the pistil. A major distinguishing feature of angiosperms is the practice of double fertilization.

An angiosperm ovule contains an egg cell and a diploid fusion nucleus, which is created through the joining of two polar nuclei within the ovule. When a pollen grain comes into contact with the stigma, or top of the pistil, it sends a pollen tube down into the ovary at the pistil's base. As the pollen tube penetrates the ovule, it releases two sperm cells. One fuses with the egg to create a diploid zygote, while the other joins with the fusion nucleus to form a triploid nucleus. This triploid nucleus turns into an endosperm, which nourishes the developing embryo (filling the role of gametophyte tissue in the gymnosperm seed). As in gymnosperms, the ovule becomes a seed, encasing the embryo and endosperm in a seed coat. But unlike gymnosperms, in angiosperms the ovary containing the ovules develops into a fruit after fertilization. The fruit gives the embryos the double benefit of added protection against desiccation and increased dispersal, since it is eaten by far-ranging animals who then excrete the seeds. (For a full discussion of the parts of the flower contributing to reproduction, see Plant Structures, Flowers)

In order for fertilization to occur, angiosperms either self-pollinate, in which a particular plant fertilizes itself, or cross-pollinate, in which one plant is fertilized by another of the same species. Cross-pollination generally produces far more vigorous plants, and is encouraged through differential development of the male and female gametophytes on a flower, or through the positioning of these gametophytes so that self-pollination is difficult.

3.13 Micro-Propagation and Misting Units

3.13.1 Micropropagation

Micro propagation is the clonal propagation of plants in closed vessels under aseptic conditions. It is used to multiply a wide variety of plants, such as those that have

been genetically modified or bred through conventional plant breeding methods. It is also used to provide a sufficient number of plantlets for planting from seedless plants, plants that do not respond well to vegetative reproduction or where micro propagation is the cheaper means of propagating (e.g. Orchids.) Cornell University botanist Frederick Campion Steward discovered and pioneered micro propagation and plant tissue culture in the late 1950s and early 1960s.^[3]

In short, steps of micro propagation can be divided into 4 stages.

- (i). Selection of mother plant
- (ii). Multiplication
- (iii). Rooting and acclimatizing
- (iv). Transfer new plant to soil

(i). **Selection of mother plant:** Micro propagation begins with the selection of plant material to be propagated. The plant tissues are removed from an intact plant in a sterile condition. Clean stock

materials that are free of viruses and fungi are important in the production of the healthiest plants.

Once the plant material is chosen for culture, the collection of explants (s) begins and is dependent on the type of tissue to be used; including stem tips, anthers, petals, pollen and other plant tissues. The explants

material is then surface sterilized, usually in multiple courses of bleach and alcohol washes, and finally rinsed in sterilized water. This small portion of plant tissue, sometimes only a single cell, is placed on a growth medium, typically containing Macro and micro nutrients, water, sucrose as an energy source and one or more plant growth regulators (plant hormones). Usually the medium is thickened with a gelling agent, such as agar, to create a gel which supports the explant during growth. Some plants are easily grown on simple media, but others require more complicated media for successful growth; the plant tissue grows



Figure 5. *In vitro* culture of plants in a controlled, sterile environment

and differentiates into new tissues depending on the medium. For example, media containing cytokinin are used to create branched shoots from plant buds.

(ii). Multiplication: Multiplication is the taking of tissue samples produced during the first stage and increasing their number. Following the successful introduction and growth of plant tissue, the establishment stage is followed by multiplication. Through repeated cycles of this process, a single explant sample may be increased from one to hundreds and thousands of plants. Depending on the type of tissue grown, multiplication can involve different methods and media. If the plant material grown is callus tissue, it can be placed in a blender and cut into smaller pieces and recultured on the same type of culture medium to grow more callus tissue. If the tissue is grown as small plants called plantlets, hormones are often added that cause the plantlets to produce many small offshoots. After the formation of multiple shoots, these shoots are transferred to rooting medium with a high auxin\cytokinin ratio. After the development of roots, plantlets can be used for hardening.

(iii).Pre transplant: This stage involves treating the plantlets/shoots produced to encourage root growth and "hardening." It is performed *in vitro*, or in a sterile "test tube" environment.

"Hardening" refers to the preparation of the plants for a natural growth environment.

Until this stage, the plantlets have been grown in "ideal" conditions, designed to encourage rapid growth. Due



Figure 6. Banana plantlets transferred to soil (with vermi-compost) from plant media.

to the controlled nature of their maturation, the plantlets often do not have fully functional dermal coverings. This causes them to be highly susceptible to disease and inefficient in their use of water and energy. *In vitro* conditions are high in humidity, and plants grown under these conditions often do not form a working cuticle and stomata that keep the plant from drying out. When taken out of culture, the plantlets need time to adjust to more natural environmental conditions. Hardening typically involves slowly weaning the plantlets from a high-humidity; low

light, warm environment to what would be considered a normal growth environment for the species in question.

(iv). **Transfer from culture:** In the final stage of plant micro propagation, the plantlets are removed from the plant media and transferred to soil or (more commonly) potting compost for continued growth by conventional methods. This stage is often combined with the "pretransplant" stage.

3.13.2 Methods Micro Propagation

(i). **Meristem culture:** In Meristem culture, the meristem and a few subtending leaf primordia are placed into a suitable growing media where they are induced to form new meristem. These meristems are then divided and further grown and multiplied. To produce plantlets the meristems are taken of from their proliferation medium and put on a regeneration medium. When an elongated rooted plantlet is produced after some



Figure 7. Plant tissue cultures being grown at a USDA seed bank,

weeks, it can be transferred to the soil. A disease free plant can be produced by this method. Experimental result also suggest that this technique can be successfully utilized for rapid multiplication of various plant species, e.g. Coconut,^[4] Strawberry,^[5] Sugarcane.^[6]

(ii). **Callus culture:** A callus is mass of undifferentiated parenchymatous cells. When a living plant tissue is placed in an artificial growing medium with other conditions favorable, callus is formed. The growth of callus varies with the homogenous levels of auxin and Cytokinin and can be manipulated by endogenous supply of these growth regulators in the culture medium. The callus growth and its organogenesis or embryogenesis can be referred into three different stages.

- **Stage I:** Rapid production of callus after placing the explants in culture medium
- **Stage II:** The callus is transferred to other medium containing growth regulators for the induction of adventitious organs.
- **Stage III:** The new plantlet is then exposed gradually to the environmental condition.

(iii).**Embryo culture:** In embryo culture, the embryo is excised and placed into a culture medium with proper nutrient in aseptic condition. To obtain a quick and optimum growth into plantlets, it is transferred to soil. It is particularly important for the production of inter-specific and inter-generic hybrids and to overcome the embryo.

(iv).**Protoplast culture:** In protoplast culture, the plant cell can be isolated with the help of wall degrading enzymes and growth in a suitable culture medium in a controlled condition for regeneration of plantlets. Under suitable conditions the protoplast develops a cell wall followed by an increase in cell division and differentiation and grows into a new plant. The protoplast are first cultured in liquid medium at 25 to 28 C with a light intensity of 100 to 500 lux or in dark and after undergoing substantial cell division, they are transferred into solid medium congenial or morphogenesis in many horticultural crops respond well to protoplast culture.

3.13.3 Advantages of Micro-propagation

Micropropagation has a number of advantages over traditional plant propagation techniques:

- The main advantage of micropropagation is the production of many plants that are clones of each other.
- Micropropagation can be used to produce disease-free plants.
- It can have an extraordinarily high fecundity rate, producing thousands of propagules while conventional techniques might only produce a fraction of this number.
- It is the only viable method of regenerating genetically modified cells or cells after protoplast fusion.
- It is useful in multiplying plants which produce seeds in uneconomical amounts, or when plants are sterile and do not produce viable seeds or when seed cannot be stored (see recalcitrant seeds).
- Micropropagation often produces more robust plants, leading to accelerated growth compared to similar plants produced by conventional methods - like seeds or cuttings.

- Some plants with very small seeds, including most orchids, are most reliably grown from seed in sterile culture.
- A greater number of plants can be produced per square meter and the propagules can be stored longer and in a smaller area.

3.13.4 Disadvantages of Micro-propagation

Micropropagation is not always the perfect means of multiplying plants. Conditions that limits its use include:

- Labour may make up 50%-69% of operating costs.^[7]
- A monoculture is produced after micropropagation, leading to a lack of overall disease resilience, as all progeny plants may be vulnerable to the same infections.
- An infected plant sample can produce infected progeny. This is uncommon as the stock plants are carefully screened and vetted to prevent culturing plants infected with virus or fungus.
- Not all plants can be successfully tissue cultured, often because the proper medium for growth is not known or the plants produce secondary metabolic chemicals that stunt or kill the explants.
- Sometimes plants or cultivars do not come true to type after being tissue cultured. This is often dependent on the type of explants material utilized during the initiation phase or the result of the age of the cell or propagule line.
- Some plants are very difficult to disinfect of fungal organisms.

The major limitation in the use of micro propagation for many plants is the cost of production; for many plants the use of seeds, which are normally disease free and produced in good numbers, readily produce plants (see orthodox seed) in good numbers at a lower cost. For this reason, many plant breeders do not utilize micro propagation because the cost is prohibitive. Other breeders use it to produce stock plants that are then used for seed multiplication. Mechanization of the process could reduce labor costs, but has proven difficult to achieve, despite active attempts to develop technological solutions.

3.13.5 Mist chamber

Nursery plants propagated by cuttings are grown in mist chambers. In Mist Chamber, Relative humidity is maintained artificially at high level with the help of mist installations, which spray water under pressure. Fog formation induces rooting and

acclimatization. High relative humidity facilitates better root initiation and cooling effect prevents the cutting from drying out. This method results in faster rooting of the cuttings, create optimum microclimate for better root initiation and development and higher success rate in propagation of hard wood cuttings. Temperature and humidity control in the mist chamber is affected through automated control systems.

The mist chamber is used for research purpose as well as propagation of garden plants. *Myristica spp.*, *Kingiodendron pinnatum*, *Vatica chinensis*, *Hydnocarpus macrocarpa*, *Cynometra sp.* etc are a few RETs and *Cinnamomum verum*, *Oroxylum indicum*, *Persea macrantha*, *Sapindus trifoliatus* as NTFPs among the propagation protocols developed.



Figure 8: Mist chamber

Advantages of mist chamber

- This method results in faster rooting of the cuttings.
- Create optimum Microclimate for better root initiation and development.
- Higher success rate found in propagation of hard wood cuttings.

Disadvantages of mist chamber

- Hardening of rooted cuttings is more difficult and requires careful attention. Selection of right medium is very important.
- Under mist conditions oxygen deficiency can create problem.

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Unit 4: Plantation establishment

Unit Structure

4.0 Learning objectives

4.1 Legal title of land, survey

4.2 Selection of site

4.2.1 Location

4.2.2 Soil

4.2.3 Topography

4.2.4 Site Selection

4.3 Layout

4.3.1 Planning and Layout

4.4 Planting pattern

4.4.1 Square system

4.4.2 Rectangular system

4.4.3 Triangular system

4.4.4 Hexagonal system

4.4.5 Quincunx system

4.4.6 Contour system

4.5 Spacing

4.6 Season of Planting

4.7 Taungya System of cultivation

4.7.1 Types of Taungya

4.8 Enrichment planting

4.9 Nurse and Cover Crops

4.0 Learning objectives

After going through this unit you will be able to:

- Understand about the Planting layout
- Formulate the plan and layout of the nursery.
- Identify the facilities required to establish a nursery.
- What are planting methods?
- Taungya plantation and nurse crops

4.1 Legal title of land, survey

The first step in a plantation programme is to carry out pre planting survey of the planting area and preparation of treatment map. After selection of the land various information pertaining to land viz; soil type, soil depth, slope, site quality, neighboring

vegetation, status of land etc. should be recorded so that various decisions regarding treatments to be given to the area may be made. This includes:

- (i) Decision regarding area to be planted and area to be left unplanted for protection, conservation, research or other purposes.
- (ii) Selection of species for different patches or zones of area.
- (iii) Determining type of site preparation required for different areas.
- (iv) Layout of roads, inspection paths, fire lines, water points etc.

The area selected for plantation or Afforestation is divided into different zones giving the details of

- (i) Terrain
- (ii) Vegetation type
- (iii) Geology and soil type
- (iv) Drainage conditions
- (v) Communication and approach roads etc.
- (vi) Rights of access, grazing rights, collection of minor forest produce etc.

4.2 Selection of site

The selection of site is depending on the following criteria:

- (i) Recently clear felled forest area for replacement of crop or forest area devoid of natural vegetation.
- (ii) Forest area selected for under planting where soil is easily erodable.
- (iii) Open area in the forest or any wasteland including land, private farm, and community land etc. where site limiting factors.
- (iv) Strips along road, railway line, canal etc. or for agroforestry plantation. The following points need ration while selecting site for the plantation :
- (v) There should be enough area to be tackled for consecutive years. The same should be marked on map.
- (vi) The planting should be easily approachable during soon so that there is no problem in transport of planting, weeding etc.

- (vii) The participation of local labor should be enough facilities should be made available to the labor.

4.2.1 Location

The selected site for establishing a nursery should preferably be located in an established nursery area. By doing so, one can share the experiences of fellow nurserymen and thereby many mistakes can be avoided in planning, management and marketing of the nursery stock.

The selected site should preferably be near the highway or at least connected with a good motorable road, which facilitates easy and economic transport of inputs and nursery plants to the users, orchardists and fruit growers. The selected site should also have electricity and communication facilities. These facilities will improve the production as well as marketing.

4.2.2 Soil

The success of any nursery depends mainly upon the nature of soil and the abundant supply of good quality water. Before selecting the site for nursery, soil and water analysis must be done, since most of the fruit and ornamental plants cannot tolerate salinity and alkalinity. The soil should be light to medium in texture with good fertility and sufficient water holding capacity along with good drainage. A soil pH of 6.0 to 7.0 is most suitable for any nursery. Salinity in soil and irrigation water leads to salt injury resulting in nutritional deficiencies, marginal browning of leaves and in acute cases death of the plants especially in summer months. Therefore, a careful selection of soil with good quality irrigation water supply is very important for the success of a commercial nursery.

4.2.3 Topography

The topography of the land should be plain with about one per cent slope. The slope facilitates a smooth flow of irrigation water and also gives a grand panoramic view, if planned and laid out properly which impresses the customers easily. The extent of land required for the nursery depends upon the targets of planting materials of different fruit crops and ornamental plants and the varieties to be produced/ multiplied. For example, to produce about one lakh mango grafts at least 2 hectares of nursery land is required.

4.2.4 Site Selection

Critical points needed to be considered while selecting nursery area are:

- Area selected should be well drained, and free from water logging
- There should be proper sunlight
- The nursery should be near the water supply so that irrigation can be easy.
- The area should be well protected from pet and wild animals

4.3 Layout

The layout of the orchard is a very important operation. Under this, the arrangement of fruit plants in the plot is carefully done to put the plants at a suitable distance for proper development and for accommodating the requisite number of plants per unit area in addition to improving the aesthetic look of the orchard. Hence, the factors which are considered important for proper layout of the orchard are (i) system of planting and (ii) planting distance of individual fruit species which again would provide the following advantages:

- (i) Allow equidistance for each tree for uniform growth.
- (ii) Allow easy orchard operations like cultivation, intercropping, irrigation, spraying of plant protection chemicals and growth regulators, harvesting etc.
- (iii) Proper utilization of orchard space avoiding wastage of land.
- (iv) Help in proper supervision and management of the orchard.
- (v) Allow further extension of area from time to time so that subsequent planting would match with the existing orchard planting.

The ideal "propagation environment" is at the heart of the nursery, and, therefore, the entire facility should be arranged with respect to it. Container nurseries should always be laid out to utilize the maximum sunlight in the propagation areas. Open growing compounds should be situated to receive maximum sunlight while receiving due protection from wind. They should not be located near large trees, buildings, or other obstructions that can cause shade during the major part of the day. As a general rule, a growing compound should be located at a distance of at least 2.5 times the height of the nearest object to the south, east, and west. Properly located shelterbelts can reduce adverse effects of wind. A well-designed wind barrier or a tree shelterbelt can

significantly reduce heat losses of propagation structures, decrease the irrigation wind drift in shelter houses or open growing compounds, and provide protection from damaging storms. The most important steps for raising seedlings in the nursery are to select a proper site for seedbeds, seed sowing, care of seedbeds, care of seedlings and then transplanting of the seedlings. Growing of plants in the nursery seems to be easy in words but in reality it is a difficult job and can be done effectively and efficiently only after attaining some experience. Thus, it is considered as a specialized job because 15 Types and Components of Nursery one has to acquire fair knowledge about the plants to be raised. Similarly, one should have sufficient knowledge about the cultural requirements of the plants to be raised in the nursery.

Usually seeds of most vegetables (tomato, chillies, brinjal, cabbage, cauliflower etc.) and flowering annuals (daisy, calendula, zinnia, marigold, larkspur etc.) are sown about a month prior to their planting in the field. The seeds of tropical and sub-tropical fruits are sown during monsoon (June - July) or in the beginning of spring (February - March). Generally mango, kagzi



lime and jack fruit seeds are sown during June - July while those of guava, ber and aonla, during February - March. Seeds of temperate fruits are generally available during June - October and their sowing should be done after their dormancy period is over

The seeds are usually sown at a depth 3-4 times of their size. Sowing may be done a little deeper in light soils than in heavy soils. The seed sale depends on many factors, particularly on the species, purpose and spacing.

4.3.1 Planning and Layout

After the selection of the site for the establishment of a nursery, planning may be done in consultation with an experienced horticulturist or a nurseryman. So the cost on establishment, production and marketing can be reduced substantially, besides performing various nursery operations most efficiently and economically. While planning and layout of the nursery, the following components are to be taken care of and provision should be made for them.

4.3.1.1 Fence

Prior to the establishment of a nursery, a good fence with barbed wire must be erected all around the nursery to prevent the trespass of animals and theft. The fence could be further strengthened by planting a live hedge with thorny fruit plants (like Assam Lemon). This also adds beauty in bearing and also provides additional income through sale of fruits and seedlings.

4.3.1.2 Roads and Paths

A proper planning for roads and paths inside the nursery will not only add beauty, but also make the nursery operations easy and economical. This could be achieved by dividing the nursery into different blocks and various sections. But at the same time, the land should not be wasted by unnecessarily laying out of paths and roads. Each road/path should lead the customers to a point of interest in the nursery area.

4.3.1.3 Progeny Block

Progeny block is the block of plants where true-to-type mother plants of superior varieties are maintained in the nursery according to the requirement. The nursery should have a well maintained progeny block or mother plant block/scion block planted with those varieties which are in good demand. The grafts/layers/ rooted cuttings/seedlings should be obtained preferably from the original breeder/research institutes from where it is released or from a reputed nursery. One should remember that the success of any nursery largely depends upon the initial selection of the progeny plants or mother plants for further multiplication. Any mistake made in this aspect will result in a loss of the reputation of the nursery. A well managed progeny block or mother plants block will not only create confidence among the customers but also reduces the cost of production and increases the success rate of grafting/budding/layering because of the availability of fresh scion material throughout the season within the

nursery itself and there will not be any lag period between the separations of scion and graft age.

4.3.1.4 Wells, Pipelines, Generators etc

Fruit and ornamental nursery plants require abundant quantity of water for establishment, growth and development since they are grown in polybags or pots with limited quantity of potting mixture. Hence suitable arrangement should be made to irrigate the seedlings, seed beds, pots etc. In areas with low water yields and frequent power failures, provision to store sufficient quantity of water to irrigate the nursery plants is very much essential. In areas where electricity failure is a problem, an alternative power supply (generator) should be maintained for the smooth running of pumpset. Since water scarcity is a limiting factor in most of the areas particularly during the winter months, a well laid out PVC pipeline system will solve the problem to a great extent. An experienced agricultural engineer may be consulted in this regard for the layout of pipelines. This would facilitate efficient and economic distribution of irrigation water to various components in the nursery.

4.3.1.5 Office–cum-Store

An office-cum-stores is needed for an effective management of the nursery. The office building may be constructed in a place which offers better supervision of the nursery and enables the nursery staff to receive and take care of the customers. The office building may be decorated with attractive photographs of the fruit and ornamental varieties propagated in the nursery with details about them. A store room of a suitable size is needed for storing poly bags, tools and implements, packaging materials, labels, pesticides, fertilizers etc.

4.3.1.6 Seed Beds

In a nursery, this component is essential to raise the seedlings and rootstocks. These are to be laid out near the water source, since they require frequent watering and irrigation. Beds of one meter width of any convenient length are to be made. A working area of 60 cm between the beds is necessary. This facilitates sowing of seeds, weeding, watering, spraying and lifting of seedlings. Irrigation channels are to be laid out conveniently. Alternatively, sprinkler irrigation system may be provided for watering the beds. Sprinkler irrigation helps in uniform germination and seedling growth.

4.3.1.7 Nursery Beds /Poly bag

The raising of seedlings/rootstocks in poly bags requires more space compared to nursery beds but the mortality rate of seedlings/rootstocks is greatly reduced after transplanting. Further, uniformity in the growth of the seedlings/rootstocks can be maintained when raised in poly bags. Nursery bed area should also have a provision to keep the grafted plants in trenches of 30 cm deep and one meter wide so as to accommodate 500 grafts/layers in each bed. Alternatively, the grafts/ layers can be arranged on the ground in beds of one meter wide with 60 cm working place in between the beds. Such beds can be irrigated either with a rose fitted to a flexible hosepipe or by overhead micro sprinklers

4.3.1.8 Potting Mixture and Potting Yard

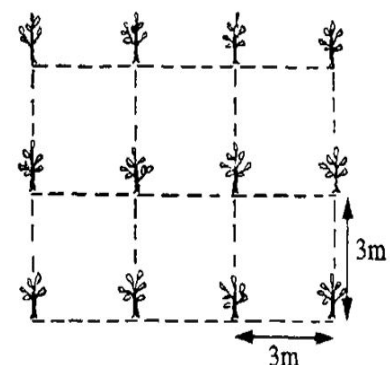
For achieving better success in respect of nursery plants, a good potting mixture is necessary. The potting mixtures for different purposes can be prepared by mixing fertile red soil, well rotten FYM, vermin-compost, leaf mold, oil cakes etc. in different proportions. The potting mixture may be prepared well in advance by adding sufficient quantity of super phosphate for better decomposition and solubilization. The potting mixture may be kept near the potting yard, where potting/pocketing is done. Construction of a potting yard of suitable size facilitates for potting of seedlings or grafting/ budding operations even on a rainy day.

4.4 Planting pattern

The system of planting to be adopted is selected after considering the slope of land, purpose of utilizing the orchard space, convenience etc. Generally, six systems of planting are recommended.

4.4.1 Square system

This system is considered to be the simplest of all the system and is adopted widely. In this system, the plot is divided into squares and trees are planted at the four corners of the square, in straight rows running at right angles. While laying out the plot a base line is first drawn parallel to the road, fence or adjacent orchard, at a distance equal to

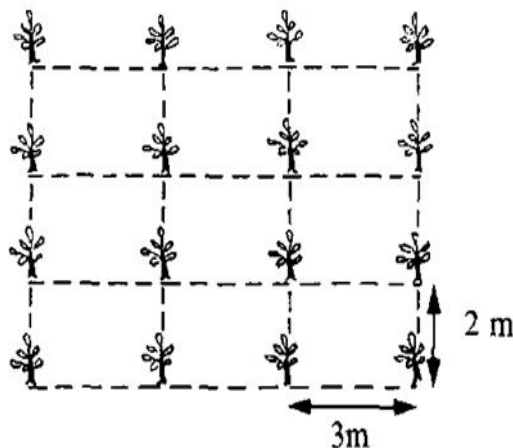


half the spacing to be given between the trees. Pegs are fixed on this line at the desired distances. At both ends of the base line right angles are drawn by following the simple carpenter's 3, 4, 5 meters system. After the formation of three lines it is easy to fix all the other pegs to mark the tree locations in between the lines at the required spacing by using ropes connecting the pegs of the lines in opposite directions.

Under this system, intercultural operations, spraying, harvesting etc., can be done conveniently and easily. Planting of quick growing fruit trees like papaya, banana, guava during the early life of the orchard is possible. Raising of inter-crops like vegetables, ginger, turmeric, cumin, coriander and such other spices can be done conveniently cultivation and irrigation can be done in two directions.

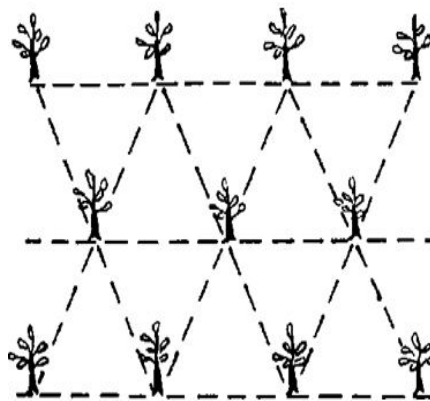
4.4.2 Rectangular system

In this system, the plot is divided into rectangles instead of squares and trees are planted at the four corners of the rectangle in straight rows running at right angles. The same advantages which have been mentioned in the square system are also enjoyed here. The only difference is that in this system more plants can be accommodated in the row keeping more space between the rows.



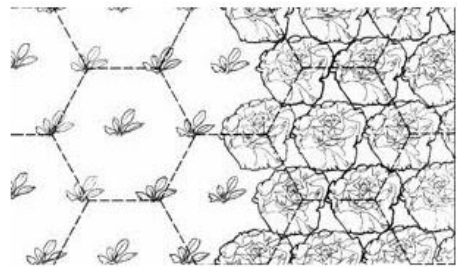
4.4.3 Triangular system

In this system, trees are planted as in the square system but the plants in the 2nd, 4th, 6th and such other alternate rows are planted midway between the 1st, 3rd, 5th and such other alternate rows. This system has no special advantage over the square system except providing more open space for the trees and for intercrops. It is not only a difficult layout but cultivation also in the plots under this system becomes difficult.



4.4.4 Hexagonal system

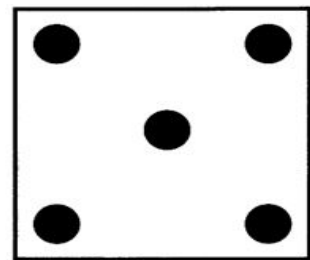
In this system, the trees are planted at the corners of an equilateral triangle and thus, six trees form a hexagon with the seventh tree at the centre. This system is generally followed where the land is costly and very fertile with ample provision of irrigation water. Though 15 per cent more trees can be planted in a unit area by this method over the square system, fruit growers usually do not adopt it, as it is difficult to layout and cultivation in the plot cannot be done so easily as in the square system.



For laying out the plot, a base line is drawn in one side as in the square system. Then an equilateral triangle having rings at each corner and with sides equal to the length of the required distance is made of heavy wire or chain. Two of these rings are then placed on the stakes of the base line and the position of the third ring indicates the position of a tree in the second row. This row is then used as the base line and pegs are set in the third row. In this way entire plot is laid out.

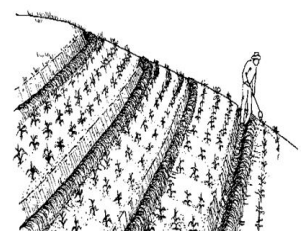
4.4.5 Quincunx system

This system of planting fruit trees is similar to square system, except that a fifth tree is planted at the centre of each square. As a result the tree number in an unit area becomes almost double the number in the square system. The additional tree in the centre is known as “filler”. The fillers are usually quick growing, early maturing and erect type fruit trees like banana, papaya, pomegranate, etc., which are removed as soon as the main fruit trees planted at the corner of the square come into bearing. The planting of filler trees provides an additional income to the grower in the early life of the orchard.



4.4.6 Contour system

It is generally followed on the hills with high slopes. It particularly suits to a land with undulated topography, where there is greater danger of erosion and irrigation of the orchard is difficult. The main purpose of this system is



to minimize land erosion and to conserve soil moisture so as to make the slope fit for growing fruits. So, the contour line is designed and graded in such a way that the flow of water in the irrigation channel becomes slow and thus finds time to penetrate into the soil without causing erosion.

4.5 Spacing

One of the advantages of artificial regeneration over natural regeneration is the control of no. of trees per unit area and their uniform distribution over the land area. An optimum spacing will produce the greatest volume in proper size form and quality of trees required. Trees with wider spacing grow more rapidly than those planted in narrow spacing. Trees planted at wider spacing have greater taper, thicker branches with deeper and wider crowns. Closer spacing is adopted in order to facilitate natural pruning for production of clean and straight bole. Too close spacing results in thinner diameter of trees. The spacing depends upon 1) Site 2) purpose 3) Management 4) Species.

4.6 Season of Planting

Planting seasons varies with the species and the commencement of monsoon, Teak and *D. sissoo* stumps are planted with the onset of rains. *Casuarina*, *Eucalyptus* and other pot culture plants are planted after the monsoon sets in or advanced to some extent. In the east coast where north east monsoon is dependable, planting is done in September – October. In area of South west monsoon planting is done during June – July.

4.7 Taungya System of cultivation

- The taungya system was used primarily as an inexpensive means of establishing timber plantations but is finally a recognized AF system.
- The taungya (taung = hill, ya = cultivation) is a Burmese word coined in Burma in 1850. The system was introduced to India by Brandis in 1890 and the first taungya plantations were raised in 1896 in North Bengal.
- It was introduced to S Africa in 1887 and was taken to Chittagong and Sylhat (Now in Bangladesh) in 1870.
- In India it started in 1896 in North Bengal. In 1890, it was introduced to Coorg in Karnataka. Regular plantation however started in North Bengal in 1911 for

raising Sal plantations and in 1912, extended for raising Teak. In 1923 it was adopted in UP for raising Sal plantations.

- It is still practiced in the states of Kerala, West Bengal, Orissa, Karnataka and the north- eastern hill region.
- This is a modified form of shifting cultivation in which the labour is permitted to raise agri-crops in an area but only side by side with the forest species planted by it. The practice consists of land preparation, tree planting, growing agricultural crops for 1-3 years, until shade becomes too dense, and then moving on to repeat the cycle in a different area. A large variety of crops and trees, depending on the soil and climatic conditions, are grown in India. In fact this system was introduced to raise forest plantations, but finally became recognized agroforestry system.

4.7.1 Types of Taungya

- Departmental Taungya:** Under this, agricultural crops and plantation are raised by the forest department by employing a number of labourers on daily wages. The main aim of raising crops along with the plantation is to keep down weed growth.
- Leased Taungya:** The plantation land is given on lease to the person who offers the highest money for raising crops for a specified number of years and ensures care of tree plantation.
- Village Taungya:** This is the most successful of the three taungya systems. In this crops are raised by the people who have settled down in a village inside the forest for this purpose. Usually each family has about 0.8 to 1.7 ha of land to raise trees and cultivate crops for 3 to 4 years.

Table 1: Trees and crops grown in Taungya across the country

State	Tree crop	Associated agricultural crops
U.P.	<i>Shorea robusta</i> , <i>Tectona grandis</i> <i>Acacia catechu</i> , <i>Dalbergia sisso</i> , <i>Eucalyptus spp.</i> <i>Populus spp.</i>	Maize, paddy, sorghum, pigeon-pea, soyabean, wheat, barley, chick-pea, rape-seeand miscellaneous

Andhra Pradesh (AP)	<i>Anacardium occidentale</i> , <i>Tectona grandis</i> , <i>Bombax ceiba</i> , <i>Bamboo</i> , <i>Eucalyptus spp.</i>	Hill paddy, groundnut, sweet potato
Kerala	<i>Tectona grandis</i> <i>Bombax ceiba</i> <i>Eucalyptus spp.</i>	Paddy, tapioca, ginger, turmeric, etc.
Assam	<i>Shorea robusta</i> , <i>S assamica</i>	Paddy
Tamil Nadu	<i>Tectona grandis</i> , <i>Santalum album</i> <i>Tamarindus indica</i> , <i>Acacia nilotica</i> <i>Acacia mearnsii</i> , <i>Ceiba pentandra</i> <i>Cashew</i> , <i>Rubber</i> , <i>Bamboo</i>	Millet, pulses, groundnut, cotton
Andaman and Nicoba Islands	<i>Pterocarpus dalbergioides</i>	Sugar-cane, maize
Maharashtra	<i>Tectona grandis</i> , <i>Acacia nilotica</i>	Sunhemp, jute, mesta, sunflower, castor etc.
Tripura	<i>Shorea spp.</i> , <i>Schima spp.</i> , <i>Michelia spp.</i>	Paddy, maize etc
West Bengal	<i>Tectona grandis</i> , <i>Shorea robusta</i> <i>Schima wallichii</i> , <i>Cryptomeria japonica</i> , <i>Quercus spp.</i> <i>Michelia doltsoa</i>	Paddy, maize, millets, turmeric, ginger, lady's, finger, pineapple, sunhemp
Karnataka	<i>Tectona grandis</i> , <i>Santalum album</i> , <i>Cassia siamea</i>	Paddy, tapioca, etc.

4.7.1.1 Advantages of Taungya

- Artificial regeneration of the forest is obtained cheaply;
- Problems of unemployment are solved;
- Helps towards maximum utilization of the site;
- Low cost method of forest plantation establishment;
- In every case, highly remunerative to the forest departments;
- Provision of food crops from forest land; and
- Weed, climber growth, etc. is eliminated.

4.7.1.2 Disadvantages of Taungya:

- Loss of soil fertility and exposure of soil;
- Danger of epidemics;
- Legal problems created;
- Susceptibility of land to accelerated erosion increases; and,
- It is a form of exploitation of human labour

4.8 Enrichment planting

Enrichment planting is one of the important techniques used in forest rehabilitation. It is defined as 'the introduction of valuable species to degraded forest without elimination of valuable species which already exist at that particular site. It is commonly used for increasing the density of desired species in the secondary forest. The word enrichment plantation means plantation for beauty. The word enrichment also means to fertilize or to make rich. Enrichment planting can be used successfully to increase the value of secondary forests and prevent their conversion to other land uses. Thus, reducing deforestation. Enrichment planting could be an important land use strategy in context of the current international attempts to control deforestation in developing countries. Enrichment planting involves planting of indigenous and exotic species in large gaps. The plants can be collected from the seedlings in the forest floor or they can be grown in the nurseries before planting.

Selection of species for planting: Ideally, priority must be given to planting of high quality species that are indigenous to the areas to be enriched. In introducing the species that are exotic to the site, every effort must be given towards matching the introduced species to the local site conditions. This avoids the waste of money, efforts as well as the disappointment from failure resulting from the introduction of the wrong species. Select the species for enrichment planting on the basis the following silvicultural features:

- (i) Frequent flowering.
- (ii) Easy nursery handling.
- (iii) High germination rate.
- (iv) Fast height growth in early stages.

- (v) Tolerant to drought and site competition.
- (vi) High survival rate.
- (vii) Naturally self pruning.
- (viii) Normally free from all types of insect and diseases.
- (ix) Rapid growth in girth.
- (x) Producer of timber of high quality.

4.9 Nurse and Cover Crops

Nurse Crops: Nurse Crops are those which are raised with the primary object of helping up a less hardy species. They are usually removed at an early stage as soon as they have served their purpose. The nurse crops are usually raised to protect the main crop from sun, frost and other natural and biotic factors. The examples are as under:

- *Dipterocarpus turbinatus* - *Gmelina arborea* to protect from sun.
- Sal, Teak, *Macaranga* spp., arhar, castor etc., to protect from sun.
- Tephrosia- Castor to protect from frost etc.
- The nurse crops are raised mainly for the benefit of shade bearer species which are frost tender in initial stages. The nurse crop selected should not become leafless during winter season.
- These are meant for tender spp and tenderness is usually in younger age. So for this, an additional crop is raised under which the actual crop is grown. The guardian crop is grown first after which the actual crop is raised.
- Some spp are shade bearing. Such spp are so tender that they are killed by direct sunlight, some are less shade bearing, and others are more. For instance, some firs have open wide forest in the hill. This is due to the reason that seedlings are hypersensitive but in later ages, they become hardy and light demander.
- For *Abies pindrow*, nurse crop is *Pinus wallichiana* (blue pine) is required. Walnut and Poplar can also serve the same purpose.
- Another example is an IP of Punjab where Shisham is serving as a nurse crop for mulberry.

Cover Crop: The cover crops are subsidiary species usually low shrubs but sometimes small trees or even herbs intentionally introduced into a plantation with the primary object of restoring a cover to the soil as quickly as possible to minimize risk of soil erosion due to exposure. The cover crop checks surface erosion adds organic matter and restores humus to the soil and improves physical and chemical properties of soil and keeps away injurious weeds and grasses. They also improve soil aeration. Cover crop is often required for tea, rubber and other economic crops. The leguminous shrubs and creepers are efficient cover crops. *Tephrosia candida* has been most widely used in forest plantations (sal etc.) of Bengal and Assam. The other cover crops are *Indigofera tinctoria* (in first year of sal plantation), *Crotalaria juncia*, *Desmodium spp.*, *Leucaena glauca*, *Imperata* grass etc.

The cover crop is introduced in between the seedling lines. Sometimes soil working, weeding etc. may be required for establishing a cover crop. It may take away nutrition from the soil but the cover crop is beneficial for the main crop in the long run. A cover crop is meant for covering soil. Interspaces are not covered especially in case of light demanders. Since crowns hardly touch each other, the soil is either occupied by weeds or exposed to light wind and rains. So it needs protection against erosion hazard and improvement in fertility as well. For this purpose some leguminous shrubs, small trees or herbs are grown but until now there is no good cover crop available in Pakistan and almost all crops compete with actual species.

Unit 5: Choice of Species for Plantation on Ecological Aspects

Unit Structure

5.0 Learning Objectives

5.1 Introduction

5.2 Ecological zones and choice of species

5.3 Afforestation of dry land

5.4 Afforestation of wet land and other adverse or problematic sites

5.4.1 Afforestation of drought prone areas

5.4.2 Afforestation of marshy areas

5.4.3 Afforestation of saline land areas

5.4.4 Afforestation of sandy soils areas

5.4.5 Inland River Sand

Summary

5.0 Learning Objectives

On completion of this unit you should be able to understand about:

- What is afforestation?
- Ecological zones and choice of species
- Afforestation of dry lands, drought prone areas and marshy areas
- Afforestation of saline land areas and sandy soils

5.1 Introduction

There is enormous diversity in the range of ecological conditions in the Indian subcontinent. This has given rise to many problems and at the same time opportunities in tree planting at different sites. The choice of species is determined not only by the climatic or edaphic variations but also by the pressing needs of the local community. The species planted must supply wood products as well as non-wood requirements for the present and future generations. India is rich in flora and there is no dearth of species for different purposes out of which selection can be made for planting in the diverse ecological tracts.

The exotics which have been successfully planted can also be selected for plantation. The essential features of a locality are-

(i) Soil, (ii) Water, (iii) Temperature, (iv) Humidity and (v) Biotic Factors.

Planting a given area is quite expensive therefore, the sound knowledge of climatic elements and the effects of weather and soil on plant establishment and growth must be known to the planter in addition to the nursery technique and silvicultural requirements of the species selected for planting. The plantation must cater to the socio-economic development of the people in accordance with the National and State policy in forestry. For growing timber the species having large rotation are suitable in the forests whereas for raising fuel wood, fruit and medicinal plants indigenous or exotic trees having medium to short rotation may be desirable.

The objects of plantations may be categorized as below-

(a) Industrial Uses: Timber, pulpwood, paneled products, hardboards, plywood, packing cases, furniture, match sticks, lac cultivation, tussor silk production etc.

(b) Domestic uses: Poles, Fuel wood, scaffolding, fodder, fruits, flowers and many other miscellaneous uses.

(c) Protective uses: Soil and water conservation, shelter belts or windbreaks, development of wastelands, etc.

(d) Other uses: Control of pollution, roadside, avenue and hill beautification, landscaping, environmental conservation.

While taking up plantations the preliminary studies or knowledge of the following items is necessary:

- (i) Selection of species according to ecological zones.
- (ii) Technique of plantation viz. polypot planting, root shoot planting etc.
- (iii) Influence of wind breaks on crop production.
- (iv) Silvipastoral systems to create grazing reserves. etc.
- (v) Yield of timber, fuelwood, resins, gum, lac, bamboo, rubber, etc.
- (vi) Management of species for leaf fodder, fruits, flowers etc.

- (vii) Ease of establishment and growth rate.
- (viii) Coppicing ability.
- (ix) Resistance to pests and diseases.
- (x) Marketability of the produce.

Economic significance of tree planting varies widely from region to region depending on the utility and value of different species. Now-a-days plantations are being raised on the denuded lands, canal sides, roadsides, along the railway lines and on all types of waste-lands available. Some plantations in arid regions have shown gains by tree planting and it is sure that entire socio-economic development of arid and semi-arid regions can be changed by proper management of land by large scale plantations. Many species are capable of growing in spite of the inhospitable conditions and most of - these can meet chronic fodder and fuel shortage, small timber and other forest products. In the past the choice was restricted to *Prosopis* and sometimes to *Acacias* but now a large number of species have been successfully established e.g. *Azadirachta indica*, *Pongamia pinnata*, *Albizia lebbek*, *Parkinsonia aculeata*, *Tecomella undulata*, *Zizyphus mauritiana* and many shrubs yielding fuelwood, fruits and fodder, etc. The feasibility of a tree planting programme would however, be limited by various institutional and market constraints and overall compulsions of social attitudes. It is important to consider in the domain of its objectives the scope, impact on farm output, production of fodder and fuel, rural employment and role in ecological security.

Afforestation : Raising of forest crop on lands which were not originally forested and it may be undertaken for productive protective and bio-aesthetic purpose.

Objectives of afforestation : The main objectives of afforestation is to bring out over all development and prosperity in the area.

- (i) To meet the needs of fuel wood, fodder, small timber and other minor forest produce.
- (ii) To release the cow-dung as a manure for increasing agriculture production.
- (iii) To provide gainful employment opportunities to the rural masses.
- (iv) To develop cottage industries in rural areas.

- (v) To utilize all available land according its productive capacity to the best advantage.
- (vi) To provide efficient soil and water conservation.
- (vii) To improve the aesthetic value of the area and to meet recreational needs of the people.
- (viii) As integrated development programme it aims to bring out overall development of the rural areas.

5.2 Ecological zones and choice of species

An Ecological Zone (EZ) is defined as: "A zone or area with broad yet relatively homogeneous natural vegetation formations, similar (not necessarily identical) in physiognomy. Boundaries of the EZs approximately coincide with the map of Köppen-Trewartha climatic types, which was based on temperature and rainfall. An exception to this definition are "Mountain systems", classified as one separate EZ in each Domain and characterized by a high variation in both vegetation formations and climatic conditions caused by large altitude and topographic variation" (Simons, 2001).

The woodland development programme covers a wide range of habitats and topographical features. However, because of tremendous diversity of locality factors, it is difficult to inventory land capability for all species accurately. But before deciding choice of species study of ecological factors such as climate, landform, soil profile, moisture, depth and fertility is required.

India can be divided into three major ecological zones e.g. temperate region, sub-tropical region and tropical region and ten sub-zones based on the climatic considerations mainly rainfall and temperature. These zones and the tree recommended for planting are described below. Priority in the choice of species in each sub-zone should be given to those which have been successfully planted in each area.

(A) Temperate Region

The temperate region is distributed in the states of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh, West Bengal and Arunachal Pradesh along the Himalayas in the North and Kerala and Tamil Nadu in the Nilgiris in the South. These regions have

extremely low temperature in the winter which often goes down below freezing point. Temperature is determined more by altitude than by latitude. Fall of 1°C in temperature occurs with 270m rise in altitude and above 1500 m height the fall is more rapid. The entire temperate region can be further sub-divided into the following four sub-regions mainly on the basis of precipitation. They are: (i) Wet temperate sub-region. (ii) Moist temperate sub-region. (iii) Dry temperate sub-region, and (iv) Southern temperate sub-region.

(i) **Wet Temperate Sub-Region:** This region occurs in the Eastern Himalayas on the higher hills of West Bengal, Arunachal Pradesh and Nagaland. The terrain of this region is entirely hilly and usually steep. The altitude in these hilly regions varies from 1800m to 3000m where it merges with sub-alpine region. The mean minimum temperature during the three winter months of December to February for the middle of the zone is near to freezing point. The region falls under the high monsoon rainfall of at least 2000 mm or even more. The winter months November to March are relatively dry with less than 60mm rainfall monthly but good showers fall in April. In July monthly rainfall is 670mm or more. Dense mist during monsoon is the main climatic feature of this region. The species recommended are - *Abies densa*, *Acer campbelli*, *Alnus nepalensis*, *Betula utilis*, *Betula alnoides*, *Carpinus viminea*, *Cryptomeria japonica*, *Cupressus torulosa*, *Exbucklandia populnea*, *Juglans regia*, *Lithocarpus pachyphylla*, *Machillus odoratissima*, *Picea smithiana*, *Populus ciliata*, *P.alba*, *Prunus padus*, *P. persica*, *P. cerasoides*, *P. nepalensis*, *Quercus spp.*, *Salix alba*, *S. babylonica* and *S. viminalis*.

(ii) **Moist Temperate Sub-Region:** This region extends along the whole length of the Himalayas occurring in Kashmir, Himachal Pradesh, Uttar Pradesh, West Bengal, Sikkim and Bhutan. The altitude varies from 1500m to 3300m, limits varying with aspects and configuration. The terrain is hilly with steep slopes. The precipitation is mainly from south-west monsoon and falls during July to September. In north-west some precipitation is brought by north-west winds during the winter months. This falls largely as snow and is undoubtedly a factor of importance in deciding the growth of species in this region. The mean annual rainfall in this region varies from about 1000 to 2000 mm. The temperature varies from 5°C (mean minimum) to 20°C (mean

maximum). The soil shows a wide range but loam is predominant. The forests once upon a time had luxuriant oak crops.

The species recommended for this region are - *Abies pindrow*, *Acer acuminatum*, *A. campbelli*, *A. oblongum*, *Aesculus indica*, *Alnus nepalensis*, *A. nitida*, *Betula utilis*, *Celtis australis*, *Coriaria nepalensis*, *Cupressus cashmeriana*, *Eucalyptus saligna*, *Fraxinus excelsa*, *Juglans regia*, *Morus alba*, *M. nigra*, *Picea smithiana*, *Pinus wallichiana*, *Populus alba*, *P. ciliata*, *P. deltoides*, *P. nigra*, *Prunus persica*, *P. domestica*, *P. padus*, *Quercus species*, *Salix species*, *Toona serrata* and *Ulmus wallichiana*.

(iii) Dry Temperate Sub-Region: It includes parts of Kashmir hills (Ladakh), Himachal Pradesh (Lahaul-spiti), Uttar Pradesh (Inner Garhwal) and parts of Sikkim. This type is confined to hilly country with altitude above 1700m, and most of this is on steep often rocky slopes. Soil in this region has formed as a result of disintegration and crumbling of mountain rocks due to extreme temperature amplitude. Glacial and alluvial deposits are also common. High mountain peaks are usually snow covered with incidence of awlanches. The area is very dry around most of the year due to the fact that moisture remains frozen and unavailable for a long time due to low temperature and also due to low atmospheric humidity and high wind that sweeps through the valleys. Erosion hazard of these terrain is different from the Himalayan region where concentrated precipitation is the principal factor accentuated by the terrain conditions and prevalent landuse practices. The mountains are stony with precipitous cliffs. Tree planting can be taken up by making moisture available through management and harvesting of water from the snow channels and the little precipitation that occurs in the region. Following species can be planted in this zone: *Juglans regia*, *Juniperus communis*, *J. polycarpus*, *J. squamata*, *Morus alba*, *Populus species*, *Pinus girardiana*, *Prunus amygdalis* and *Salix species*.

(iv) Southern Temperate Sub-Region: It includes high hills of Tamil Nadu and Kerala (Nilgiri, Annamalai, Palni and Tirunelvali) with altitude above 1500m. The total climate February to combined about rainfall is 6250mm with is equitable and typically a and well or its even distributed the seasonal is driest more conditioned month. rainfall The

distribution south-west Rainfall from by the both monsoon varies mountain the monsoons. From considerably gives situation 1500mm rain The in April onwards with a maximum in June and July, followed by a drier August/September and then north-east monsoon giving a second spell in October. December to March is the driest period. The relative importance of two monsoons depends on situation and exposures. The annual range between the highest and the lowest temperature of the year is only 9°C. This region is exposed to high winds and adverse effects of high winds are seen on the tree vegetation. The forest is usually found in patches (sholas) in the more sheltered sites. The soil is reddish or yellow clayey soil. The following species can be planted in this region - *Acacia dealbata*, *Acacia mearnsii*, *Acacia decurrens*, *Acacia melanoxylon*, *Eucalyptus globulus*, *Eucalyptus citriodora*, and *Pinus petula*.

(B) Sub-Tropical Region

Above the submontane tropical region and below the temperate zone, the principal sub-tropical zone forms a somewhat crescent shaped band sweeping right along the length of the Himalayas and the adjoining chain of hillocks, from Jammu and Kashmir to Arunachal Pradesh. It is mostly confined to outer Himalayas but also penetrates deep into the inner valleys. This zone also covers the upper reaches of the Khasi, the Jaintia and the nearby hills, the higher hill tops of central Indian highlands and the annular rings circumscribing temperate areas of higher hill tops of south India. This zone is roughly confined between elevations of 1000m to 2000m. The aspect factor plays a major role. This broad region can be sub-divided into three main sub-regions.

(i) Wet sub-tropical, (ii) Moist sub-tropical and (iii) Dry sub-tropical.

(i) **Wet Sub-Tropical Sub-Region:** This includes parts of the Western Ghats falling in Kerala, Karnataka, Tamil Nadu and Maharashtra. This area also extends along the lower hills of West Bengal, Assam and parts of the Arunachal Pradesh and adjoining areas. This region is generally hilly with altitude ranging between 1000-2000 m. The mean annual temperature variation is from 15°C to about 25°C. Frost is not severe but affects plants. Moisture is the main variable and deciding factor in planting practices. The range of annual rainfall is wide and it varies from 2000 mm to 2600 mm

with exceptionally high rainfall of 10,800 mm at Cherapunji. The length of the dry season varies from virtually none to seven months mainly in southern India. The soil is intermediate between tropical red earth and the temperate brown earth in southern India. There may be a thick lateritic cap covering trap rock and a typically laterite soil, (Maharashtra).

The following species are recommended for this region *Acrocarpus fraxinifolius*, *Aesculus assamica*, *Acer thomsoni*, *Albizzia species*, *Ailanthus grandis*, *Alnus nepalensis*, *Bauhinia species*, *Bombax ceiba*, *Cupressus cashmeriana*, *Duabanga grandiflora*, *Exbucklandia populnea*, *Eucalyptus spp .*, *Garcinia paniculata*, *Grevillea robusta*, *Grewia elastica*, *Melia azedarach*, *Morus species*, *Stereospermum personatum*, *Mesua ferrea*, *Phoebe lanceolata*, *Populus species*, *Pinus petula*, *Salix alba*, *S. babylonica*, *S. viminalis*, *Stereospermum personatum*, *Terminalia species*, *Quercus spp .*, and *Toona ciliata*.

- (ii) **Moist Sub-Tropical Sub-Region:** It includes parts of Uttar Pradesh, Himachal Pradesh, West Bengal, Assam, Arunachal Pradesh, Tripura, Manipur and hills of Madhya Pradesh, Maharashtra and Orissa. The terrain is hilly. The altitude ranges between 800m to 1800m extending on ridges down to 600m. On southern exposure the region is stretched upto an altitude of 2300m. The mean annual temperature lies between 15°C and 20°C. The rainfall is largely derived from south-west monsoon falling in the summer months varying from 1000mm to 3000mm. The following species are recommended for planting in this region- *Acacia catechu*, *Acer oblongum*, *Aesculus species*, *Acrocarpus fraxinifolius*, *Albizzia species*, *Alnus nitida*, *Alnus nepalensis*, *Anogeissus latifolia*, *Bauhinia species*, *Celtis australis*, *Cupressus cashmeriana*, *Chukrasia velutina*, *Dalbergia latifolia*, *Dalbergia sissoo*, *Duabanga grandiflora*, *Erythrina variegata*, *Eucalyptus grandis*, *Eucalyptus saligna*, *Grewia optiwa*, *Grevillea robusta*, *Holoptelea integrifolia*, *Melia azedarach*, *Mesua ferrea*, *Mesua oblonga*, *Morus species*, *Pinus roxburghii*, *Populus deltoides*, *Pinus kesiya*, *Pinus petula*, *Pinus caribaea*, *Prunus armenica*, *P. communis*, *P. domestica*, *Salix viminalis*, *Stereospermum personatum* and *Terminalia myriocarpa*.

(iii) **Dry Sub-Tropical Sub-Region:** This region includes parts of Jammu, Punjab, Haryana, Uttar Pradesh and Himanchal Pradesh (Bhabhar, Siwalik and foothills of the Himalayas). It is characterized by a long hot and very dry season and a cold winter with extending the main rarely dry season and a cold winter with occasional frost. The annual rainfall rarely exceeds and 1000mm but is usually over 500 mm occurring a mostly in July-August but with a fair proportion of winter rains. Soil is usually shallow and dry and vegetation is quite sparse. Vegetation is often sparse and sometimes hillsides are totally devoid of any tree growth. The species recommended are - *Acacia catechu*, *Acacia modesta*, *Anogeissus latifolia*, *Albizzia lebbek*, *Azadirachta indica*, *Bombax ceiba*, *Dalbergia sissoo*, *Dendrocalamus strictus*, *Dodonea viscosa*, *Emblica officinalis*, *Kydia calycina*, *Eucalyptus camaldulensis*, *Holoptelea integrifolia*, *Ougenia oojeinensis* and *Pinus roxburghii*.

(C) Tropical Region

The tropical region in India is the most extensive and includes major parts of the country excluding the Himalayas and the hill ranges of the penninsular India above 1000m. This region has prolonged humid summer and absence of pronounced winter. The mean annual temperature in this region is over 24°C and the mean January temperature is around 18°C. The rainfall varies from as low as 250mm to as high as 6000 mm. This region can be sub-divided into the following three sub regions:-

(i) Wet tropical sub-region, (ii) Moist tropical sub-region and (iii) Dry tropical sub-region.

(i) **Wet Tropical Sub-Region:** It includes tropical areas of Maharashtra, Karnataka, Tamil Nadu, Kerala, West Bengal and Assam wherever the rainfall is high and its distribution satisfactory. This region occurs in flat or hilly undulating land on gentle slopes from almost sea level extending through valleys to about 1200 mm or so. It also includes flat lands of the Gangetic plain. The mean annual temperature lies between 22°C to 27°C. In north India temperature goes down to 10°C compared with a typical 2000mm figure of to 16°C about for 6000 southern India. The species recommended are: *Acacia nilotica*, *Acacia modesta*, *Albizzia species*, *Aesculus Bambusa D. sissoo*, *B. indica*, *Artocarpus nutans*, *Holoptelea spp*, *Casuarina .*, *chaplasha*, *Duabanga equisetifolia*, *integrifolia*, *Artocarpus grandiflora*, *Mangifera indica*, *Mesua ferrea*,

Morus alba, Michelia champaca, Melocanna baccifera, Pterocarpus dalbergioides, Salix tetrasperma, Sesbania grandiflora, Terminalia species, Trewia nudiflora and Shorea assamica.

- (ii) **Moist Tropical Sub-Region:** This region covers a large part of India and occurs in almost all the states viz. Andhra Pradesh, Assam, Arunachal Pradesh, Bihar, Gujarat, Kerala, Karnataka, Maharashtra, Madhya Pradesh, Orissa, Tripura, Uttar Pradesh and West Bengal.

This region has varied terrain consisting of flat ground, fairly flat plateau and hilly or undulating ground. The mean annual temperature is around 26°C in southern India and 24°C in northern India. The mean maximum temperature varies from 30°C to 34°C and in isolated localities it goes upto and above this. The rainfall is mostly confined to four monsoon months of June to September and ranges from 1500 mm to 3000 mm. The dry season is short or moderate. The soil factors vary widely. Most of the area is covered by tropical red soil in the southern region and alluvial in the north. Black humus rich soils are also encountered in some localities.

The species recommended are- *Acacia auriculiformis, A. catechu, A. nilotica, Adina cordifolia, Aegle marmelos, Aesculus assamica, Ailanthus excelsa, Albizzia species, Anacardium occidentale, Anthocephalus cadamba, Anogeissus latifolia, Azadirachta indica, Artocarpus species, Bambusa nutans, B. tulda, Bauhinia species, Boswellia serrata, Cassia fistula, Cassia melanoxylon, siamea, Cordia Dendrocalamus myxa, Dalbergia strictus, sissoo, D. D. latifolia, Diospyros species, Garcinia Gmelina arborea, hamiltonii, Erythrina Kydia calycina, Melia Lannea indica, azedarach, grandis, Pithecollo-Madhuka Holoptelea integrifolia, indica, Mangifera indica, species, Morus Samanea alba, Swietenia mahasaman, bium dulce, Pterocarpus Tectona grandis, Mesua ferrea, Pongamia pinnata, goni, Terminalia Salix tetrasperma, species, Santalum album, Schleicheria trijuga, Shorea assamica, Toona ciliate and Zizyphus mauritiana.*

- (iii) **Dry Tropical Sub Region:** It includes parts of Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh, Rajasthan, Tamil Nadu and Karnataka in the western and Southern region of Punjab, Uttar Pradesh, Bihar, Orissa, West Bengal in the Northern

and eastern region. A large variety of rock types are exhibited in this region. The soil is dry for most part of the year. Soil and water conservation measures in this zone are critical factors for stand establishment. The following species are recommended for this region- *Acacia auriculiformis*, *A. catechu*, *A. modesta*, *A. nilotica*, *Aegle marmelos*, *Albizia amara*, *A. lebbek*, *Azadirachta indica*, *Cassia fistula*, *C. siamea*, *Dalbergia sissoo*, *Emblia officinalis*, *Ficus species*, *Leucaena leucocephala*, *Pongamia pinnata*, *Santalum album*, *Syzygium cumini*, *Terminalia belerica*, *Tectona grandis* and *zizyphus mauritiana*.

TABLE 2
FAO Global Ecological Zoning framework for 2000 (from Simmons (2001))

EZ Level 1 – Domain		EZ Level 2 – Global Ecological Zone		
Name	Criteria (Equivalent to Köppen-Trewartha Climatic groups)	Name (reflecting dominant zonal ^a vegetation)	Code	Criteria (approximate equivalent of Köppen – Trewartha Climatic types, in combination with vegetation physiognomy and one orographic zone within each domain)
Tropical	All months without frost: in marine areas over 18°C	Tropical rain forest	TAr	Wet: 0 – 3 months dry ^b . When dry period, during winter
		Tropical moist deciduous forest	TAWa	Wet/dry: 3 – 5 months dry, during winter
		Tropical dry forest	TAWb	Dry/wet: 5 – 8 months dry, during winter
		Tropical shrubland	TBSh	Semi-Arid: Evaporation > Precipitation
		Tropical desert	TBWh	Arid: All months dry
		Tropical mountain systems	TM	Approximate > 1000 m altitude (local variations)
Subtropical	Eight months or more over 10°C	Subtropical humid forest	SCf	Humid: No dry season
		Subtropical dry forest	SCs	Seasonally Dry: Winter rains, dry summer
		Subtropical steppe	SBSH	Semi-Arid: Evaporation > Precipitation
		Subtropical desert	SBWh	Arid All months dry
		Subtropical mountain systems	SM	Approximate > 800-1000 m altitude
Temperate	Four to eight months over 10°C	Temperate oceanic forest	TeDo	Oceanic climate: coldest month over 0°C
		Temperate continental forest	TeDc	Continental climate: coldest month under 0°C
		Temperate steppe	TeBsk	Semi-Arid: Evaporation > Precipitation
		Temperate desert	TeBWk	Arid: All months dry
		Temperate mountain systems	TeM	Approximate > 800 m altitude
Boreal	Up to 3 months over 10°C	Boreal coniferous forest	Ba	Vegetation physiognomy: coniferous dense forest dominant
		Boreal tundra woodland	Bb	Vegetation physiognomy: woodland and sparse forest dominant
		Boreal mountain systems	BM	Approximate > 600 m altitude
Polar	All months below 10°C	Polar	P	Same as domain level

^a Zonal vegetation: resulting from the variation in environmental, i.e. climatic, conditions in a north south direction.

^b A dry month is defined as the month in which the total of precipitation P expressed in millimeters is equal to or less than twice the mean Temperature in degrees Centigrade.

5.3 Afforestation of dry land

(A) Afforestation of Dry Areas without Irrigation

Dry areas may be defined as an area which receives less than 900 mm of rainfall in a year. According to this definition about two fifth of the whole country falls in dry zone which extends practically in all states except Assam and Meghalaya.

The soil varies from place to place with the underlying rock. Denudation has deteriorated it considerably. Annual rainfall varies from about 250mm to 750 mm and it falls in a limited number of showers. Thus the number of rainy days varies from 14 in Barmer (Rajasthan) to 57 in Mysore. During summer, the temperature, which may, at selected places, go as high as 50°C, is generally high while during the winter, frosts are very serious. Pressure of human and animal population is great and this poses a great threat to Afforestation work.

(i) **Soil Preparation:** As the areas are dry, soil preparation is done in such a way so as to conserve maximum moisture and also to facilitate development of a deep root system. This can be achieved by digging the soil as deep as possible. If the area is sloping, interrupted contour trenches are made. The dug up soil is usually filled in a ridge-ditch pattern or heaped in the form of ridge along the lower side of the trench, after pickaxing the ground. The soil should not be heaped into a ridge on a hard ground as the roots on reaching it do not penetrate it but turn to a side along the hard surface. As they have no contact with permanent soil moisture, they die on drying up of the heaped soil. Various methods of soil preparation suggested by Seth have already been described earlier and any one of those suitable for the locality may be adopted.

(ii) **Choice of species:** For such difficult sites, only those species should be selected which are fast-growing as well as frost and drought-resistant. The following are some of the species which are commonly used: *Acacia arabica*, *A. senegal*, *A. leucophloea*, *catechu*, *A. tortilis*, *Dalbergia sissoo*, *Albizia lebbek*, *Holoptelia integrifolia*, *Ailanthus excels'*, *Ziziphus*, *Pongamia*, *Cassia fistula*, *C. siamea*, *Azadirachta indica*, *Casuarina*, *Eucalyptus*, *Prosopis juliflora*, *P. cineraria*, *Anacardium*, *Pterocarpus santalinus*, etc.

(iii) **Method of sowing and planting:** Most of the species can be raised by direct sowing cheaply but as moisture is a limiting factor, it is better if plants raised in polythene bags are planted out, as far as possible.

(B) Afforestation of Dry Areas with Irrigation

Afforestation of dry areas with irrigation is done on a small scale • a few states because available irrigation is not even sufficient for agricultural fields. However, irrigated plantations have been raised in Haryana, Rajasthan and to limited extent, in Tamil Nadu.

(i) **Factors of locality:** The area is mostly thorn scrub forest in which *Prosopis spicigera*, *Capparis decidua*, *Salvador' oleoides* and *Tamarix aphylla* predominate. While the area is generally heavily grazed and often cleared for cultivation, the existing species are heavily lopped and browsed.

In order to irrigate, the areas should be level as far as possible. But generally mounds of blown sand occur. Soil varies from sandy to clayey. Occasionally pH is high and there is 30 to 100 cm thick kankar pan, usually at a depth of 1 to 2 metres. Above this there is generally a thinner kankar pan 15 to 25 cm thick at a depth of 60 to 90 cm below the surface. In Rajasthan, however, there are only kankar nodules but nopan. While water table in Haryana is about 8 m deep and is rising at an alarming rate due to Bhakra canal system, it is very deep in Rajasthan. Rainfall varies from place to place. In fianumangarn (Rajasthan) it is only 260 mm. But in Saraswati irrigated plantations of Haryana it is about 800 mm. The maximum temperature ranges from 44° C in Haryana plantations to 48° C in Rajasthan. The high temperature is accompanied with strong, hot and dry winds during summer. During the winter temperature falls considerably and severe frosts are common. There is a heavy pressure of human and animal popula-tions. Locally termites are very destructive.

(ii) **Soil preparation:** For effective irrigation, the area has to be thoroughly levelled and stumps removed. In Haryana this work is done by ploughing with D4 caterpillar tractors followed by harrowing. After this the area is divided into irrigation chaks of about 200 hectares each. Each chak is divided into 10 hectare rectangles called compartment. Each chak is generally served by one outlet which feeds the main irrigation channel called the main khal which runs along the upper boundary of the compartment across

the slope. The main khal branches into several branch khals which feed a system of pasels. The pasels run parallel to the khals and feed a unit of 90 to 100 trenches aligned at right angles to them, the pasels are 45 cm wide at the top, 30 cm at the bottom and 30 cm deep.

The trenches are about 27 m long, 30 cm wide and 30 cm deep and are spaced 3 m apart. 20 cm wide berm is left along the length of the trench and after that a ridge is made from the dugout earth. The irrigation is done at night. It starts from the bottom of the khal upwards and only 10 trenches are irrigated at a time. The trenches are filled to the berm and are not allowed to overflow.

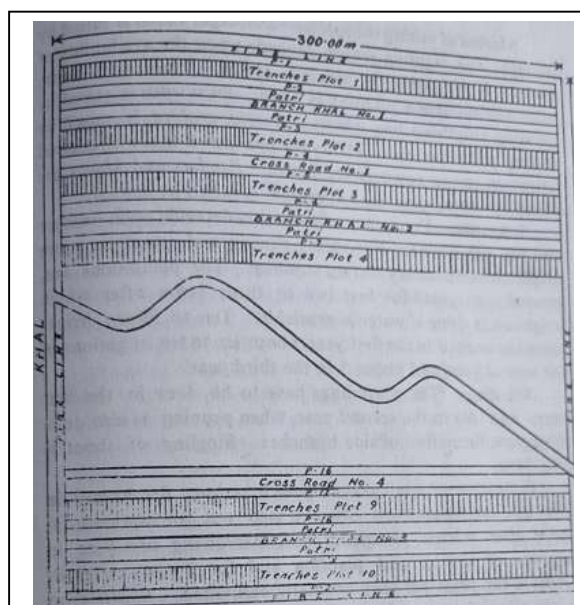


Fig. 1. Plan of irrigation channels in a compartment. Pi, P2, etc., stand for pasel serial numbers.

(iii) **Choice of species:** It depends upon climatic and soil conditions. The existing vegetation gives a good indication of the soil condition and what can possibly grow. For examples, while *Salvadora* and *Tamarix* indicate poor kallar soil. *Prosopis spicigera* and *Capparis* indicate soils free of salts and therefore, fit for most species. Severe frost in winter limits the choice of species to frost-hardy species and on this basis *D. sissoo* has been raised on a large scale in Haryana but most of it is dying within 10 years or so. Therefore, it is being replaced by *Eucalyptus hybrid*. Experience indicates that it is not proper to raise pure plantations. It would be better to raise mixed plantations of *Acacia arabica*, *Bornbax ceiba*, *Morus*, *Syzygiuni*, *Eucalyptus*.

(iv) **Method of raising the species:** *Dalbergia sissoo* is raised by stumps. The planting season depends upon the availability of water. If irrigation is assured, spring planting is done; otherwise monsoon planting is done. *Eucalyptus* is raised by planting polythene

bag plants. *Acacia arabica* is raised by sowing and experience in Haryana has shown that with assured irrigation spring sowings are better. *Bombax* and *Morus* are raised by stump planting; *Syzygium* is raised by sowing. Irrigation—Frequency of irrigation depends upon weather and soil conditions. For spring sowing and planting, more irrigation is necessary during summer. The plantations are generally, irrigated for first two to three years after which irrigation is done if water is available. Ten to fifteen irrigations are needed in the first year, about six to ten irrigations in the second year; and about 5 in the third year.

- (v) **Weedings:** Three weedings have to be done in the first year, and two in the second year, when pruning is also done to prevent formation of side branches. Singling of shoot is also done.
- (vi) **Protection:** As tall grasses pose a serious fire hazard in Haryana, interspaces are often leased out for agricultural crops after tractor ploughing and harrowing one year in advance of sowing and planting and for 2 years after it Gram is the principal crop normally cultivated. Kharif crop is not allowed to be raised. When the area cannot be leased the grass has to be harrowed. Recently, weedicides have been tried to keep down grasses. Indications are that two split application of Dalapon @ 5.5 kg per hectare (active ingredient) at an interval of 3 to 4 weeks in April and May gave 80 % control of perennial grasses *Desmostachya bipinnata* and *Vetiveria zizanioides*. Hyvar x (Bromacil) applied at 17 kg per hectare (active ingredient) effected complete control of all above ground vegetation for the season. The weedicides were applied by Backpack Knapsack sprayer mixed with 750 litres of water per hectare. It has been claimed that the application of Dalapon twice is cheaper than harrowing the grass; it eliminates fire hazard and so tractor ploughing can be restricted to ridge sites only.

5.4 Afforestation of wet land and other adverse or problematic sites

5.4.1 Afforestation of drought prone areas

Desert areas about 3.2 lakh sq. km. area of this country is occupied by tropical desert. About 315 of this area are in Rajasthan, 1/5th in Gujrat and the remaining exists in small pockets of Punjab, Haryana, Maharashtra, Andhra Pradesh and Karnataka. Conflicting

opinions have been expressed, about the spread of Rajasthan desert. Though, in the absence of quantitative data, it cannot be said definitely whether the desert is spreading or not, there are indications of fresh depositions of sand in the north east. It is, therefore, necessary not only to contain the movement of the desert sand to north east but also to immobilize it inside for the betterment of the people

- (i) **Factors of Locality:** Climate is characterized by great of the area extremes of temperature. During the summer, temperature rises to 48°C and strong, hot, sand-laden winds with velocities over 100 km per hour often blow. During the winter, the temperature falls to 3°C and severe frosts occur. The diurnal variations of temperature are also sudden and trying. Rainfall is very low and erratic. The annual rainfall varies from 100 mm in west Rajasthan to about 500 mm in Haryana. Relative humidity is low for greater part of the

5.4.2 Afforestation of marshy areas

- (i) Marshy areas cover an area of about 12 million ha in eastern, central and southern India. **Locality factors--** Rainfall varies from 750 mm to 3750 mm. The temperature is high during hot weather but these areas do not experience frost. The soil is highly ferruginous, deficient in nutrients and organic matter content and shallow. Its low fertility combined with its hard vesicular structure make it unfavorable for plant growth. Pressure of grazing is heavy.
- (ii) **Soil preparation:** The soil preparation may be done by tractor ploughing followed by ridging. In the absence of mechanization facilities, trenches or pits may be dug by manual labor. In West Bengal interrupted contour trenches with cross section of 30 cm x 25 cm are dug approximately 3 m apart in a staggered manner and the dug up earth is arranged as a ridge on the lower side of the trench. In sloping areas continuous contour trenches are also provided at suitable interval depending on slope. For Eucalyptus, pits 60 cm in diameter at top, 30 cm at the bottom and 50 cm deep are made at 2.5 m x 2.5 m. The pits are filled with pulverized soil leaving blank space of 10 cm diameter. A circular cone of manure composed of farm yard manure and tank silt is

placed with the help of two concentric tin cylinders. The seedling with ball of earth is planted in the centre of the pit.

(iii) **Choice of species** -The most suitable species are *Acacia auriculaeformis*, *Eucalyptus hybrid*, *Madhuca latifolia*, *Pteros carpus marsupium*, *Shorea robusta*, *Dendrocalamus strictus*. *Xylia xylocarpa*, *Pterocarpus santatinus* and *Tectona grandis* have also done well on lateritic soils in West Bengal. In addition, *Alstonia*, *Schleichera*, *Hardwickia*, *Bombax*, *Gme-lina*, *Ougeinia*, etc., are also considered suitable for the purpose.

5.4.3 Afforestation of saline land areas

These sites are mostly located in arid and semi arid tropics of the country. High concentration of salts, lack of moisture availability, poor permeability, presence of hardpan, high pH, toxic effects of sodium are some of the inhibiting factors for plant growth. Species having tolerance to high salt concentration soil binding characters and fast growth should be selected for afforestation of saline and alkaline soils.

About 7 million hectares of land in the country are affected by varying degree of salinity and alkalinity, and it is estimated that the area is increasing at an alarming rate of 10,000 hectare; per year. in a country where the percentage of forest area is less than the desired level and where there are practically no forests in the predominantly agricultural zone, afforestation of saline and alkaline soils can go a long way to meet the requirement of grasses, fuel and small timber of the villagers. Very few areas are purely saline or alkaline. The degree of salinity and alkalinity varies from place to place, and there-fore reclamation measures cannot be of universal application. The soil condition has to be studied, causes of salinity and alkalinity diagnosed and then remedial measures decided for application in that particular set of conditions, pH is usually high and often there is a kankar pan in the soil. The pressure of human and animal population is extremely excessive.

Soil treatment	<i>Acacia arabica</i>	<i>Albizia lebbek</i>	<i>Eucalyptus hybrid</i>	<i>Prosopis juliflora</i>	<i>Terminalia arjuna</i>
Farmyard manure	76	46	62	81	68
Gypsum	88	62	91	92	85
Gypsum and farm yard manure	102	71	120	102	95
Normal	107	87	119	100	98

- (i) **Soil preparation**-Proper method of soil working is very important in afforestation of such soils. The principal requisites of good soil working in these areas are (i) maximum retentively and utilization of available rain water, (ii) maximum reduction of salt concentration in the active root zone of young plants through leaching, (iii) use of soil amendment where necessary, and (iv) perforation of cankar pan when it exists in the subsoil.

Keeping these requisites in view, various methods of soil working such as pits, agar holes and trenches of different sizes and shapes are used in different places. In water logged areas however mounds are made. On the basis of an experiment on calcareous alkali soil in Karnal, Yadav et.al., observed that while gypsum results in more than 90% survival in case of *Albizzi lebbek*, *Eucalyptus hybrid* and *Prosopis juliflora*, application of gypsum and FYM gave as good results as soil replacement as shown above in figure. Applications of a small doze of nitrogenous and phosphate fertilizers were found to improve the results further.

- (ii) **Choice of species:** The species which can grow in such conditions are *Albizzias*, *Pongamia pinnata*, *arjuna*, *Eucalyptus hybrid*, *Acacia arabica*, *Prosopis juliflora* and *Acacia auriculaeformis*, The species should be used keeping their tolerance of salt and alkalinity in view. Among the fast growing exotics Lohani found *Leucaenia leucocephala* (varieties K8 and Fiji) to show good growth in moderate to heavy usar soils in kukrail (U. P.). Experiments conducted in U.P. indicate that saline alkali soils with toler-ably good drainage and pa upto 8.5m can be successfully afforested by planting suitable species in pits with soil amendments like gypsum or farm yard manure.

Such areas can serve as good firewood and fodder reserves. But soil with pH varying from 8.5 to 11 usually associated with poor drainage and a canker, can be afforested by planting in deep pits filled back by non-alkaline soil with soil amendments and irrigation during summer. Even then yield of grass and small timber will not be much and therefore their afforestation can be justified on aesthetic and recreational considerations.

5.4.4 Afforestation of sandy soils areas

Sandy soils are found along sea coast as well as in the interior. The inland sands are found along large rivers and in desert. As the problems of different areas are different, their afforestation is dealt with separately.

- (i) **Coastal Sand:** All along the sea coast, large quantities of sand get accumulated as a result of tides. To immobilize these sands which get blown inland by strong winds and to put these sandy wastes to productive uses to meet the ever increasing demand for firewood, afforestation of coastal sands has been taken up in almost all states having sea coast.
- (ii) **Factors of locality:** The soil is pure sand, unstable and unretentive of moisture. The depth of the water table varies from place to place, though, generally, it is fairly high with the result that open wells are dug up for irrigation. The water is generally slightly brackish. Rainfall is usually ample, though in parts of Gujrat, it is fairly low. Atmospheric humidity is high. The winds are strong and carry salt and sand with them. The pressure of increasing human and cattle population is great and it poses a real threat to the plantations.
- (iii) **Soil preparation:** As the soil is loose sand, only pits are plantations dug. They are generally 30 cm in diameter and 30 cm deep but their spacing varies from 1.8 m X 1.8 m to 3.6 m x 3.6 m in different localities. In certain areas in Orissa, which are along the high tide mark and therefore, exposed to strong winds and sand drift, the espacenet is reduce. Though pitting is the usual practice, tractor ploughing is also done in certain areas of Tamil Nadu.
- (iv) **Method of raising plantation**—When plantation is raised very near the shore or in areas subjected to strong winds resulting in shifting sands, some protective screen becomes necessary. This is achieved in Orissa by providing a palisade of leaves of *Palmyra palm*, *Pandanus*, and *Casuarina* brush-wood. In other states, species vary with local availability and may even be grasses such as *Saccharum spontaneum*, *Spinifex*, *Aristida* or species such as *Calotropis*, *Pandanus*, *Tamarix*, *Ipomea*, etc. *Casuarina* is usually planted with naked roots, but sometimes, it is also planted with ball of earth or as container plant as in Orissa and Gujrat. Planting is usually done in

June/July though in Rameshwaram is and planting is done in October/November. The plants are always watered during the first year but in places of deep water table, they are watered in the second and even third year. The watering regime varies from place to place and for this, usually 2 temporary wells per hectare are dug in the plantation area. The watering is generally done from December to June, once or twice a week.

- (v) **Protection**—Where necessary, plantations are protected against cattle by erecting a cattle-proof fence.

5.4.5 Inland River Sand

Sandy wastes are found along big rivers, e.g., Bhur wastes along Ganges in U.P.

- (i) **Factors of locality:** The soil is sandy, unstable, and deficient in nutrients. Water table is not deep and so well irrigation is possible. Rainfall is generally low and varies from place to place. Atmospheric humidity is low. Day temperature is high and diurnal range of temperature fairly wide. Severe frosts occur during winter.

Pressure of human and animal population is excessive. The excessive grazing leaves the ground bare. While, indiscriminate lopping for fuel and fodder kills out most of the tree species that may come up naturally in such areas.

- (ii) **Soil preparation:** Soil preparation consists of digging trenches and pits.

- (iii) **Choice of species:** The species generally raised are *Dalbergia sissoo*, *Acacia catechu*, *Acacia arabica*, *Albizia procera*, and *Pongamia pinnata* but *Azadirachta indica*, *Melia azedarach*, *Ailanthus excelsa*, *Haplophragma adenophyllum* have also been tried successfully.

- (iv) **Method of raising plants:** As the soil is shifting loose sand, it has first to be immobilized by planting grasses; *Eulaliopsis binata* (bobai grass), and *Saccharum* are commonly used for this purpose. Planting is preferred to sowing so that plants may take their roots to deeper layers having permanent moisture as early as possible.

Summary

Unit 6: Plantation Maintenance

Unit Structure

6.0 Learning Objectives

6.1. Fencing and types of fencing

6.2 Digging of pits and water conservation measures for different sites

6.3 Soil fertilization in plantation

6.4 Fertilizer Application in Plantation

6.5 Weed control

6.6 Climber cutting

6.7 Staking

6.8 Singling and pruning

6.9 Bud Pruning or De Budding

Summary

6.0 Learning Objectives

On completion of this unit you should be able to understand

- About fencing and its types.
- Digging of pits
- Soil fertilization in plantation
- Weed control and climber cutting

6.1. Fencing and types of fencing

The following types of fencing may be used to protect the plantations

(a) Live-Hedge Fencing

Live hedge-fencing becomes thicker and more effective as time passes. The species selected should be thorny. It should be able to come up by cuttings. It should also have good coppicing power. The species suitable for live-hedge fencing are:

Euphorbia spp., *Agave sislana*, *Agave americana*, *Jatropha curcas*, *Acacia nilotica*, *Acacia tortilis*, *Acacia catechu*, *Prosopis juliflora*, *Ipomaea*, etc. Similarly brushwood cuttings may also be used for fencing for short periods.

(b) **Wire Fencing:** The wire fencing is of three kinds:

(i) **Barbed wire fencing:** This is most effective but very costly. Four to six strands of galvanized iron barbed wire is used horizontally and criss-cross knitted on angle iron or cement posts. U-nails are used for fixing the strands of barbed wire.

(ii) **Plane wire fencing:** The plane wire fencing with wooden posts is effective against big animals, but is not effective against goats, and sheep. In place of wooden posts (pole or sawn timber) the bamboo stakes can also be used. The Bamboo is used as posts and also as vertical and criss-cross stakes to fix posts and wire. The wood or bamboo used should be treated with bitumen or preservatives like Arsenic-Copper sulphate (ASCU).

(iii) **Woven wire fencing:** Woven wire net is supported on angle iron, cement posts, or wooden posts. The woven wire fencing prohibits even small animals to pass through. The porcupines, goats, deers, rabbits, pigs and even the rodents find it difficult to pass through. The woven wire fencing should be used to protect very valuable and delicate plants. This is also called game proof or porcupine proof fencing. The woven wire can also be used in combination with the barbed wire. The barbed wire is tied on the upper part of fencing.

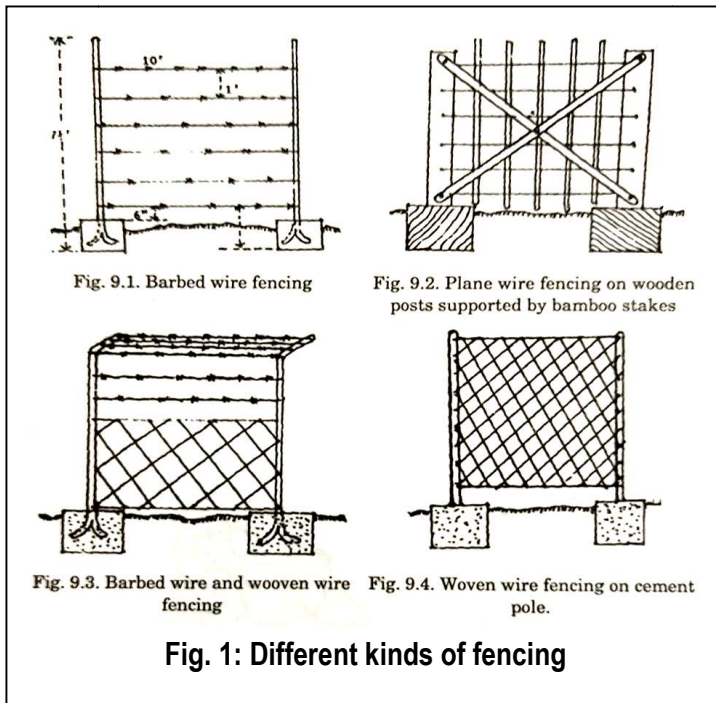
(C) Trench cum Mound (TCM) Fencing

This type of fencing does not require any fencing material. The trench is dug all around the plantation area. The excavated soil makes the mound. It is 1m deep, having 1.90 m top width and 0.60 m wide at the bottom. The slope of TCM along the area afforested would be almost perpendicular, while the earth work involved is 1250 m³ per km. The perimeter of a 20 ha plots with sides 500 m x 400 m would be 1800 m. The average length of TCM would be 90 m per ha. with 112.5 m³ of earth work. The upper fertile layer of soil may be heaped on the outer edge of the inner wall of the TCM, while the lower infertile may be heaped inwards next to it. Wherever the substratum is hard and rocky and excavation is not possible the gap in TOM is plugged by rubble or stone wall of sufficient height, to prevent cattle trespass. Regular attention should be paid to prompt maintenance and repairs to the TCM.

The boundary of the area afforested should follow the contour and if it does not, the TOM would give rise to incipient soil-erosion during monsoons and will

develop into a gully or ravine. To overcome this problem baffle walls are retained within the trench at appropriate intervals, so as to help arrest the sudden flow of rain water and thereby minimizing its adverse scouring effect. The TCM also serves as a water-trap on sloppy areas. The baffle walls are made triangular in cross section having height of 0.30 m, but it should not allow cattle's to cross the trench. The distance between two successive baffle walls is governed by the longitudinal slope of the trench. On plain ground the maximum interval is kept as 30 m but on steeper slopes this interval varies from 20 m to 10 m. Steeper the slope lesser will be the distance.

The TCM as a pre-planting operation should be completed by June so that a live hedge could be planted thereon in July of the PPO year itself. The advantage in completing the TCM earlier would be, that the area to be afforested would re-coupe quicker and there would be complete protection from



biotic interference and ingress of cattle in places where the cattle population is abnormally high and grazing pressure is heavy.

The species to be planted on the mound should be thorny and must have fast growth. The species preferred for TCM planting are: *Agave bulbils*, *Acacia nilotica*, *Caesalpinia sepiaria* (chilhar), *Prosopis juliflora* (vilayati babul), *Kumath*, *Israeli babul*, *Ratanjot*, *Pithecoll-obiunz dulce* (jungle jalebi), *Nagar*, *Thor*, *Khejri*, *Munza grass* etc. The planting is done by seed sowing but polybag planting must always be preferred for greater success.

(D) Rubble Wall Fencing

Stone wall or rubble wall fencing is made where the stones are easily and cheaply available. The wall 1.25 m high and 1 m thick is made of stone or rubble pieces. Sometimes cattle find a way through the rubble wall. To avoid this rubble should be tied with woven iron-wire nets of sufficient strength.

(E) Stone Walling

This kind of fencing by stone planks are common in western Rajasthan where the stones are easily available. The stone of nearly 1 feet width and 1.5 m to 2.5 m height are fixed on the ground along the boundary. This type of fencing is quite strong, but needs repeated repairs.

(F) Electric Fencing

This is not very common in our country due to various factors. This type of fencing has been tried in some national parks but there is no social acceptability by the local inhabitants. The choice of fencing should depend upon the nature of problem, soil depth and budget available for fencing, works.

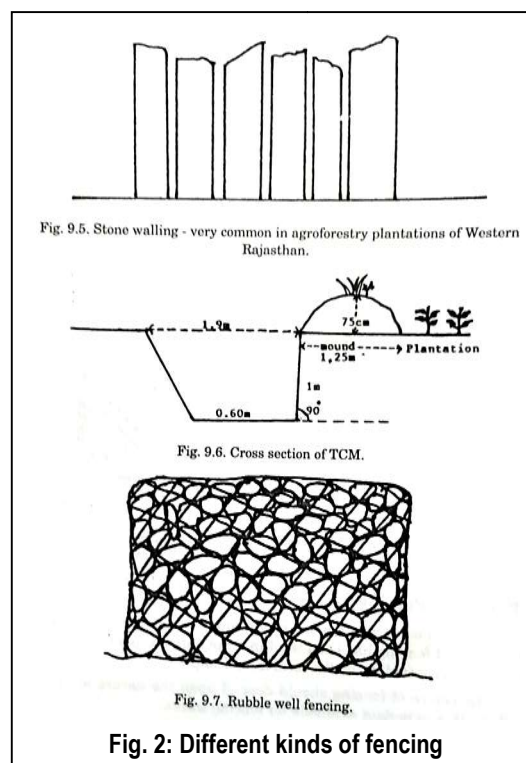
(G) Combined Fencing

Such type of fencing is made by combining two or more types of fencing e.g. (i) TCM and barbed wire (ii) live hedge and stone (iii)

barbed wire, live hedge and TOM 6v) barbed wire and woven wire (v) dwarf pakka wall, barbed wire and live hedge and so on.

6.2 Digging of pits and water conservation measures for different sites

A. Digging of pits: There are mainly three types of pits:



(i) **Ordinary Pit:** If the area is not too slopy the ordinary pits are commonly dug for planting. The various sizes of pits are 30 x 30 x 30 cm³ , 45 x 45 x 45 cm³ or 60 x 60 x 60 cm³. In semi arid and arid tracts where hard calcareous pan is present 20 to 30 cm below the surface the pits must be dug 90 cm deep. The pits are suitable for clayey, alkaline and saline soils. Ordinary pit has crest with deepest part of the water storage *.r) ring away from the highest point of mound. Pits are made in the heavier soil. The pits can be dug by spade, pic-axe, long iron bars (sabbal) or semi-circular spade. The pits should vid be dug 2 to 3 months before planting so that weathering of soil can take place. Regular 'treading' should be done after planting. Less led beating up is required in pit planting method.

(ii) **Saucer Pit:** For making saucer pit, the pit is dug but the area around pit is scrapped to form a shallow saucer of 1m radius. The saucer helps in conserving the moisture. The soil obtained from scrapping is put along the edge of the saucer. Saucer pits may be suitable for water harvesting in arid and sandy areas.

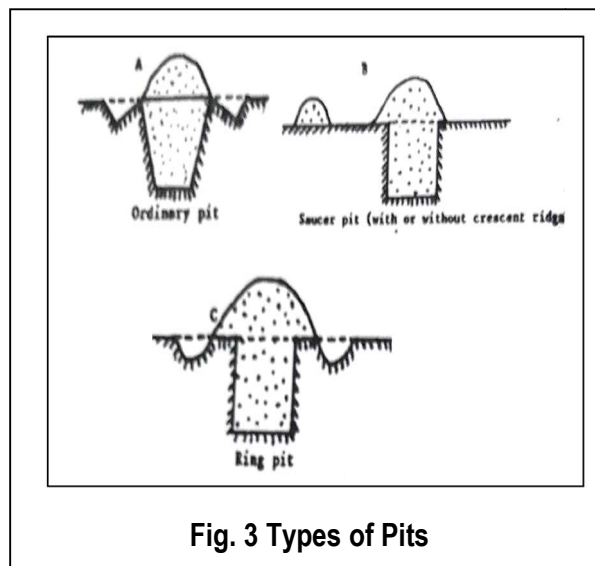


Fig. 3 Types of Pits

(iii) **Ring Pit:** For digging ring pit, first the pit is prepared and then a circular trench about 20 cm away from the pit is dug, the depth being 30 to 40 cm. Ring pit is suitable for very sandy areas having less rainfall. The circular trench collects water for growth of plants. The idea is to accumulate maximum amount of water for the benefit of roots. The key point to note while digging pits (and also trenches) are that the top fertile soil should be kept aside by scrapping and it is first to be filled in the pits while carrying out half filling operation in the pits. The pits are dug in the month of January/February i.e. nearly six months in advance of planting and the half filling (or refilling of pits) are done one or two months before the planting season so that soil gets nearly four to five months for natural weathering. The winds and rains may wash away the top fertile soil if refilling or half filling operation is not carried out in time.

B. Watering

Availability of moisture ensures good survival and success plantation. Watering is generally not required if plantations are done during monsoon. But watering is of great help as soon as the monsoon terminates. This will ensure less mortality and fast growth. For winter planting watering is a must. Natural (by rains) or artificial watering is a must after planting trees. The availability of water makes the roots to set in and wilting of plants are avoided. Irrigation is costly and rarely necessary in forestry plantation. Watering be done if facilities and funds exist. In arid and semi-arid areas where rainfall is poor watering becomes important for establishment of plants and to make the species economically acceptable. Watering is also necessary where fast growth is wanted as in industrial, roadside and similar plantations.

6.3 Soil fertilization in plantation

The fertilizers have importance during initial growth period of tree species when they face heavy competition. In afforestation programmes normally fertilizers are not used because of high cost. But if available within the planting budget, it should be applied. In absence of fertilizers all weeds should be removed and good soil working should be carried out. Irrigation will always be beneficial to the tree as it will increase the availability of nitrogen etc. to the roots of plant. Once the plants get established their nutrient requirement is met through nutrient cycling. In denuded and degraded land nutrient status is very low and application of fertilizer for fast growing and short rotation crops become essential. The nutrient utilization by fast growing short rotation tree species e.g. *Eucalyptus*, *Casuarina* etc. is rapid but restoration of nutrient cycling is not enough. In absence of sufficient nutrition the plants will have reduced growth and may become prone to disease and damage.

6.4 Fertilizer Application in Plantation

Application of fertilizer to plantations is a costly. Applications of fertilizers in the form of urea or NPK doses have been found to stimulate growth of plants even in moderate or good soils. Application of fertilizer within three months of planting produces the maximum response (Chapman and Allan, 1978). The species that show good growth after fertilizer application are *Eucalyptus*, *Casuarina*, *Tectona* etc. The fertilizer should be applied when deficiency symptoms appear.

They need no application on good soil as very little effect on growth performance is seen but on poor soils favorable response can be seen. Generally forest soils have sufficient nutrients and application of fertilizer may not be required. The long rotation crops meet their nutrient requirement through nutrient cycling. Application of fertilizer during the period of establishment gives a boost to height growth of plants. Fertilizers if applied within three months of planting produces the maximum response (Champan and Allan, 1978). It should be applied when the initial growth is not satisfactory. Application of three d of urea each of 10 g was found to boost up considerably the first year teak plantation raised in lateritic soil in Central Chanchla division of Maharashtra. In the first year of plantation two or three doses of urea each of 10 g would immensely benefit the plants. In second and third year the plants hardly need any fertilizer. The ground should be moist when applying fertilizer but if heavy rains are expected the manuring should be postponed till the conditions become favourable. Before applying fertilizer in the form of nitrogen, phosphorous or potassium etc. some preliminary trials are necessary.

6.5 Weed control

Weeds are grasses and undesirable plants which hinder the growth of planted seedlings. They check the growth of seedlings by sharing moisture, nutrient and light. At the time of planting there may not be any weed but with the break of rains different seeds, root stocks and bamboo rhizomes come up and start competing with the seedling. Therefore their periodical removal is a must for the success of plantation. Weeding is a practice of eliminating and/or suppressing undesirable plants. The intensity and type of weeding to be carried out depends on nature of species, slope of area and likely competition of weeds with the seedlings. Weeds are either annual or perennial plants e.g. shrubs, herbs, climbers, grasses, rhizomes etc. The weeds are eliminated mainly in two ways:

- (i) **By uprooting:** In moist areas if the weeds have not developed deep root.; they are eliminated by uprooting. Re-occurrence of Weeds are not possible after uprooting. The additional advantage is that soil aeration is also improved. Care should be taken that no damage is caused to the seedlings While uprooting deep rooted weeds. If the seedlings are likely to be affected weeds should be removed by

cutting. Some soil working e.g. scrapping, digging etc. is also by for good uprooting. For this khurpi or spade with small blade should be used.

(ii) **By Cutting:** Where uprooting is not possible or desirable the weeds are eliminated by cutting. The various implements like spade, sickle, axe, lihurpi etc. are used for this purpose. The different types of weeding are

- Circular/square weeding
- Strip weeding
- Complete weeding

The following kinds of weeding are recommended for the plantations:

Ist year plantation

- (a) First weeding – circular or square weeding (july)
- (b) Second weeding – strip weeding (Aug-Sep.)
- (c) Third weeding – strip weeding (Sept. –Oct.)

The time of weed However, the first we early before the weed! weeding in the first rather than late. Sii should be decided ac weeding are timely

IInd year plantation

- (a) First weeding – Strip weeding (july- Aug.)
- (b) Second weeding – strip weeding (Sep.-Oct.)

IIIrd year plantation

- (a) First weeding – One circular weeding only (Aug.)

The time of weeding should depend on the condition of soil. However, the first weeding is very important and should be made early before the weeds try to suppress the young seedlings. The first weeding in the first year of plantation needs to be carried out early rather than late. Similarly the time of second and third

weeding should be decided according to the conditions in the field. If the two weeding

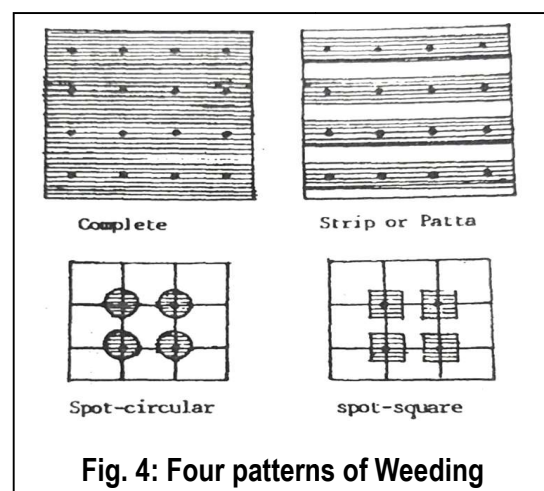


Fig. 4: Four patterns of Weeding

are timely and properly done, the third is seldom necessary but it may always be beneficial to the plants. The weeding in the second year depends on the success of the first year weeding. The first weeding in second year should be carried out early rather than late, to check the growth of weeds effectively. This can be done by arranging different gangs of labor for first year and second year plantations. If the same gang of labor is employed in the first year and second year work the success of second year works suffer.

The only one weeding in third year plantation should be done at the proper time. The cleaning operation should necessarily be accompanied with third weeding as many unwanted plants and tall weeds if not removed shall affect the availability of light to the plants. This is the last weeding made available to the plants and therefore, it should not be taken lightly. Its importance is seen at the time of first thinning operation. The first weeding in first year and second year of plantation needs to be carried out early rather than late. Weeds should not be allowed to suppress the plants. The amount of weeding to be done depends upon various factors such as:

- Soil fertility: In more fertile soil the weed growth is heavier.
- Season: The warm and wet conditions help in weed growth.
- Size of plants: When the plants are smaller more weeding is required.
- Light requirement of species: The shade bearer plants can tolerate certain heavy weed growth better than the light demander species.

6.6 Climber cutting

Climber cutting should be carried out as a part of tending operation. The climbers are harmful when the trees are young. If not removed they do a lot of damage to young plantations. In older trees also, the climbers constrict the stem and deteriorate the value of wood. The important climbers in moist deciduous forests are: *Bauhinia vahlii*, *Butea superba*, *B. parviflora*, *Vitis spp.*, *Millettia auriculata*, *Smilax spp*, *Ipomoea spp.*, *Combretum spp.*, *Africanin rordata* etc. In the conifer forests the moninterfering climber are *Mawwren spp.*, *Rosa spp.*, *Vitis tpp*, *liedera spp.* etc. The climbers should be cut near to the ground and care should be taken to check regrowth at the cut end. For the plantations on fertile soils it is necessary to carry out early weeding operations to

include uprooting and grubbing of vines and creepers during rainy season. All climbers should be cut during monsoon period.

6.7 Staking

The planting spots or soil working spots are marked with stakes and this operation is called staking. The stakes can be made of branches, stones or halved bamboo pieces pointed at one end. Staking with the help of bamboo stakes or stones is done in case of stump planting. The stakes are firmly fixed in the ground. The root-shoots or plants must be planted on the same side of each stake. The stakes take care that the planting is carried out at the uniform spacing.

6.8 Singling and pruning

- (i) **Singling:** Singling operation is carried out in a plantation where the seed-lings are forked or have multiple stems. Singling operation is done in second and third year teak plantation in Maharashtra so that only one stem is able to grow with good health and vigour. Singling operation should be carried out after the plants have attained height of more than 2 m. In a plantation raised by coppice method singling is an essential operation to be carried out with weeding and soil working.
- (ii) **Pruning:** Pruning is an operation of live or dead branches from the standing III crop for the betterment or improvement of trees or its timber. Pruning helps to get cleared bole, knot free, straight and good quality timber. The elimination of branches by natural or biotic agencies is called "natural pruning". The "artificial pruning" is the removal of branches from the selected portion of the trees by mechanical means. Pruning according to kind of branches to be removed is classified -) into: (i) Dry pruning (ii) Green pruning.
 - a. Dry Pruning: Pruning of dead branches, and
 - b. Green Pruning: Pruning of living branches

Natural pruning: Natural pruning occurs due to deficiency of light and other environmental factors such as decay and snow. It, occurs autocratically when the density of the crop is high. The natural regeneration involves three stages viz: Killing of branches, shedding of dead branches and healing of branches stub. It is common in *Eucalyptus* spp. *Bombax ceiba*, *Anthocephalus chinensis* etc.

In order to accelerate height growth 'artificial pruning' is practiced. It depends on object of management. For obtaining clear baled straight and good quality timber within short rotation some pruning must be performed. In artificial pruning the moribund and lower green branches are cut off fresh as near the trunk as possible by using a sharp instrument e.g. axe or hand saw etc. The height of pruning depends upon species, age and local conditions, for this a small ladder may also be necessary. In case of young plantation it can be carried out upto one half to three-fifth of the total height of the tree. In Teak plantations artificial pruning has been found to give good result only during initial period of establishment.

There are two kinds of top pruning (a) heading back and (b) thinning out. In heading back, the terminal Portion of twigs, canes or shoots is, the basal portion is not. In thinning out the entire twig, can or shoot is removed.

6.9 Bud Pruning or De Budding

The object of pruning operation is to produce knot free timber which can be obtained more effectively by removing lateral buds before they get time to develop into branches. Bud pruning method involves removal of lateral buds by rubbing off or clipping off very young branches. In Poplars adventitious buds are removed as soon as possible they appear in the next spring season. The large branches are pruned in the spring before the sap rises so that wounds are healed up or occluded early. This is also practiced in case of *Salix alba* (willow) which produces timber for cricket bats. This is also practiced to some extent in conifers too. After bud-pruning the saplings which become lankly are liable to be affected by wind.

Unit 7: Protection of Plantations

Unit Structure

7.0. Learning Objectives

7.1 Introduction

7.2 Adverse weather conditions

7.2.1 Frost

7.2.2 Lightning

7.2.3 Snowfall

7.2.4 Wind

7.2.5 Hot Sun

7.2.6 Drought

7.2.7 Floods

7.2.7 Air Pollution

7.3 Damage by grazing

7.4 Wild animals

7.5 Disease

7.6 Plantation Diseases

7.6 Insects

7.7. Forest fires

7.7.1 Classification of Forest Fire

7.7.2 Types of Forest Fire

7.7.3 Fire Damage

7.7.5 The needs of the fire management

7.7.6 Prevention of Fire

7.7.7 Fire Detection and Suppression

7.8 General Control Measures

Summary

7.0. Learning Objectives

After completing this unit you shall be able to:

- Define protection of plantations
- Explain damage caused by grazing, wild animals, insects and forest fires.
- Explain different control measures

7.1 Introduction

Protection of plantation is essential to avoid failure in plantation. A failed plantation means wastage of money and efforts and loss in productivity value of land. The

plantations need protection from (i) weather, (ii) wild animals, (iii) grazing, (iv) pests and diseases and (v) fire.

7.2 Adverse weather conditions

Man is unable to protect plants from adverse weather conditions e.g. frost, lightning, snow fall, wind, hot sun, drought, floods, hailstorm, cyclones, avalanches, etc. They may cause extensive damage to plants. However, some efforts can mitigate the effects of drought and floods etc. The hardy species should be planted to overcome the baneful effects of natural factors.

7.2.1 Frost

The frost occurs due to condensation of water on the surface of the soil and parts of plants. There are two types of frost viz. radiation frost and pool frost. Radiation frost is common in plain areas during clear winter nights and young seedlings are damaged by the frost. The pool frost or convection frost occurs in hilly areas. In Doon valley the pool frost does considerable damage to Sal seedlings. The southern slopes of hills are more affected by frost damage as compared to northern slopes. Sometimes injury to plants is also caused by intensity of cold in winter.

The frost injury is caused through dehydration, freezing of extra cellular and intracellular water molecules, destruction of colloidal properties of protoplasm, precipitation of proteins in the cell and death of protoplasm. A sudden thaw increases the damage. The south and south-east aspects suffer most especially in case of nurseries. Frost cracks or fissures get developed in the wood. Frost crack causes cambium being injured due to which the timber becomes blemished.

Frost rib is caused by the repeated frosts year after year; the thin barked trees are most susceptible. The heavy pool frost may kill back saplings and poles to the ground level. The roots of the seedlings growing in the freezing soil, when exposed in the morning, due to increased transpiration rates are unable to draw moisture and therefore get killed.

To overcome this problem frost hardy species should be planted in frost prone areas. Some species are frost tender in the early stages but become frost hardy as they grow on. The different measures adopted to check frost damage are : application of

potassium and phosphorous, hardening-off of plants before planting, avoiding clear felling etc. The nursery seedlings are protected from frost by mulching, providing shade, application of fertilizer and arranging smoky fires. The frost tender and frost hardy species are:

(A) Frost Tender: *Acacia nilotica*, *Azadirachta indica*, *Boswellia serrata*, *Shorea robusta*, *Tectona grandis*, *Terminalia arjuna*, *T. tomentosa*, *Dendrocalamus strictus*, *Callygonum polygonoides* etc.

(B) Frost Hardy: *Acacia catechu*, *Acacia tortilis*, *Anogeissus pendula*, *Dalbergia sissoo*, *Albizia lebbek*, *Alnus nitida*, *Diospyros melanoxylon*, *Eucalyptus spp.*, *Hardwickia binata*, *Madhuka indica*, *Mangifera indica*, *Ougenia oojeinensis*, *Pinus roxburghii*, *Prosopis juliflora*, *P. cineraria*, *Stereospermum mopane*, *Tecomella undulata*, *Toona ciliata*, *Zizyphus mauritiana*, *Z. nummularia*, etc.

7.2.2 Lightning

The damage from lightning is caused in two ways firstly by scarring or cracking and secondly by complete rending or tearing of the tree. The smooth barked trees suffer less than rough barked trees. Large trees and old trees are often struck more frequently than small ones or younger ones.

7.2.3 Snowfall

The snow can damage trees by breaking of leading or side branches. The plantation can be severely damaged by snow if it has been under-thinned. The snow injury is followed by injury by another agent such as fungi and wind damage. Evergreen trees generally suffer more than deciduous trees. The trees having drooping or flexible branches suffer less from snow damage than the trees with stiff horizontal branching habit.

7.2.4 Wind

The movement of wind is governed by various factors such as change in temperature, altitude, geographical features, etc. The coastal areas are subjected to cyclonic and strong winds. High winds are of frequent occurrence during summer in the desert areas of western Rajasthan. Lack of vegetational barrier may cause considerable damage to plantations. The under thinning encourages damage by wind. Cold winds

are responsible for frost damage to the plantations. Winds help in seed dissemination and new areas are colonized. Winds also help in pollination among big trees when pollen in great quantities is produced.

The fast winds do considerable damage by uprooting the trees, rupturing the branches, shaking of roots, bending of trees and killing of branches. Winds are responsible for forming elliptic stems, wolf trees and short statured tree forms. The bamboos culms get entangled bent and take different forms. The harmful effects of wind can be seen in different forms viz. (a) blowing out of the tops of trees, (b) blowing down of individual trees or group of trees, (c) distortion of the crown where the wind is of frequent occurrence, especially near the sea coast, (d) high transpiration losses resulting in stunted growth, (e) winds help in burning process during forest fires, (f) wind erosion and formation of sand dunes.

The trees growing in arid areas, on the margin of field and in isolated places develop strong root system due to which they are able to withstand the pressure of wind. The trees if suddenly exposed to wind are likely to be blown out as their roots are unable to withstand the strains of wind. The wind damage go on spreading after a 'hole' has been made in an even-aged stand. The following measures can be adopted to check damage by winds:

- (A) Planting of shelterbelts at suitable positions,
- (B) Planting of wind firm and deep rooted species,
- (C) The area should be properly drained. Wet-waterlogged soil provides ideal conditions for wind blow,
- (D) The thinning should be adequate and regular. Under thinning should not be done as it creates conditions for wind damage.
- (E) The young plants in a plantation can be protected from winds by tree tubes. They are simply plastic tubes which are also known as tree shelters. The plastic tube can be placed over a young tree so as to provide it adequate protection and create conditions inside the shelter for faster growth. Each tube can be attached to a stake to ensure its stability. The shape of tree tubes is square or round.

The height may vary from 0.6 m (2 ft) to 1.8 m (5 ft 10") whereas the diameter or sides may vary from 15 cm to 30 cm. The tube is open from both the ends and the bottom of the tube is not fixed or inserted in the soil. Tree tubes provide good protection to young plants against erratic and high winds.

7.2.5 Hot Sun

The young plantations are severely affected by hot sun when the temperature goes above 45°C. High temperature accompanied by drying wind in April and May is responsible for serious damage to many tree species. The small trees and plants exposed to hot sun suffer from leaf scorch. The bark of young trees or the whole tree may be damaged and charred when the temperature goes above 48°C. The harmful effect of high temperature is often seen on rocky areas and black cotton soil. Many species wilt and die due to high soil temperature. In a plantation after heavy thinning has been carried out the bark of the trees are damaged due to sudden exposure to the hot sun. Many nursery seedlings are killed due to high soil temperature therefore they should be protected by providing shade.

The plantation can be saved from hot sun by planting tall seedlings which are less prone to damage by heat. The soil temperature should be regulated by mulching with grasses and shrubs e.g. *Crotalaria burhia*, *Capparis decidua* etc.

7.2.6 Drought

The survival of plants is dependent upon rainfall or precipitation. The water constitutes nearly 90 to 95% of the cell wall and 80% of the protoplasm. Water brings in turgidity which is necessary for growth of plants. The occurrence of drought upsets the hydrological cycle, humidity falls down and rate of transpiration loss becomes high. Some of the water is returned to the plant and soil in the night due to condensation and formation of dew in the winter season. The long spell of drought accompanied by high temperature is responsible for high mortality of young plants. Rainfall of a particular area is the main factor that decides the structure of vegetation and forest types. A deficiency in water supply causes die back of the leading shoots of young trees and old trees become stag headed. The harmful effect of drought is over come timely by: (a) commencing Plantation work as soon as the monsoon comes. Timely rainfall determines the success and failure of plantation, (b) soil working and mulching during

the period of drought, c) planting tall seedlings, d) selecting drought hardy species for planting.

Drought hardy species:- *Acacia nilotica*, *Acacia tortilis*, *Bombax ceiba*, *Boswellia serrata*, *Cassia siamea*, *Dalbergia latifolia*, *Eucalyptus camaldulensis*, *Diospyros melanoxylon*, *Hardwickia binata*, *Kydia calycina*, *Lagerstroemia parviflora*, *Lannea coromandelica*, *Mallotus philippinensis*, *Ougenia oojeinensis*, *Pongamia pinnata*, *Stereospermum mopane*, *Syzygium cumini*, *Zizyphus mauritiana*, *Prosopis juliflora*.

Drought sensitive species: *Anogeissus latifolia*, *Madhuka indica*, *Mangifera indica*, *Pterocarpus marsupium*, *Shorea robusta*, *Tectona grandis*, *Terminalia tomentosa*, *Terminalia arjuna*, *Toona ciliata*.

7.2.7 Floods

The flood causes heavy soil erosion. It destroys plantation by mechanically damaging the plants and by checking soil aeration completely. Excess of water, is harmful and turns a land into wet desert where only grasses and small shrubs are able to come up. An excess of water causes death of young plants and produces stag headedness in mature or near mature trees. The soil deposited by floods raises the pH value of soil which is harmful for many species. The flood prone area should be planted by hardy deep rooted species which can withstand water logging and high soil salinity. e.g. *Eucalyptus spp.*, *Syzygium cumini*, *Prosopis juliflora*, *Dalbergia sissoo*.

7.2.7 Air Pollution

The effect of air pollution can be seen in the form of "acid rain". The various chemicals responsible for long- term pollution are primary and secondary chemicals:

Primary group: Sulphur dioxide (SO₂), Hydrogen chloride (HCl), Nitric oxide (NO), Ammonia (NH₃), Carbon monoxide (CO), Hydrocarbon (HC).

Secondary group: Sulphate (SO₄), Ozone (O₃). These pollutants get deposited in dry or wet forms.

To overcome these problems trees that have air purifying capacity and are not affected easily by these chemicals should be planted.

The suitable species for controlling air pollution are: *Tectona grandis* (5.35), *Shorea robusta* (4.50), *Terminalia arjuna* (4.49), *Mangifera indica* (4.05), *Bauhinia purpurea*

(3.90), *Butea monosperma* (3.05), *Azadirachta indica* (2.92), *Cassia fistula* (2.24), *Tamarindus indica* (2.08) (figures in the bracket denote the dust collected in gram per square meter of leaf surface.)

The trees can control pollution if they are themselves not affected by the pollutants or chemicals if present in tolerable limit. Neem is tolerant to sulphur-di-oxide whereas sissoo is sensitive to it. The sensitive species act as indicators of air pollution. Some of them are:

Smoke indicator: *Azadirachta indica*,

Dust indicator: *Erythrina indica*, *Mangifera indica*.

Fluoride indicator: *Cassia fistula*, *Dalbergia sissoo*.

Sulphur-di-oxide indicator: *Adina cordifolia*, *Buchnanian lanzan*, *Diospyros melanoxylon*.

Combination of pollutants: *Aegle marmelos*, *Diospyros melanoxylon*, *Mangifera indica*, *Melia indica*, *Tectona grandis*.

7.3 Damage by grazing

Grazing by domestic animals is the most destructive factor for failure of plantation. The animals should not be allowed to graze in the plantation and forest areas. In villages people maintain large number of livestock for manure and milk etc. The age old practice of letting them in forest or plantation area is still being continued due to which there is a large scale destruction of forests or plantations. The regeneration is completely absent due to grazing. The stall feeding is the best solution to protect trees and shrubs. But it may not be possible to implement stall feeding due to various factors e.g. (i) Animals have habit of moving in the forests. Sudden change in their habit would greatly affect their health. (ii) The people are mostly poor and therefore, women folk also go for agricultural work or for collection of firewood and other forest produce. In such a situation bringing fodder from the forests or nearby areas is time consuming and is disliked by the family of the cattle owner. (iii) The number of cattle owned by a family is large and bringing fodder for all the animals is not an easy task. But it is our duty to protect the forests and plantations by closure of the area. The plants if not protected, may be damaged by browsing, trampling, scratching, uprooting, bending of stems etc.

7.4 Wild animals

The animals like Black Buck, Nilgai, Sambhar, Cheetal, Deer, Bison, Elephant, Bear, Wild Boar, Porcupine, Rats, Hares, Rabbits etc. do a lot of damage by tree browsing or debarking to the plants. They eat the leaves and branches. The other forms of damage are soil compaction, trampling of seedlings, digging out of rhizomes and roots (pigs etc.), debarking, girdling, bending and breaking of branches. The compacted surface becomes hard and shows adverse effect on plantation. Sambhar and Cheetal do extensive damage to Sal plantation. The elephants etc. can easily trample the plants. Wild boars easily uproot the bamboo rhizomes and other roots. Rabbits and hares damage young plantations by gnawing and debarking the stem and biting the leading shoots of mostly broadleaved spp. Porcupines dig forest floor in search of roots of Semal, Salai etc. Desert rats do extensive damage in plantations of *Acacia senegal* in Rajasthan.

Protection from hoofed animals is done by erecting high and strong fencing of various types. Common brushwood fencing may be made for protection against barking deer, black buck, wild boars etc. For protection against deer fencing of 7 strands of wire and 2.5m tall angle irons are used. The barbed wire near the ground level should be at closer spacing so that smaller animals may not find its way through the fencing. For sound protection the barbed wire should also be woven vertically.

For protection against porcupines which make underground tunnel, porcupine proof fencing is used which is woven wire net of sufficient strength. This net is also buried up to 30cm depth in the ground to check the possibility of tunneling. The wire mesh is 90 to 100cm above the ground level. Trench cum mound fencing is also made for protection against many animals but it needs regular repair. Any bridge formed due to soil slipping should be broken otherwise the animals will find it easy to enter into the plantation area. The protection from wild animals is done by (a) fencing (b) planting hedges (c) ditches (d) trapping and removal and (e) poison baiting.

The plantation watchman should remain present in the night too, where the wild animals frequently visit the plantation area. He can keep off the animals by making fire or making noise by beating of drums.

7.5 Disease

Factors that influence the quantity and quality of nursery seedlings may also influence our future timber supply. These factors include seedling diseases caused by fungi, bacteria, and nematodes. These diseases, which are active from the time of sowing throughout planting, may kill seedlings directly, or stunt or malformed them so they must be rejected. Nursery diseases may also lower field survival of out planted seedlings. Nursery diseases may be a threat to our forests when infected seedlings are planted in forested areas where the disease does not and has not existed. The economic losses due to diseases in forest nurseries must include more than just the cost of producing the dead and culled seedlings. They include the cost of a second site preparation of the plantation when plantable seedlings are not available due to disease losses at the nursery, or the cost of a second planting or inter-planting when seedling diseases continue to cause mortality in the plantation. The basic land cost must also be included when forest land is held out of production by nursery disease problems. Thus the economic losses resulting from nursery diseases are not restricted to the nursery operation; impacts on the forests may be even greater. The various symptoms of the diseases are:

- i). Wilting: Non physiological.
- ii). Canker formation: Pathogenic or due to frost, sun scorch, fire or drought which invite pathogens to cause diseases in trees.
- iii). Decay: Break down of tissues by fungi, causing heart rot, root rot, stem rot etc.
- iv). Dwarfing: Viral or may be due to genetic factor.
- v). Epicormic branches: Dying of top due to fungal infection.
- vi). Formation of gall, burls or tumors, abnormal swellings, hairs on leaves witch-brooms etc.
- vii). Exudations: Caused due to bacteria, gummosis, excessive out flow of resin (resinosis) etc.
- viii). Leaf rusts.

7.6 Plantation Diseases

(a) Root Diseases: The roots are below the ground level and therefore, the diseases caused in the roots are noticed only when symptoms on the above ground parts are

manifested. The root diseases may be due to parasitic causes such as fungi, bacteria, nematodes, insects etc. or it may be due to physiogenic causes. The root infecting fungi may be (a) soil-inhabiting fungi or (b) Root-inhabiting fungi.

Some fungi kill the host tissues by their toxic excretions whereas some fungi destroy the tissues of plant. The mycorrhizae are parasites belonging to soil-inhabiting fungi group, whose relationship with the hosts is one of symbiosis. The fungi causing vascular wilts are restricted in the vascular tract such as *Verticillium* and *Fusarium*. In wilting the foliage becomes yellow and falls off. The affected branch or plant slowly dies. Apart from wilt fungus-water imbalance is common in all wilt diseases. The root-rot symptom is not manifested till the large percentage of roots is affected. The fungi *Ganoderma lucidum* causes root rot but do not affect the heartwood while the other type of fungi viz. *Fomes annosus*, *Armillaria mellea* etc, causes roots rot and also butt rot. To control root diseases fumigation with methyl bromide and steam are practiced in glass house before sowing operations. It is also controlled by changing planting time and taking mixed plantations of susceptible and resistant species.

Similarly a sound knowledge of silviculture is necessary to select suitable site. For example, *D. sissoo* plantation grows healthy in sandy loam soils with good drainage, but is affected by root fungi, when it is raised in stiff soils of clay or clay loam or in water logged areas (Streets, 1962). The controlled burning also checks development of root diseases e.g. control of *Polyporus shoreae* in moist Sal forests.

Similarly while preparing site the stumps should be uprooted to control various root fungi. Isolation trenches are also made to control spread of the diseases. The cheap chemicals which are non-poisonous to livestock and wildlife can also be used. The chemicals such as creosote, ammonium fluoride, sodium nitrite, borax, urea and ammonium sulphamate have been used with success.

(b) Heart Rot: The heart rot causes heavy loss in value of important timber species. The decay starts only after the formation of heartwood i.e., after nearly 15-25 years of age depending upon the species. The decay starts after a portion of heart wood is exposed due to various reasons. The sap wood is not affected. The heartwood which is dead goes on decaying by heart rot whereas the sapwood and outer appearance of tree is not affected even till the rotation age. The sapwood due to high moisture content prevents heart rot fungi to develop. There are natural toxic extractives (phenol

etc.) which prevent decay of heartwood. This decay resistance varies from species to species and also depends on age, size and growth rate of the tree. Example of toxic extractives is tectol in teak. But these extractives may degenerate due to oxidative enzymes or micro-organisms and become ineffective later on.

The infection depends on age also. Sal is frost tender when young but frost causes cankers and *Fomes Caryophylli* establishes itself but it declines with age. The site is not related to heart rot whereas site has direct influence on infections due to root and butt rot fungi. Generally dry sites are more vulnerable for progress of heart rots as compared to wet sites. For some species soil texture has influence in causing heart rot. For example in the decay is greater in clayey soils but less on sandy soils. For detecting heart rot direct probing may be necessary if the external symptoms fail to manifest the disease.

7.6 Insects

There are innumerable insects and pests affecting trees in the insects eat leaves, tender shoots, flowers and fruits damage the tree through roots and stems. The injurious be divided into five classes, namely: (a) foliage destroying insects other than those which bore into broing insects, (d) bark feeding insects, (e) root-feeding insects and (f) gall-making insects. Some of the harmful insect pests as:

***Acacia catechu*:** *Diapromorpha turcica*, *Myloccerus catechu*-beetle defoliator; *Laccifer lacca*-wood borer.

***Azadirachta indica*:** Larvae of *Enarmonia koenigana* feed on rolled leaves and bore tender shoots.

***Dalbergia sissoo*:** Nearly a dozen beetle defoliators belong to the family Curculionidae. It is for severely a considerable defoliated part by Placoptera of the year, reflexa hampering which makes growth or even death may occur to the tree.

***Shorea robusta*:** *Hoplocerambyx spinicorn* makes tunnel through the bark and sapwood and finally through the heartwood causing death of the attacked trees.

***Tectona grandis*:** Its leaves are skeletonized by two insects- *Hapalia machaeralis* (teak skeletonizer) and *Hyblaea puera* (teak defoliator). Complete or partial defoliation takes place in young teak plants leading to dying back and forking. The biological control is done by releasing *Cedria paradoxa*.

Cedrus deodara: It is defoliated by *Ectropis deodarae*. Death of defoliated tree starts from the top. The bark dies in longitudinal patches. The cambium may also be affected. The predator which eats caterpillars is *Calesoma beelsoni*. The trees are grease-banded before March to stop breeding.

Bambax ceiba: The shoot borer of Semal is *Tonica nivifera*. The attacked plants should be cut and burnt. The pupae of shoot borer is collected and destroyed.

Pinus roxburghii: During its sapling, pole and even older stages, it is attacked by borer *Ips longifolia*. To control it slash disposal is carried out and all felled material should be debarked.

Shorea robusta: *Hoplocerymbax spinicornis* is the most serious pest of sal. It causes damage in two forms:

- a. The larvae eat up the cambium and kill the tree.
- b. The pest bores long galleries in sapwood and heartwood.

This lowers the commercial value of the timber. Two methods are employed to control it.

(i) Silvicultural Control

- (a) The crop should be dense.
- (b) Harvesting should be carried out between October and March.

(ii) Mechanical Control

- (a) Traps are used on the trees.
- (b) Beetles attracted by oozing sap are killed by severing of the garvbol head.

7.7. Forest fires

The most common hazard in forests is forests fire. Forests fires are as old as the forests themselves. They pose a threat not only to the forest wealth but also to the entire regime to fauna and flora seriously disturbing the bio-diversity and the ecology and environment of a region. During summer, when there is no rain for months, the forests become littered with dry senescent leaves and twinges, which could burst into flames ignited by the slightest spark. The Himalayan forests, particularly, Garhwal

Himalayas have been burning regularly during the last few summers, with colossal loss of vegetation cover of that region.

Forest fire causes imbalances in nature and endangers biodiversity by reducing faunal and floral wealth. Traditional methods of fire prevention are not proving effective and it is now essential to raise public awareness on the matter, particularly among those people who live close to or in forested areas.

Forest fires are caused by Natural causes as well as manmade causes:

- **Natural causes-** Many forest fires start from natural causes such as lightning which set trees on fire. However, rain extinguishes such fires without causing much damage. High atmospheric temperatures and dryness (low humidity) offer favorable circumstance for a fire to start.
- **Man made causes-** Fire is caused when a source of fire like naked flame, cigarette or bidi, electric spark or any source of ignition comes into contact with inflammable material.

Traditionally Indian forests have been affected by fires. The menace has been aggravated with rising human and cattle population and the consequent increase in demand for Forest products by individuals and communities. Causes of forest fires can be divided into two broad categories: *environmental* (which are beyond control) and *human related* (which are controllable).

- **Environmental causes:** are largely related to climatic conditions such as temperature, wind speed and direction, level of moisture in soil and atmosphere and duration of dry spells. Other natural causes are the friction of bamboos swaying due to high wind velocity and rolling stones that result in sparks setting off fires in highly inflammable leaf litter on the forest floor.
- **Human related causes** result from human activity as well as methods of forest management. These can be intentional or unintentional, for example:
 - Grazers and gatherers of various forest products starting small fires to obtain good grazing grass as well as to facilitate gathering of minor forest produce like flowers of *Madhuca indica* and leaves of *Diospyros melanoxylon*

- The centuries old practice of shifting cultivation (especially in the North-Eastern region of India and in parts of the States of Orissa and Andhra Pradesh).
- The use of fires by villagers to ward off wild animals
- Fires lit intentionally by people living around forests for recreation
- Fires started accidentally by careless visitors to forests who discard cigarette butts.

The causes of forest fire have been increasing rapidly. The problem has been accentuated by the growing human and cattle population. People enter forests ever more frequently to graze cattle, collect fuelwood, timber and other minor forest produce. It has been estimated that 90% of forest fires in India are man-made

7.7.1 Classification of Forest Fire

Forest fire can broadly be classified into three categories; Natural or controlled forest fire.

- Forest fires caused by heat generated in the litter and other biomes in summer through carelessness of people (human neglect) and
- Forest fires purposely caused by local inhabitants.

7.7.2 Types of Forest Fire

There are two types of forest fire i) Surface Fire and ii) Crown Fire

- Creeping or Ground Fire:** The creeping or ground fire destroys grasses, leaf litters, stumps, logging wastes; wind fallen trees, etc. on its way. It advances with low speed as the availability of fuel is not much and it is just to sustain the fire. The ground fire occurs where the top layer of soil contains semi decayed vegetation. The fire hardly contains flames but is marked by constant black smouldering fire. The creeping or ground fire is difficult to extinguish because exact position of fire is difficult to locate. Even after the fire has been apparently extinguished the ground fire may strike again unexpectedly. The ground fire occurs both in deciduous and coniferous forests where partially decomposed leaf litters or needles are present.

ii). **Surface Fire:** It is more intense as compared to the creeping fire because the availability of fuel is more. The fire destroys whatever comes in its way. Majority of the forest fires are surface fires. It advances rapidly and even destroys shrubs, seedlings and saplings. The ground fire has capacity to do lot of damage when the wind is also blowing fast. Young plantations up to 10 years of age can be wiped out whereas older plantations are badly scorched.

The majority of fires are surface fires that burn mostly left over material and leaf litter on the forest floor. Surface fires are easy to control if tackled in a right way and at the right time. Every small forest fire can become a big fire if combination of dry weather and high winds occur. If dry fuel is available in plenty over the vast area it takes the form of a running fire. Such type of bad fires fanned by high winds can destroy anything on its way. Surface fires do lot of damage to young conifers whereas broadleaved spp. have greater power of recovery. Even the seedlings and larger trees are damaged considerably.

iii). **Crown Fire:** The crown fires are deadly and occur mostly in combination with surface fire. It is of two types: low crown fire and high crown fire. The crown fire starts initially as surface fire but due to strong winds develop into crown fire and leaps from one tree to another. These fires, due to high temperature, jump by sparks as heat travels by way of radiation. The ignition takes place because of strong heat radiation for which actual contact of fire and material is not necessary. The crown fires occur mostly in coniferous forests. It is rare in broadleaved forests because the green leaves of hardwoods are not easily ignited. Low crown fire destroys lower branches of big trees whereas small trees are completely destroyed. High crown fire destroys everything on its way.

7.7.3 Fire Damage

The high temperature of forest fire destroys many seeds. Soft seeds may be consumed by fire whereas; seeds of the species having hard coats require fairly high temperature to break the dormancy. Accordingly the forest succession is changed and regeneration of species can be seen after the forest fire. Fire reduces content of organic matter in the soil. It also affects nitrogen content, cation exchange capacity,

exchangeable calcium and magnesium, availability of phosphorous and potassium. It also reduces water holding capacity of soil and increases soil erosion by breaking large stable aggregates.

The losses due to timber and property are apparent but there are intangible losses or damages which are hard to recognize. The loss due to killing of seedlings which would provide future timber crops cannot be measured. After fire only shrubby growth of many species are observed. The area becomes degraded and repeated fires turn the good forest land into unproductive wasteland.

In addition to this, standing trees that are damaged due to forest fires become prone to wood rot. Fire weakened trees are quickly attacked by pathogens and insects which in future are likely to be felled by the wind. The forest floor is unable to use accumulated water and surface run-off carries away huge quantity of fertile soils. Many animals and birds fall prey to fire. The wood ashes accumulated in rivers and ponds kill many fishes and aquatic life.

7.7.4 Effect of Forest Fire

Fires are a major cause of forest degradation and have wide ranging adverse ecological, economic and social impacts, including:

- Loss of valuable timber resources
- Degradation of catchment areas
- Loss of biodiversity and extinction of plants and animals
- Loss of wildlife habitat and depletion of wildlife
- Loss of natural regeneration and reduction in forest cover
- Global warming
- Loss of carbon sink resource and increase in percentage of co₂ in atmosphere
- Change in the microclimate of the area with unhealthy living conditions
- Soil erosion affecting productivity of soils and production
- Ozone layer depletion
- Health problems leading to diseases

- Loss of livelihood for tribal people and the rural poor, as approximately 300 million people are directly dependent upon collection of non-timber forest products from forest areas for their livelihood.

7.7.5 The needs of the fire management

The incidence of forest fires in the country is on the increase and more area is burned each year. The major cause of this failure is the piecemeal approach to the problem. Both the national focus and the technical resources required for sustaining a systematic forest fire management programme are lacking in the country. Important forest fire management elements like strategic fire centres, coordination among Ministries, funding, human resource development, fire research, fire management, and extension programmes are missing.

Taking into consideration the serious nature of the problem, it is necessary to make some major improvements in the forest fire management strategy for the country. The Ministry of Environment and Forests, Government of India, has prepared a National Master Plan for Forest Fire Control. This plan proposes to introduce a well-coordinated and integrated fire-management programme that includes the following components:

- Prevention of human-caused fires through education and environmental modification. It will include silvicultural activities, engineering works, people participation, and education and enforcement. It is proposed that more emphasis be given to people participation through Joint Forest Fire Management for fire prevention.
- Prompt detection of fires through a well coordinated network of observation points, efficient ground patrolling, and communication networks. Remote sensing technology is to be given due importance in fire detection. For successful fire management and administration, a National Fire Danger Rating System (NFDRS) and Fire Forecasting System are to be developed in the country.
- Fast initial attack measures.
- Vigorous follow up action.
- Introducing a forest fuel modification system at strategic points.
- Firefighting resources.

Each of the above components plays an important role in the success of the entire system of fire management. Special emphasis is to be given to research, training, and development

7.7.6 Prevention of Fire

Whatever might be the causes of fire, the people should under controlling stand the importance staff should of of be forest the prepared fires and are change to man meet their made any behavior emergency and fire prevention situation The forest round the clock. Most of the fires are manmade and fire prevention programme therefore should include the education of people, control through legislation and training to forest personnel's. The trained staff should keep the map of the forest area and equipments for fire fighting.

The prophylactic or preventive measures against fire includes

- (i). Good silvicultural practices including weeding, cleaning, removal that fuel of dead is not and available dying trees, to the climber spreading cutting, fire .thinning etc. so that fuel is not available to the spreading fire.
- (ii). Selection of fire resistant species and avoiding pure stands.
- (iii). Controlled and planned grazing to check the ability of undergrowth from catching and spreading fire.
- (iv). Controlled burning to keep inflammable material at low level. The controlled burning should be carried out in humid conditions at suitable time and when the wind is not blowing.
- (v). Use of herbicides such as 2, 4-D; 2, 4,5-T
- (vi). Cleaning and maintenance of fire breaks and roads. Fire lines are cleared strips of sufficient width made all around plantations and running criss-cross inside plantation so that a compact block or area is separated from the other area. Fire-lines should be cleared before start of fire season. Similarly fire breaks should be maintained to provide fuel-free barrier to fire. Fire lines can be aligned inside as well as outside the boundary of plantation. The compartment lines, roads, water channels etc. also serve as fire lines therefore needs to be maintained in good condition.

(vii). Planting of evergreen species as firebreaks. Such species are *Syzygium*, *Sesbania* etc.

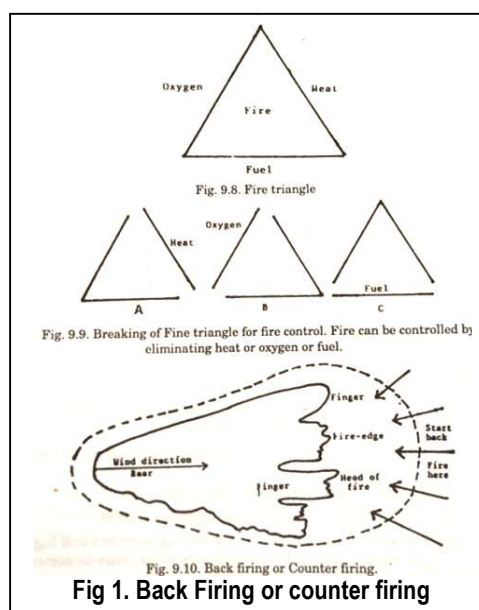
(viii). Creation of watch towers and deployment of fire watchers for 24 hours. The fire watch towers should be created near plantation area and should be manned with various facilities. The watch towers should command the most extensive view.

7.7.7 Fire Detection and Suppression

Constant patrolling and watch is necessary for quick and efficient 74%4 detection of fire. The smoke seen within or near the forest area should not be ignored as it may be the beginning of big devastating fire. The forest protection force must go to the spot and find out the source of smoke. If it happens to be a forest fire it should be extinguished without any delay. For extinguishing quickly a forest fire, the following factors are important.

(i) Immediate arrival at the fire, (ii) Sufficient fire-fighting force, (iii) Equipments for fire fighting, (iv) Skilled organization of fire fighting crew, (v) Skill in attacking and fighting the fire and (vi) Mopping up and sufficient patrolling to check and stop the new outbreaks of fire.

If the fire is small it can be put off by one to five people but if the fire is large it may take hundred people or even more and would take many days to fully extinguish the fire. Since the fire requires three necessary commodities, (i) heat (ii) fuel and (iii) oxygen or air, the removal of any one would extinguish the fire. For a fire to occur all three are important and form a fire triangle therefore, removal of any one will immediately bring fire under control (Fig. 1).



The fire can be extinguished by the use of following methods:—

- I. By eliminating heat: To eliminate heat we can use water or mineral soil.
- II. By beating with the broom made of elastic green branches and twigs available at the spot. The behavior of any two forest fires is seldom alike. Each fire poses different

problems due to variation in fuel types, weather, slope, nature of terrain, and approach to fire and so on. In order to extinguish a fire two types of methods are used. They are (i) Direct attack and (ii) Indirect attack on the different parts of fire. In the initial stage when fire is small and rate of spread of fire is slow and the heat generated is also not too great direct attack on fire is made. Immediately fire line should be made with the help of rakes and showels and fire should be beaten with green branches etc. The water if available must be used. In indirect attack since the heat is great, the work of fire line etc. is done at some distance away from the fire. Indirect attack method requires lot of labor force and equipments. The new fire line is made or any other barrier may be used to stop the fire. Very hot fires should be attacked from a distance so that by the time fire travels there the barrier is already prepared to stop the fire. In direct attack method the area between the fire edge and control line is allowed to be burned off.

The natural barrier to stop a fire may be open land, roads, bare rocks, water streams etc. In absence of any such natural barrier the special barrier or fire line or control line needs to be made wisely to confine the fire to the smallest possible area. Sometimes it may necessary to cut bushes small trees. The fire line can be made with the help of a tractor. The water should also be used for extinguishing fire.

III. Combination of direct attack and indirect attack method is also used to extinguish the fire.

(iv) By Counter firing or Back-Firing: The counter firing is the fire set to meet the opposite fire and calm it down. When the two fires meet since there are no combustible material between these two fires the fire is automatically extinguished.

(v) By Mopping Up or Post Fire Suppression Operation: After the fire has been put down patrolling should be done to check any shouldering material or spark left in the fire burnt area. Therefore, mopping up and patrolling is required till the fire is completely extinguished. During mopping up operations sufficient water and earth should be used. If there is any unburnt dry wood it should be pulled back from the burnt out area to prevent any likelihood of future fires. The patrolling staff before leaving the area should make it sure that there is no danger spot left untackled.

7.8 General Control Measures

The various methods adopted for the control of various insect pests are:

(i) Mechanical Methods: This includes catching of insects and destroying them by many types of traps. Many types of traps are used for catching insects. To check climbing of band is tied on the tree trunks. Larvae up the tree. To control easy in sal heartwood. Borer trapping method is employed.

(ii) Silvicultural Method: It includes better hygiene, good drainage, thinning, felling, clean-lug etc. The trees likely to be affected viz. malformed, disease, wind neck broken, fire damaged etc. should be removed. Resistant species are planted. Certain species support the parasites of the pest, fame on a species should be grown to harbor parasites. The trees growing should be made vigorous by proper weeding, cleaning and lower branches?

(iii) Biological Methods: In the biological method of control the population of predators and parasites of pests are increased. Similarly insectivorous birds are encouraged. This method is difficult to practice because of insufficient knowledge and other constraints.

(iv) Chemical Control: Many chemicals like insecticides and pesticides are used to control the insects. They are categorised as under:

- a) Contact poison : Lime-sulphur, MIC, Aldrex, Dieldrine, thimet, paramor, termax, Rogor, Dimecron, Aldrin.
- b) Stomach poison: Calcium arsenate, Sodium fluoride etc.
- c) Fumigants-Creosote, naphthalene, bordeaux mixture etc.
- d) Systemic insecticides.

Summary

Unit 8: Thinning

Unit Structure

8.0 Learning Objectives

8.1 Introduction

8.1.1 Difference between tending and cultural operations

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8.2 Thinning: definition and objectives

8.2.1 Objectives of Thinning

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8.7 Factors Affecting Thinning Practice

8.7.1 Advantages of Thinning

8.0 Learning Objectives

On completion of this unit you should be able to understand

- What is thinning?
- Difference between tending and cultural operation.
- Kinds of thinning
- Objectives of thinning
- Effect of thinning on stand development

8.1 Introduction

For its proper development, a forest crop requires food and light from the very beginning. The individual members constituting the crop have to compete for these essentials not compete only amongst themselves but also with the individuals of the unwanted species which appear on the forest floor by them-selves. As the crops grow in age, the requirements of individual members increase and their growth is seriously affected if their increasing requirements in respect of food and light are not met by

proper tending which may be defined 'as an operation carried out for the benefit of a forest crop, at any stage of its life between the seedling and the mature stages; it essentially covers operations both on crop itself and on the competing 'vegetation, e.g., weeding, cleaning, thinning, and even improvement felling and also pruning, climber cutting and girdling of unwanted growth, but does not include regeneration felling and ground operations like, soil working, drainage, irrigation and controlled-burning'.

8.1.1 Difference between tending and cultural operations

- i. Tending is carried out for the benefit of a forest crop by creating best possible conditions of growth. On the other hand, cultural operations are carried out not only to promote proper development of a crop but also to assist or complete existing regeneration and to minimize the after-effects of felling damage. Thus the scope of cultural operations is more extensive than that of tending.
- ii. Tending does not aim at obtaining natural regeneration while cultural operations aim at obtaining it as one of their objects is to complete existing regeneration.
- iii. Tending includes pruning but does not include controlled-burning. On the other hand, cultural operations do not include pruning but include controlled-burning and even piling of felling debris.
- iv. Tending is carried out generally every year for the first two or three years of a new seedling crop and thereafter at an interval of years increasing gradually from 2 or 3 to 10 or even more. But cultural operations are carried out in the year following a felling; their periodicity, therefore, depends on the felling done in the area.
- v. Tending is carried out in crops obtained both from natural as well as artificial regeneration but cultural operations are more often associated with silvicultural systems, relying primarily on natural regeneration.

8.1.2 Importance of tending

Tending helps in producing high quality timber and maximizing returns per unit area; it is, therefore, an important silvicultural operation. The above objects can, however, be achieved only when tending operations are done properly and on time.

8.2 Thinning: definition and objectives

Thinning includes removal of tree species in an immature stand for the purpose of increasing the growth rate of desired individuals and mainly those individuals are removed which are not in a dominant position. It should not be confused with improvement felling in which under the canopy tree individuals are removed whereas in case of thinning individuals overtopping the desired ones are removed. Thinning can be differentiated with cleanings, liberation cuttings, and improvement cuttings in the sense that in the former mostly trees not in a dominant position are removed whereas in other mainly overtopping individuals are removed. Further, thinning are those cuttings which are carried out after cleanings or improvement cuttings or salvage cuttings. In other words, thinning is a term which covers almost any kind of cutting which removes stems of desired species but impairing the growth and development of desired one.

It may be defined as 'a felling made in an immature stand for the purpose of improving the growth and form of the trees that remain, without permanently breaking the canopy'. In the silvicultural systems depending on natural regeneration, the number of trees is reduced to obtain regeneration

Thinning is defined as a felling made in an immature stand for the purpose of improving the growth and form of the trees that remain, without permanently breaking the canopy. It is a treatment of forest crop whereby the numbers of trees growing in a stand are reduced. Thinning consists of a series of successive felling operation for a number of times before the crop matures. The interval between two successive felling may be fixed but it is dependent on the time required for canopy closure. Thinning is carried out in a crop after it reaches the sapling stage and continued up to the beginning of the regeneration period. The thinning principles are applicable to pure and even aged or nearly even-aged crop or even-aged groups of the trees in a crop. Thinning always increases spacing and decreases number of trees per unit area. Most of the tree species in India are raised at a close spacing i.e. 2m x 2m or 3m x 3m or 3m x 1m etc. After five or ten years depending upon species and site conditions, the canopy closes or root competition is so heavy that the plants are not able to grow unless they are thinned out. They require space for crown as well as root development. For example, in a teak plantation raised at a spacing of 2m x 2m or 2500 plants/ha

after the first thinning the number of plants would be 1250 and after second thinning number of plants would become 625 and so on. Thinning is based on the principle of natural development of crop. After each thinning, number of trees/ha decreases but this is compensated by its diameter and height growth.

8.2.1 Objectives of Thinning

Thinning is done in crops with following objects:

(1) To distribute growth potential of a site amongst the trees retained: Total volume of timber to be produced by a stand is governed by the site it occupies. In better site qualities, the volume of timber produced is more while in poorer sites, it is less. But the total volume of timber to be produced by a stand per unit area on a given site at a given age for a given composition is constant as well as optimum irrespective of density of the crop. Even though the total volume of timber to be produced by a given stand cannot be increased by silvicultural operations, it can be distributed amongst an optimum number of trees selected on the basis of their form, quality and potentially of growth in future by removing or felling other inferior trees. Thus, thinning results in the production of an optimum number of big-sized trees of good form and quality.

(2) To increase the net yield of timber and money from a stand: Even though the total volume of timber to be produced by a stand cannot be increased, the net yield of timber is increased partly by salvaging the timber in the form of thinned material, which would have otherwise perished in the natural struggle for existence and fires, etc., and partly because the percentage of conversion of timber from trees of larger sizes and good form is more than that from smaller-sized trees of poor form. The increase in the net yield of timber results in increased financial yield not only because of increased volume but also because of higher rate obtained for bigger-sized and relatively better quality timber from trees of larger sizes and good form.

(3) To obtain earlier returns from capital invested in a stand: As large sums of money are invested in regenerating a stand, whether naturally or artificially, and tending it to maturity, it is very important from the economic point of view that the returns from the capital invested, are received early. Thinning achieves this object by (a) utilizing the thinned material and (b) shortening the rotation as shown below:

a) **Utilization of thinned material**—As thinning are started from the time the crop passes into pole stage, all the trees that would have perished in natural

selection are removed in thinning and utilized. The following table prepared from the yield tables gives the percentage of yield of thinning to the total yield of standard as well as small wood. The

Species	Age in years	Grade of thinning	Site quality	Total yield	Accumulated yield of thinnings	Percentage
Teak (Plantation)	80	C	I	9,230	4,300	46.6
			II	7,030	3,460	49.3
			III	4,825	2,455	50.9
Deodar	140	E	I	24,870	12,730	51.2
			II	19,680	9,610	49.0
		D	I	25,090	8,700	34.7
			II	19,640	7,160	36.4
		C	I	25,350	6,980	27.5
			II	20,120	5,430	27.0
Sal	140	C	I	21,190	14,780	69.7
			II	15,330	10,450	68.2
			III	9,440	6,140	65.0

sale of the thinned material gives financial return on the capital invested from a fairly early age periodically throughout the rotation.

b) **Shortening the rotation:** As the reduction in number of trees in thinning, increases the diameter of the remaining trees, a given exploitable diameter can be reached in shorter period by heavier grades of thinning. For example, in I quality area. According to multiple yield tables, deodar reaches an average diameter of 22.0" by E grade thinning in 99 years, by D grade thinning in 110 years and by C grade thinning in 121 years. Thus rotation can be reduced by judicious heavier thinning.

(4) To produce a different smaller size of timber which can meet a different object of management: Poles and smaller-sized trees produced during thinning cater to a different market, e.g., for transmission poles in case of Sal and some other species. Sometimes, this produce is almost as much or even more valuable than the main crop.

(5) To maintain hygienic conditions in the stand: The thinning remove the diseased as well as dead or dying trees which are liable to insect attack and thus ensure the production of disease-free healthy stand. They also reduce the fire hazard by removing the suppressed trees along with the dead and dying trees. Thus the losses due to attack by injurious insects, fungi as well as by fire are considerably reduced.

(6) **To obtain timber of the desired quality and mechanical strength:** Thinning improves the quality of wood produced from a stand by removing trees of poor quality in favor of best trees. Quality of the wood is also improved by controlling the rate of growth and keeping it uniform by judicious thinning.

(7) **To ensure decomposition of raw humus in temperate forests--**As thinning opens up the crop, they increase the light and temperature on the forest floor. This results in decomposition of raw humus and consequently in increasing the fertility of the soil as well as in helping natural regeneration to establish.

- **Basis for thinning:** In order to carry out thinning, the forester should have an idea of trees which are leading in the struggle for existence and are promising from the point of view of future growth, the potential growing capacity of a site and the optimum number of trees that should be retained to make full use of the site. For this he requires certain easily visible and understandable factors concerning the stand. Such factors could be qualitative as well as quantitative.
- **Qualitative factors:** By qualitative factors is meant the character which may give indication about the present achievements and future prospects of a tree in the social competition. These factors are largely subjective and can be based upon the total height, crown development, and stem form. As the height of tree is an index of quality of site as well as its own potentialities for growth, therefore the tree classification used in thinning is based on the relative dominance of the trees. After classifying the trees according to height, the development of the crown and stem form is used for sub-classification of the dominance categories. Another view is that the crown length and width are useful indices of the growth potentialities of trees and their relation to total height will provide a good basis for thinning. For example, in well thinned Sal forests, crown length is slightly less than of the total height and crown width is approximately the same.

8.3 Kinds and Methods of thinning

The methods of thinning are as follows:

- i. Mechanical thinning
- ii. Low thinning method or ordinary thinning (German Thinning)
- iii. The crown thinning (French Thinning)

- iv. Selection thinning
- v. Free thinning
- vi. Maximum thinning
- vii. Advance thinning

1. Mechanical Thinning: In this type of thinning the trees are removed by some thumb rule e.g. removal of alternate, rows, removal of alternate diagonals, or removal of every second, third, fourth line etc. or where the spacing is irregular the minimum spacing is maintained by using "standard stick" method. This type of thinning is applied to young plantations e.g. teak etc. in which canopy differentiation has not taken place.

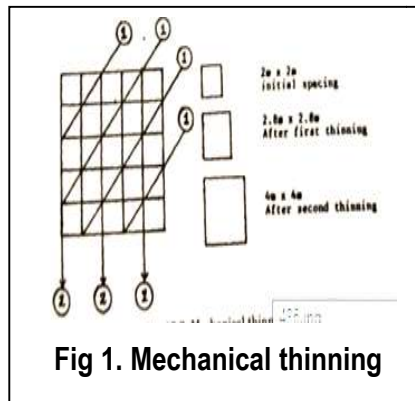


Fig 1. Mechanical thinning

There are two types of system for mechanical thinning:-

- (i) Row Thinning in which trees are removed in lines or rows.
- (ii) Spacing Thinning In which trees at fixed intervals of distance are selected by using "stick" for retention and all others are cut.

This method is well suited to plantations having uniform productivity, but in case of high mortality plantation this is difficult to apply. In Teak plantations at an spacing of 2m x 2m (2500 trees/ha) the alternate diagonals are removed in first thinning (5th year) and alternate rows are removed in second thinning (10th year). The number of trees niter first, and second thinning would become 1250 and 625 per ha. respectively as shown in the Figure 1. The formulas evolved for some species to carry out thinnings are—

Glover's formula for deodar $D = d$

Warren's formula for deodar $1) 1 = 1 d = 3/2d = 1_.5d 2$

Laurie's formula for sal $1) = 1.5d$

Sagreiya's formula for teak $D = 1.5 (d+4)$ or $D = 2 (d+3)$

Proward's formula for sissou $D = 2d$

Where D = spacing of trees in feet and d = average diameter of trees in inches

This method may be good for a area having uniform productivity. The disadvantage of this method is that many good trees which fall in diagonals or rows are removed.

2. Low or Ordinary Thinning: This is also known as 'german thinning' or thinning from the below and consists of the removal of inferior individuals starting from the suppressed class and then taking the dominated class and ultimately some of the dominant class. It is very common form of selective thinning in regular crops. It has been devised to be in line with the nature because only those trees which have been unsuccessful in the struggle for growth are removed first.

The ordinary thinning has following advantages —

- It is useful in areas where the demand of small timber is more and has market for selling.
- It is most suited for light demander species eg. Teak, Sal, Chirpine, *D. Sissoo*, Semal etc.
- It is simple to apply and even a less trained staff can mark the trees for felling.
- This thinning practice improves the hygienic condition because several diseased and insect infected trees are removed.
- This thinning is preferred where climber infestation is a problem but should not be carried out where there is danger of soil erosion.
- In this method since smaller and less vigorous trees are removed, the vigorous trees are retained for fast growth. But to achieve the desired result, some dominant trees may also be removed for reducing root competition.
- Removal of lower crown classes help in the natural regene-ration of the species

The demerits of ordinary thinning are as below –

- i. In several areas where the thorny bushes, undesirable trees and climber infestation are heavy, the removal of trees of lower crown classes is troublesome and expensive. In this case of sal the dense understory develops in areas where heavy openings are created by removing lower crown classes.
- ii. This thinning is carried out after the trees have remained in competition for a long time to develop crown differentiation. Due to this the whole crop including dominants is already affected due to adverse effect of competition.
- iii. In a situation*where the predominant and dominants are not able to utilize the site perfectly, the lower classes may be useful. The surplus of the nutrients store is utilized by lower crown classes and remains in cycling.

- iv. In absence of the demand or market of small thinning poles, the thinning material cannot be utilized economically. If allowed to remain in the jungle depot it would increase the fire hazards.
- v. There is always danger of exposure of the soil. The soil erosion may be increased, particularly in sloppy areas by removal of lower crown classes. Many of these trees may therefore, be retained as soil cover and as an insurance against casualties among the larger trees.

8.4 Grades of Ordinary Thinning

The grade of thinning to be adopted depends on experience. There are various grades of thinning:

(1) A Grade: Light thinning: Removal of dead, dying diseased and suppressed trees i.e. class V, IV AND III.

(ii) B Grade: Moderate thinning: In addition to trees in A grade further removal of defective dominated stems and whips. Branchy advance growth which can not be pruned or lopped may also be removed i.e. class V, IV, III, II(b), I(d) and an occasional I (c).

(iii) C Grade Heavy thinning: This includes trees in grade A and B and all remaining dominated, defective co-dominants that may be removed without making lasting gaps in canopy i.e. class V, IV, III, II and I (b), I(c) and I (d). The C grade thinning is the standard grade in vogue for yield table computation.

(iv) D Grade Very heavy thinning: This includes trees of all above grades and some good dominants so that no lasting or permanent gap develops in canopy. The left over trees are with good boles and crowns, well spaced and evenly distributed over the site for future development. The removal of trees are made from the classes V, IV, III, II, I(b), I (c), I (d) and some I (a).

(v) E Grade extremely heavy thinning: This type of thinning is adopted mainly for research purposes. This is the heaviest thinning that can be made in the crop without creating permanent gaps in the canopy. Many dominant stems including that of class I (a) are also removed. It is always better to make C-Grade or D-Grade thinning in a dense crop in which thinning has been unduly delayed. The removal of trees should be

economic or of hygienic value. In addition to above classes the intermediate grades of thinning such as C/D or D/E are also carried out.

8.4.1 Crown Thinning

This is a kind of selective thinning in which thinning is primarily directed to the dominant trees in a regular crop, the less promising ones being removed in the interest of the best available individuals; the dominated and suppressed stems are retained unless they are dead, dying or diseased. The crown thinning favors the crown development of selected potential final crop, trees. Retaining trees of lower crown classes can help in natural pruning of the dominant trees which are to make the final crop. This method is also known as "French thinning" or high thinning. The bulk of trees of lower crown classes e.g. dominated and suppressed are ignored and allowed to grow after each thinning. The selection of the trees to be retained after thinning depends basically on the health, vigour, form and species. If all the trees are good in health, vigour, form and species, only co-dominants are removed which are interfering with the growth of predominant (dominant) trees. In cafe of choice between relatively poor predominant and promising co-dominants, the co-dominants are favored for retention. The object in crown thinning is to promote the growth of promising trees and ensure a good value of future crop. It is suited for moderately shade tolerant species e.g. Sal, Deodar etc. in which the retention of the lower canopy classes presents no difficulty. It is not suited to Teak, Chir-Pine, Sissoo, Shivan etc. It is suitable for forests where damage due to frost, snow, wind etc. are common because the gaps created by dominant trees is filled by the trees of lower crown classes. The crown thinning should be carried out where there is no demand for small sized timber.

Advantages of crown thinning	Disadvantages of crown thinning
(i). This method checks soil erosion and damage due to frost, snow, wind etc. is reduced. Shade bearing trees are also protected. (ii). The side branches are pruned in a better way due to the presence of trees of lower crown classes. (iii). The lower crown classes help in controlling weeds and shrub growth. (iv). The removal of some dominant trees provide light and room for some dominated trees to develop, many of which may later take their place among the dominants.	(i). The dominants are adversely affected when growth factors are limited and there is tough root, competition for moisture end nutrients. (ii). The lower tree classes make difficult various operations e.g. marking, felling, logging nod extraction of the thinned (iii). It requires experience nod skill. The method being flexible requires greater check on the trees to the marked and removed (iv). The diseased end inflects infested trees of lower crown classes are always sources of infection for the crop.

Only two types of thinning have been recognized as defined below:

(A) Light Crown Thinning (L.C. Grade): This consists in the removal of dead, dying, diseased and wolf trees with such of the defective and after them the better dominants, as are necessary to leave room for further development of the best available trees evenly distributed over the area. The trees belonging to classes V, VI, I(d), I (c), many of I(b) and a few of I (a) but not III and II are removed. This is like D grade ordinary thinning, but retains all III, II and is not quite so heavy only.

(B) Heavy Crown Thinning (H.C. Grade): This grade of thinning pays even more attention to favoring the selected best stems by removing all the remaining I (b) which can be taken, without creating permanent gaps and more of I(a), i.e. classes V, IV, I(d), I (c) most of I(b) some of I(a); but not III and II. The final crop is targeted to achieve certain stockings e.g. 500 to 600 trees per ha. The dominated and suppressed trees are not removed.

8.4.2 Free Thinning

This is also called HECK'S free thinning and is a modification of crown thinning. It is also called 'Elite Thinning' or "Single Stem Silviculture" The attention is concentrated still further on the selection of elites or alpha stems, evenly spaced over the ground, which are retained upto maturity or till the last thinning or two, and thinning operations. may accordingly be directed primarily to the removal of other stem hindering their optimum development. The emphasis is made on freeing the selection of most promising stems called "elite or alpha stems" from the competition of their less promising neighbors. The number of future stems to be required at the rotation age are first selected and retained evenly distributed over the area. After selecting and marking the elites, rest of the crop is considered from the point of view of their effect on elite trees, if considered necessary, they are cut otherwise left for the protection of the site.

The crop after free thinning do not differ much in appearance from those subjected to crown thinning, but the attention is concentrated on the trees to be retained rather than on the trees to be removed (just as in seeding felling). Co-dominants or even dominated trees of perfect stem form, and standing in the necessary position relative to neighboring elite stems, may be preferred to quite fair but less acceptable dominants. The variation in intensity of felling which have not been standardized is quite possible and needs a practical demonstration before starting the whole thinning.

This method was applied in teak plantation of Nilambur forest division (Kerala) during 1956 and 1967 but was abandoned due to many reasons viz.

- (i). Difficulty in identifying elites.
- (ii). The involvement of heavy thinning around elite trees made them wolf trees. After thinning elites may be attacked by some disease or may be damaged by wind and there may not be any suitable substitute near to it.
- (iii). The marking done by paint attracts elephants and other animals. The elephants do a lot of damage to saplings and poles. In young plantations, the elites are extensively damaged.
- (iv). If the whole lot consists of bad individuals, the selection of one elite from every quadrat of 10m x 10m makes it often obligatory to select bad elites.
- (v). The thinning in "buffer stock" between elites are often neglected thus creating islands of congested stock which grow in suppression and affect the intermediate yield.
- (vi). The amount of work done varies with the availability of fund.
- (vii). It is cumbersome and time consuming.

8.4.3 Advance Thinning

It differs from all other methods described above as thinning is carried out before the competition among individual trees has set in. The surplus individuals are taken out regularly for the advantage of the residual ones. This may cause loss of total volume production but should ensure maximum growth of the elite trees. This method was developed by Craib (1939) and O'Connor for wattle and pine plantations in South Africa. Advance thinning was tried for Sal, Teak and Chir-Pine stands in India. The correlated curve trend (C.C.T.) correlating number of stems per unit area with crop age (growing free from competition from neighbors) was drawn and indications are that this method is not suitable for light demanding species under tropical Indian conditions. The correct time of suppression and hence thinning is difficult to determine.

The rapid extension of crown and quick closure of the canopy after 40 a felling that took place in S. Africa, do not occur, whereas grass and other weed growth is encouraged reacting unfavorably on growth and increasing fire hazard.

8.4.4 Maximum / Numerical Thinning

Where, the yield table exists, it can be used as standard of IN reference. During thinning the number of stems per unit area, diameter and height serve as a guiding factor for the optimum density of the crop. These factors vary with the site quality, therefore, even if the yield table exists, a really subjective approach is necessary for different sites. In absence of yield tables a standard of reference has to be found within the crop itself. The following types of approaches are generally followed.

- (i). **N/D Relationship:** The NM curve for Indian species has not been found independent) of the site quality. But it is possible to calculate the number of trees APP' corresponding to a given diameter for different species on the basis of ..., stand density index (S.D.I.), which is the number of trees corresponding to a given standard average diameter. A standard logarithmic equation for the given grade of thinning can be formed —

$$\text{Log } n = -a \log d + K$$

Where, 'a' and 'k.' are constants

- (ii). **N/H² Relationship:** Many workers have established that for a given site, the optimum number of trees per unit area is inversely proportional to the square of the height of the stand (for this purpose the top height or the height may equally be liken). The relationship is

$$N \propto \frac{1}{H^2} \text{ (Czcinowaski, 1969)}$$

- (iii). **Tree-Area Ratio:** If Y = area occupied by a single tree and d = diameter then for that tree:

$$y = a_0 + a_1 d + a_2 d^2$$

For a stand having n trees per unit area the total ground area Y is given by:

$$Y = \sum^n y = a_0 (n) + a_1 \sum^n d + a_2 \sum^n d^2 \text{ (for unit area)}$$

The constants a_0 , a_1 , a_2 are evaluated from the yield tables or a representative number of fully stocked plots thinned to the same grade.

- (iv). **Basal Area:** The basal area of the tree is related to density. If the basal area per acre in a fully stocked stand is plotted against average diameter for different ages, a grid is obtained from which the percentage basal area of the stand of a given average diameter is calculated. This gives density. The 100 per cent stocking curve is drawn from the tree-area ratio method.

8.5 Precautions in First Thinning

The first thinning is very important for any crop. The following factors should be considered at the time of first thinning:

- (i). The thinning should take place before adjoining trees check one another's growth.
- (ii). The thinning should not be postponed on the ground that the poles obtained will be non-saleable or uneconomic.
- (iii). The age of first thinning should be taken on the basis of height or size attained. But if it is found that the requisite growth has not taken place the thinning may be postponed a year or more till the development becomes normal.
- (iv). The heavy thinning should not be carried out on poorer sites, drier areas and steeper slopes, because the gapes may not be filled up due to poor growth of trees.
- (v). The all thinning should first be done on the silvicultural lines. The further adjustment should be made after making due numerical checks.
- (vi). The light demander species may require heavier thinning as compared to the shade bearer species. For example teak requires early and heavy thinning and stagnation adversely affects its growth.
- (vii). If the mechanical thinning is not possible due to low survival rate, poor growth and interference by other species, it is best to carry out silvicultural thinning. Some admixture of secondary species may be retained where this is desired on silvicultural or protection grounds.

8.6 Thinning in Irregular Crops

It is difficult to classify tree in an irregular crop. The general classification which is used for the research purposes are three crown positions and three crown forms viz. D, d and s, good, medium and small. Seth (1956) has suggested that in irregular crops the degree of crown freedom and their further sub-classification into large, medium and small crown sizes should be taken into account.

Crown freedom	Free	Restricted	Confined
Crown development or Crown site.	Well developed or Large	Average or Medium	Poor or Small

The crown freedom is judged irrespective of the size of the tree and its position in the stratification. The thinning is an irregular crop is done by selection method. All such trees, which might have been retained in crown and ordinary thinning, are likely to be cut. The trees to be cut are that which restrict the growth of their neighbors on all sides and should not be more valuable than their neighbors. The aim should be to maintain crop of all diameter classes in sufficient numbers of maximum sustained yield. The valuable species are retained whereas inferior trees of all diameter classes are removed. The removals of trees are carried out in diameter classes. It aims at continuous improvement by repeated removal of inferior stems in all diameter classes so that basal area or standing volume becomes more or less equal to theoretical ideal value.

8.7 Factors Affecting Thinning Practice

The following factors may be considered before deciding the thinning practice:-

1. Site Factors: The site quality influence on thinning practice is that a relatively close canopy on the poorer sites should be maintained. On low quality sites heavy openings should not be made. The spacing out widely in earlier stages should not be carried out on hot, dry, slopes, on poor soils and on all sites where grass and other weed invasion is likely to occur. A poor site will usually support less stems per ha than a good one.

For Sal having crop diameter of 30 cm the no. of stems are 390 (Q.C.I.) and 356 (Q.C.III), for Chir-Pine the number per ha is 420 (Q.C.II) and 306 (Q.C.III). For teak and deodar the number is normally independent of site quality.

2. Nature of Species: The shade-bearers are more tolerant of crowding than the light demanders therefore more frequent thinning is needed for light demander species. Light demanders usually show good response to ordinary thinning whereas shade bearers to crown thinning. Teak requires early and relatively heavy thinning otherwise growth stagnates and trees become so "crown-bound" that after delayed thinning they show poor response to opening of the canopy. The plantation should not be allowed to suffer merely on the ground that thinning poles are unsalable; Chir-Pine and Sissoo, being light-demanders require heavier grades of ordinary thinning. The shade bearers should be managed with ordinary thinning but in order to protect the soil and ensure against causalities, crown thinning may be preferred. For deodar advance thinning is

suitable as the site is not likely to degrade even after exposure. The species such *Terminalia*, *Pterocarpus* etc. have frondose habit in young stage and do not produce well defined vertical stems and symmetrical crown for some years. If thinning is carried out early and heavily, the stems tend to become branchy and poor in shape and if thinning is delayed or is too light the development of straight boles and crowns are poor.

3. Age: The crown formation depends on age and in young ages when the crown formation is not completed mechanical thinning or stick thinning may be done with success. The light demander species require heavier grade of thinning at frequent intervals in younger crops. On the other hand some species in middle age or maturity require crown thinning.

8.7.1 Advantages of Thinning

The advantages of thinning are as follows:

- (i). The length of time required to grow products of the desired sizes can be shortened by means of thinning as it creates openings and reduces competition, thereby, better light, ample nutrients available for growth for both diameter and height growth.
- (ii). Thinning raise the quality of the product composing the final crop as inferior trees are removed from the lot.
- (iii). Total yield both in quantity and in value of product obtained from a given area in a defined period will be increased. Further, it removes and utilizes trees which otherwise may die in un-thinned stands. Thus, it increases the actual benefits derived from the stand.
- (iv). The yield during the rotation is increased in value for as a higher quality of product is produced, furnish financial returns comparatively early in the rotation, thus, early returns mean higher profits. Thus, an appreciable portion of the total production may be removed relatively early in thinning operations.
- (v). The expansion of the crown and root system after thinning process increases the power of trees to become resistant to wind, ice, snow etc.
- (vi). It keeps the stand free of unhealthy and dying trees, in which insects and fungi find the best opportunities for development.
- (vii). Thinning may favorably affect water yield from forested areas by increasing snow storage and lengthening the period of snow melting.

UNIT 9: Energy and Industrial Plantation

Unit Structure

9.0 Learning objectives

9.1 Introduction

9.2 Definition of Energy Plantation

9.2.1 Criteria of tree species planted for energy plantation

9.3 Scope and Advantages of Energy plantation

9.4 Choice of Species

9.4.1 Suitable Species For Firewood/Fuelwood/ Energy Plantation For Different Regions

9.5 Extractive plants

9.5.1 Latex yielding plant species

9.5.2 Vegetable oils

9.5.2.1 Seed-oil bearing plants

9.5.3 Resins

9.5.4 Calorific value

9.6 Establishment and Management and Plantation Economics

9.0 Learning objectives

After completing this unit you shall be able to:

- Define Energy plantations
- Explain scope of Energy plantation
- Explain about the choice of the specie for energy plantations

9.1 Introduction

India is one of the world's 2nd largest populated countries. India has huge human population of 125 corers. Most of the population (75%) residing in rural area which totally depends upon forest to meet out their energy requirement. The demand for fuel wood in India is increasing day by day. India's current firewood consumption is more than 133 million tons; most of it is being used in cooking. To cook 1 kg of food 1.2 kg of firewood is required. It clearly indicates that India should produce more wood than food if it is to be cooked before it is consumed. The electricity can also be generated by dried wood. According to estimate 400 million tons of cattle dung equivalent to about

60 million tons of fuel wood are burnt annually in our country. If this much quantity of cattle dung is incorporated into the soil then it could increase soil productivity. Similarly fuel wood is the most significant reason for tree cutting. To save forests from degradation, fuel wood tree growing should become part of agriculture through agroforestry in blocks in order to meet out their demands of fuel wood improve the microclimate by means of saving trees in natural forests. An energy plantation is one that is grown purely for plant material for their fuel than for fiber content.

9.2 Definition of Energy Plantation

An energy plantation is one that grown purely for plant material for their fuel value than for fiber content. In energy plantations it is necessary to select fast growing plants; spacing should be close (one meter) and short rotations of 3-4 years. This concept is based on the principle that yield of dry matter of certain fast growing species is independent of spacing. In such a method canopy closure occurs rapidly at very early stage resulting in more dry matter per unit area when compared to traditional silvicultural methods using large spacing. In this approach the idea is to use trees that grown very fast during first few years and coppice them at intervals of less than five years.

9.2.1 Criteria of tree species planted for energy plantation

- Tree species should be fast growing with high photosynthetic efficiency which results into high yields.
- Tree species should have high coppicing and pollarding capacity.
- Tree species selected to energy plantation should be conical or cylindrical in shape.
- Tree species should have wood of high calorific value, high wood density, dry weight and burns without sparks or toxic smoke.
- Tree species should be able to tolerate incidences of insects, pests and diseases.
- Tree species should have ability in them to reduce transpiration loss in arid areas.
- Tree species should have ability to fix nitrogen, if possible, that can improve soil fertility without having much competition with main crop for soil moisture, sunlight, etc.

- Tree species should be multiple in nature.

9.3 Scope and Advantages of Energy plantation

- Emit little or no sulphur and less nitrogen dioxide than fossil fuel
- Helps in rehabilitation of degraded lands
- Provide rural employment
- Alive and active growing forest and other plant biomass absorb the greenhouse gas in quantities broadly equivalent to amount emitted when plant material decay or burned. They are thus called as “Carbon neutral” fuel sources
- Growing energy crops creates a “carbon sink” which includes storing carbon underground through the tree root system
- Lower energy cost per unit area as lower inputs are required as compared to agriculture crops.
- Energy plantations are thought to remove the entire nutrient from soil. However, by use of thermo chemical process of biomass conversion it is feasible to recover all nutrients as ash which can be returned to the plantation sites
- Dependable & renewable source of energy along with afforestation of marginal lands & employment generation.
- Aesthetic value, Windbreak and Shelterbelts.
- Fodder, NTFP etc.
- Handling & disposal of by products is safe.
- Energy plantations are both ecologically as well as sociologically much sounder investments

9.4 Choice of Species

In Agro forestry one of the most important considerations is to identify species which are compatible with each other also complement with each other. Fortunately in our country we have 15,000 different vascular plants and therefore it is just a matter of

experimentation to identify suitable species fulfilling the above requirements. In the selection of suitable species due importance is to be given to those which improve the productivity of site. It is also equally necessary to establish compatibility and implement ability between the trees as well as agricultural crops to be raised in conjunction.

9.4.1 Suitable Species For Firewood/Fuelwood/ Energy Plantation For Different Regions

9.4.1.1. Tropical Dry Region

Acacia catechu, Acacia modesta, Acacia nilotica, Acacia Senegal, Acacia tortilis, Anogeissus pendula, Albizia lebbek, Azadirachta indica, Cassia siamea, Cordia rothii, Dalbergia sissoo, Emblica officinalis, Eucalyptus camaldulensis, Erythrina superb, Gmelina arborea, Parkinsonia aculeate, Peltophorum ferrugineum, Pongamia pinnata, Prosopis cineraria, Prosopis juliflora, Tamarindus indica, Tamarix troupe, Tecomella undulate, Zizyphus mauritiana etc.

9.4.1.2 Tropical Humid Region

Adina cordifolia, Acacia auriculiformis, Acacia catechu, Acacia nilotica, Albizia procera, Azadirachta indica, Cassia siamea, Casuarina equisetifolia, Dalbergia sissoo, Dendrocalamus strictus, Ficus spp., Eucalyptus spp., Kydia calycina, Leucaena leucocephala, Madhuca indica, Melia azedarach, Morus alba, Salix tetrasperma, Syzygium cuminii, Tamarindus indica, Trewia nudiflora, Gliricidia sepium and Gmelina arborea.

9.4.1.3 Sub-Tropical Region

Acacia catechu, Acacia melanoxylon, Acacia nilotica, Aesculus indica, Ailanthus excels, Celtis australis, Grevillea robusta, Michelia champaca, Populus deltoids, Populus nigra, Robinia pseudoacacia, Salix alba and Toona ciliate.

9.4.1.4 Temperate Climate

Acer spp., Aesculus indica, Alnus nepalensis, Alnus nitida, Celtis australis, Populus ciliate, Quercus semecarpifolia, Salix alba and Toona serrata

- The direct use of firewood in densely populated area should be avoided as it causes environmental pollution.

- Some firewood on burning gives toxic and irritating smoke, and foul odour.
- The firewood may be converted into charcoal which is more efficient.

9.4.1.5 Charcoal

Charcoal is an ideal smokeless fuel for cooking. 1 kg of charcoal has a replacement value of 2.38 kg of firewood or more. The combustion efficiency of charcoal is about 28 per cent. Thus, conversion of firewood into charcoal for use as a fuel will be better than firewood as such. Charcoal is also useful as a reductant in electrometallurgical industries. Manufacture of calcium carbide, carbon-disulphide and active carbon. It does not contain sulphur. The following are a few important tree species for energy plantation: (charcoal making)

Charcoal making: *Acacia nilotica*, *Adina cordifolia*, *Anogeissus latifolia*, *Casuarina equisetifolia*, *Pinus roxburghii*, *Quercus leucotrichophora*, *Quercus semecarpifolia*, *Tamarindus indica*, *Terminalia arjuna*, *Terminalia bellerica*, *Terminalia chebula* and *Terminalia catappa*

9.4.1.6 Shrubs for energy plantation

Atlantia monophylla, *Crewia latifolia*, *Clerodendron inerme*, *Dodonaea viscosa*, *Jatropha glandulifera*, *Jatropha curcas*, *Tecoma gracilis* and *Pomoea camea* etc.

Besides this firewood and charcoal plants also provide exudates and extractives. Such plant species are energy rich and may be exploited as renewable sources of energy. These species are known as „petro-crops“, since they can serve as substitutes for supplement to petro chemicals.

9.5 Extractive plants

Based on exudates and extractives, plants are classified as those bearing:

- Latex
- Vegetable oil and waxes
- Resins
- Essential oils
- Tannins and phenolic compounds bearing plants

9.5.1 Latex yielding plant species

- Plant species yielding latex belong to Family Apocynaceae, Asclepiadaceae, Euphorbiaceae, Moraceae and Sapotaceae.
- Potential petro-crops are: *Euphorbia antisyphilitica*, *E. tirucalli*, *E. lathyris*, *Pedilanthus tithymaloides*, *Calotropis procera*, *Asclepias curassavica* and *Parthenium argentatum*.

9.5.2 Vegetable oils

- Vegetable oils have great potential to be used as liquid fuel or as a source of hydrocarbons.
- Some of them can be mixed in diesel.
- The non-edible seed bearing oil tree species can be cultivated on poor, marginal and wastelands.

9.5.2.1 Seed-oil bearing plants

Antinodaphe hookeri, *Aleurites triloba*, *Anacardium occidentale*, *Aphanamixis polystachya*, *Azadirachta indica*, *Calophyllum inophyllum*, *Cocos nucifera*, *Croton tiglium*, *Garcinia indica*, *Hydnocarpus wightiana*, *Jatropha curcas*, *Madhuca indica*, *Madhuca longifolia*, *Melia azedarach*, *Mesua ferrea*, *Mimusops elengi*, *Pongamia pinnata*, *Pittosporum resiniferum*, *Ricinus communis*, *Salvadora oleoides*, *Sapium sebiferum*, *Schleichera oleosa*, *Samecarpus anacardium*, *Shorea robusta*, *Simmondsia chinensis*, *Strychnos nux-vomica* and *Vateria indica* etc.

9.5.3 Resins

Resins are collected mainly from members of family Pinaceae. These are volatile oils (turpentine) and non volatile resins (rosin). The resins are main source for synthetic rubber and other polymers. Turpines are highly combustible and they can be used in various formulations of fuel for automobiles.

9.5.4 Calorific value

The amount of heat produced when 1 g of fuel is completely burnt in excess of air oxygen. If one gram of carbon is burned completely, it produces about 30,000J

or 30 KJ/g of heat. Therefore, the calorific value of carbon is 30 KJ/g and fuel having high calorific value is regarded as good fuel. CV of hydrogen is 150 KJ/g. However, it is not commonly used fuel because of highly combustible nature and difficulty in its handling. Photosynthetic energy processes are less costly than photo-voltaic and photo thermal process.

Table 1. A few species used in energy plantations with their respective calorific value and specific gravity

Sr. No.	Species	Sp. gravity	Calorific value K cal/kg
1.	<i>Acacia auriculiformis</i>	0.60-0.78	4800-4900
2.	<i>Acacia catechu</i>	1.00	5142-5244
3.	<i>Acacia dealbata</i>	0.70-0.85	3500-4000
4.	<i>Acacia leucophloea</i>	0.78	4899-4886
5.	<i>Acacia mearnsii</i>	0.70-0.85	3500-4000
6.	<i>Acacia nilotica</i>	0.67-0.68	4800-4950
7.	<i>Acacia senegal</i>	-	3200
8.	<i>Acacia tortilis</i>	-	4400
9.	<i>Adina cordifolia</i>	-	3855
10.	<i>Aegle marmelos</i>	0.91	4495
11.	<i>Albizia lebbek</i>	0.55-0.64	5163-5166
12.	<i>Albizia odoratissima</i>	0.73	5131-5266
13.	<i>Albizia procera</i>	0.68	4870-4865
14.	<i>Alnus nepalensis</i>	0.32-0.37	4600
15.	<i>Anogeissus latifolia</i>	0.94	4948
16.	<i>Anogeissus pendula</i>	0.94	4900
17.	<i>Anthocephalus cadamba</i>	0.94-0.53	4800
18.	<i>Artocarpus heterophyllus</i>	0.51	5318
19.	<i>Azadirachta indica</i>	0.75	-
20.	<i>Barringtonia acutangula</i>	0.58	5078
21.	<i>Bauhinia retusa</i>	0.72	5027
22.	<i>Bauhinia variegata</i>	-	4800
23.	<i>Butea monosperma</i>	0.54	4909
24.	<i>Bischofia javanica</i>	0.74	5162
25.	<i>Cajanus cajan</i>	-	4594
26.	<i>Cassia siamea</i>	0.60-0.80	-
27.	<i>Casuarina equisetifolia</i>	0.80-1.2	4950
28.	<i>Cedrela toona</i>	0.57	5113-5168
29.	<i>Chloroxylon swietenia</i>	-	4759
30.	<i>Dalbergia sissoo</i>	0.75-0.80	4908-5181
31.	<i>Diospyros melanoxylon</i>	0.79-0.87	4957-5030
32.	<i>Diospyros montana</i>	0.70-0.80	5125

33.	<i>Dodonaea viscosa</i>	1.20-1.28	5035-4939
34.	<i>Emblica officinalis</i>	0.70-0.80	5200
35.	<i>Eucalyptus camaldulensis</i>	0.6	4800
36.	<i>Eucalyptus globulus</i>	0.80-1.00	4800
37.	<i>Eucalyptus grandis</i>	0.40-0.70	4900
38.	<i>Eucalyptus tereticornis</i>	0.70	4800
39.	<i>Gmelina arborea</i>	0.42-0.64	4763-4800
40.	<i>Grevillea robusta</i>	0.57	4904-4914
41.	<i>Grewia spp.</i>	0.67	5292
42.	<i>Hardwickia binata</i>	1.08	4891-4952
43.	<i>Holoptelia integrifolia</i>	0.63	5228
44.	<i>Lannea coromandelica</i>	0.55	4933
45.	<i>Leucaena leucocephala</i>	0.55-0.70	4200-4600
46.	<i>Madhuca longifolia</i>	0.56	5043-5156
47.	<i>Mangifera indica</i>	0.58	4610
48.	<i>Melia azedarach</i>	0.56	5043-5176
49.	<i>Morus alba</i>	0.63	4371-4773
50.	<i>Michelia champaca</i>	0.45	5068
51.	<i>Ougeinia oojeinensis</i>	0.85	5178
52.	<i>Pithecellobium dulce</i>	0.64	5177-5600
53.	<i>Pongamia pinnata</i>	0.75	4600
54.	<i>Populus euphratica</i>	0.48	5008-5019
55.	<i>Prosopis chilensis</i>	0.80-0.92	5000-5500
56.	<i>Prosopis cineraria</i>	0.77-0.94	5000
57.	<i>Prosopis juliflora</i>	0.70	4800
58.	<i>Pterocarpus marsupium</i>	0.79	4904-5141
59.	<i>Pterygota alata</i>	0.25-0.62	5160
60.	<i>Quercus leucotrichophora</i>	0.74	4633
61.	<i>Schleichera oleosa</i>	0.91-1.08	4928-4950
62.	<i>Sesbania grandiflora</i>	0.55	4407
63.	<i>Shorea robusta</i>	0.68-0.82	5095-5433
64.	<i>Syzygium cuminii</i>	0.67-0.78	4834
65.	<i>Tamarindus indica</i>	0.91-1.28	4909-4969
66.	<i>Tamarix aphylla</i>	0.60-0.75	4835
67.	<i>Tectona grandis</i>	0.55-0.70	4989-5535
68.	<i>Terminalia alata</i>	0.71-0.94	5047-5373
69.	<i>Terminalia arjuna</i>	0.74-0.82	5030-5128
70.	<i>Terminalia chebula</i>	0.77	3967
71.	<i>Trema orientalis</i>	0.48	3095
72.	<i>Xylia xylocarpa</i>	0.92	4975-5044
73.	<i>Zizyphus mauritiana</i>	0.93	4900

9.6 Establishment and Management and Plantation Economics

Energy plantations are the plants planted only for use as fuel. The woody plants have been used since ancient times to generate fire for domestic and industrial purpose. In recent years, to meet the ever growing demand of energy, plantation of energy plants is been encouraged. We are all aware that trees are cut in many of the forest belts of India like Gangetic plains, Siwalik region and foot-hills of Himalayas.

In terms of fuel wood production, India is the biggest, but the per capita fuel wood production is very low. In India, people of hill area hardly get fire-wood plants and they have to go to interior of forest to collect wood-falls. Also introduction of technologies developed for plains is not achievable in these areas.

For example, they cannot be motivated to use solar cooker, because of being solely traditional and religious. Even go-bar gas plant cannot be useful in hills, due to low temperatures. Therefore, renewable source of energy is highly desirable for survival of population in hills and for reducing the pressure on forests. And thus, energy plantation has got great support in our country.

For obtaining good amount of biomass, afforestation and forest management government has started many plans like social forestry, silviculture and agro-horticulture practices in waste and barren lands. These programmes include growing of drought resistant, salt resistant, pollutant resistant and high density energy plantations (HDEP) in waste and barren

The technique used in high density energy plantations, HDEP is the practice of planting trees at close spacing. Here the trees grow rapidly due to struggle for survival. It provides fast and high returns with many opportunities of permanent income and employment.

Lower energy cost per unit area as lower inputs are require as compared to agriculture crops dependable & renewable source of energy along with afforestation of marginal lands & employment generation.

Unit 10: Important Forest Tree Species

Unit Structure

10.0 Learning Objectives

10.1 Introduction

10.2 Indigenous trees species

10.3 Exotic trees Species

10.4 Advantages and disadvantages of indigenous and exotic trees

10.0 Learning Objectives

On completion of this unit you should be able to understand

- About the indigenous species
- About the Exotic species

10.1 Introduction

The indigenous trees play a crucial role in preserving the biodiversity of the area while being aware of the possible dangers posed by invasive species.

As vital sources of oxygen and habitat for a wide variety of living things, trees are nature's constant guards, safeguarding the environment's safety and well-being. Regarding their impact on regional ecosystems, however, not all trees are made equal. Indigenous and exotic trees fall into two different groups in this situation. The present unit deals with the meaning of these terms and how they affect the vitality and health of our ecosystems must be understood.

10.2 Indigenous trees species

The trees that have naturally grown, developed, or long-lived in a particular location are referred to as "indigenous trees." With the passing of time, these trees have developed

complex connections with the surrounding fauna, microorganisms in the soil, and other plant species in their original habitat. Their ability to adjust to the soil and climate of their original habitat has allowed them to become a vital part of the local ecosystem.

Indigenous trees play an extensive and vital function in their environments. By sustaining a diverse range of plants and wildlife exclusive to their natural habitat, they contribute to the local biodiversity. Compared to Exotic trees, these tree species often require less water, upkeep, and other resources since they have evolved to survive in the soil and climate of their native areas. Additionally, they give the local fauna a much-needed home and food supply. Indigenous trees are essential to the survival of the surrounding animals, from the tiny invertebrates that burrow under the bark to the enormous mammals that depend on their leaves for cover.

10.3 Exotic trees Species

Exotic trees, on the other hand, are species that have been unintentionally or purposefully introduced to new habitats outside of their zone of distribution. Human activities including international trade, landscaping, and agricultural practices can lead to these introductions. Natural phenomena such as animal migration and wind can also introduce these species into previously uninhabited areas.

The effects of exotic trees on ecosystems might be conflicting. Some species may easily adapt into their new habitats, while others may upset the equilibrium by competing with indigenous species for resources, changing habitats, or even spreading into new areas. Reduced biodiversity might result from these impacts, upending the basic basis of nearby ecosystems. Variations in the makeup of plant communities can have far-reaching ecological effects by adversely affecting nearby wildlife, upsetting the food chain, and changing the availability of habitat.

10.4 Advantages and disadvantages of indigenous and exotic trees

There are several benefits to indigenous trees, which have developed organically in a region over extended periods of time. Ideally adapted to their native habitats, these trees need minimal maintenance and resources for optimal growth. Along with maintaining local

biodiversity, they have developed alongside fauna by giving them food and shelter. Additionally, indigenous trees shield ecosystems from invasive species and sustain the balance between different species.

But this also has a negative aspect. Although indigenous trees have many advantages, certain areas may have a restricted range of indigenous species, which limits the alternatives for landscaping or ornamental diversity. There may also be challenges in managing and conserving certain indigenous trees due to their increased susceptibility to regional diseases and insect pests.

The varied shades, forms, and sizes of exotic plants may frequently provide a greater range of landscaping possibilities. Certain species have a quicker growth rate than their native equivalents, which makes them useful for building green areas or producing timber more quickly. Resistant to local pests and diseases that might harm indigenous species, certain Exotic trees can also demonstrate resilience on their own.

Nevertheless, they have the capacity to spread and compete with indigenous species for resources, which might lead to a major decline in the biodiversity of the area. The ecosystems may be upset by the introduction of these alien trees, which might change wildlife habitats and food supplies. To the detriment of indigenous species, they may also compete with them for vital resources like light, water, and nutrients.

The possible effects of exotic trees on regional ecosystems are highlighted by case studies from the real world. Eucalyptus trees were brought to California in the 1850s, as one example. These trees were sent to the Golden State from Australia specifically for their wood and visual value. Yet, these quickly spreading trees—which are suited to Australia's dry climate—displaced indigenous Californian plants in the race for water, drastically changing the region's ecosystems and endangering its indigenous animal and plant life. Similarly Chir-pine tree species were also introduced or planted for revenue generation from its resin but it affects the growth of other tree species.

On the other hand, the indigenous California Monterey pine, offers a striking contrast. This kind of tree, which is vital to many bird species and enhances the general health of the environment, has suffered severely from competition with more aggressive exotic species.

In conclusion, it is evident that understanding the differences between indigenous and exotic trees, as well as the effects they have on our regional ecosystems, is more than just a theoretical exercise. It's essential that we continue growing into more aware and responsible protectors of the environment.

Indigenous trees are incredibly beneficial to their ecosystems, as they are deeply interconnected into them and promote biodiversity and adaptability. It's important to recognize nevertheless, that not all exotic species are dangerous and that many may live in harmony with their new environments. It only serves to emphasize how important it is to research, care for, and use caution when bringing new species into our surroundings.

Future developments in our environment can be influenced by us as people and as groups of people, but this influence comes with responsibility. We may choose more sensibly and sustainably, whether it's planting trees in our garden or contributing to neighborhood reforestation, if we prepare ourselves with the essential knowledge and understanding of indigenous and exotic plants.

Table 1. The hardy indigenous/native species which can combat pollution

Source: MoEFCC, <https://pib.gov.in/Pressreleaseshare.aspx?PRID=1541596>

S.No.	Species	
	Common Names	Botanical Names
1.	Pilkhan	<i>Ficus virens</i>
2.	Peepal	<i>Ficus religiosa</i>
3.	Bargad	<i>Ficus bengalensis</i>
4.	Gular	<i>Ficus glomerata</i>
5.	Ber	<i>Zizyphus mauritiana</i>
6.	Arjun	<i>Terminalia arjuna</i>
7.	Jamun	<i>Syzygium cumini</i>
8.	Neem	<i>Azadirachta indica</i>
9.	Gundani	<i>Cordia ghara</i>
10.	Baheda	<i>Terminalia bellerica</i>
11.	Lasoor	<i>Cordia mixa</i>

12.	Mango	<i>Mangifera indica</i>
13.	Jungle Jalebi	<i>Pithecellobium dulce</i>
14.	Imli	<i>Tamarandus indica</i>
15.	Shehtoot	<i>Morus alba</i>
16.	Bakayan	<i>Melia azadirach</i>
17.	Meetha Neem/Curry patta	<i>Murraya koenigii</i>
18.	Khimi	<i>Manilkara hexandra</i>
19.	Dhak	<i>Butea monosperma</i>
20.	Harad	<i>Terminalia chebula</i>
21.	Bael Patra -	<i>Aegle Marmelos</i>

Table 2. Indigenous/native Species which have higher aesthetic value/flowering

Source: MoEFCC, <https://pib.gov.in/Pressreleaseshare.aspx?PRID=1541596>

S.No.	Species	
	Common Names	Botanical Names
1.	Amaltas	<i>Cassia fistula</i>
2.	Gulmohar	<i>Delonix regia</i>
3.	Semul	<i>Bombax ceiba</i>
4.	Indian coral tree	<i>Erythrina variegata</i>
5.	Ashoka	<i>Saraca asoca</i>
6.	Jacaranda	<i>Jacaranda mimosifolia</i>
7.	Tichoma gorichori	<i>Tecoma stans</i>
8.	Anar	<i>Punica granatum</i>
9.	Knakchampa	<i>Pterospermum acerifolium</i>
10.	Rainbow shower tree	<i>Cassio nodosa</i>
11.	Mahuwa	<i>Madhuca longifolia</i>
12.	Burmese Cassia, Burmese Pink Cassia.	<i>Cassia renigera</i> Benth.
13.	Champa	<i>Magnolia champaca</i>

14.	Kassod	<i>Cassia siamea</i>
15.	Kareel	<i>Diospyros cordifolia</i>
16.	Roheda	<i>Tecomella undulata</i>
17.	Sonjna	<i>Moringa concanensis</i>
18.	Kadamb	<i>Mitragyna parviflora</i>
19.	Jhinjheri	<i>Bauhinia racemos</i>
20.	Caper tree	<i>Capparis spinosa</i>
21.	Queen Flower	<i>Lagerstroemia flos reginae</i>
22.	Crape myrtle	<i>Lagerstroemia borelia</i>
23.	Harshingar	<i>Nyctanthes arbor-tristis</i>

Table 3. List of Some Important Tree Species

(Source: <https://mahenvis.nic.in/Pdf/Knowledge/Important%20Trees%20Of%20India.pdf>)

S. No.	Botanical Name	Common Name	Family	Use
1	<i>Acacia catechu</i>	Khair	Fabaceae	Used against the throat infections cough, diarrhoea, chronic ulceration, epistaxis and eruptions of the skin, leprosy, leucoderma and wounds. It is also useful in treating anaemia, diabetes, inflammations and intermittent fever.
2	<i>Abies pindrow</i>	Himalayan fir	Pinaceae	An important timber tree in the western Himalayas, where the tree is commonly harvested from the wild and traded. A list of plants under threat and facing possible extinction, usually with brief details of the threats and information on habitat.

3	<i>Aegle marmelos</i>	Bel	Rutaceae	Spiritual and Medicinal, one of the constituents of "Dashmoola". Roots and bark are used to treat melancholia, intermittent fevers and palpitation of the heart. Fruit pulp is nutritious and prevents heat stroke. Leaf juice extract is applied externally in abscess.
5	<i>Alangium salvifolium</i>	Ankol	Cornaceae	Spiritual and Medicinal. Seed oil used for treatment of other seeds.
6	<i>Betula utilis</i>	Bhurja, Bhojpatra	Betulaceae	Considered useful in dyspepsia, diarrhoea, epilepsy, haemophilic conditions and diseases of the ear.
7	<i>Bowellia serrata</i>	Salai guggul	Burseraceae	The gum exudate possesses anti-arthritic activity. Used in the treatment of ulcers, cystic breast, piles, skin diseases convulsions, dysentery, bronchitis, asthma, cough, jaundice, diarrhoea and dysentery.
8	<i>Buchanania cochinchinensis</i>	Chironji	Anacardiaceae	Rich source of vitamin E. The roots are acid, astringent, cooling, depurative & constipating and used in leprosy, skin diseases and diarrhoea. The leaves are reported to be cooling, digestive, expectorant, purgative, and aphrodisiac. The fruits are useful in treating leprosy,

				skin deases, burning sensation, cardiac debility, abdominal disorders, constipation cough, asthma, seminal weakness, fever, emaciation, ulcers, general debility and as a laxative.
9	<i>Butea monosperma</i>	Palash	Fabaceae	Spiritual and Medicinal. Seeds and gum are useful in worm infestation and in the treatment of ringworm, boils and pimples. The bark is used to treat dyspepsia, diarrhoea, dysentery, intestinal worms, bone fractures, rectal diseases, gonorrhoea, ulcers, tumours and diabetes. The leaves are useful in treating pimples, boils, flatulence, colic, worm infestations and inflammations. Flowers are used to treat leprosy, skin diseases and bone fractures. These are considered very efficacious in birth control. It is an excellent source of lac and natural dye.
10	<i>Canarium strictum</i>	Dhup	Burseraceae	Spiritual and Medicinal. Gum is used alon with til (seaamum) oil, in the treatment of rheumatic pains and chronic skin diseases.

11	<i>Cassia fistula</i>	Indian Labernum	Fabaceae	Ornamental. The dried fruits have a laxative property and are useful in constipation. An extract from the root bark is used in the treatment of black water fever. Flowers are useful in skin diseases, burning sensation, dry cough and bronchitis.
12	<i>Cedrus deodara</i>	Deodar	Pinaceae	Deodar is the most important timber tree providing soft wood. It can be easily worked and it is moderately strong. It possesses distinct annual rings. It is used for making cheap furniture, railway carriages, railway sleepers, packing boxes, and structural work.
13	<i>Commiphora wightii</i>	Guggul	Burseraceae	It is reported to be astringent, antiseptic and aphrodisiac. It is also employed for treatment of snake bite and scorpion sting.
14	<i>Diploknema butyracea</i>	Cheura	Sapotaceae	Traditionally, different parts of this plant have been utilized by ethnic groups of Nepal and India, mainly for food and medicinal purposes. The butter is also used as massage oil for rheumatism, headache, cracked feet and hands, acne, and boils.

15	<i>Dalbergia sissoo</i>	Shisham	Fabaceae	Excellent timber. It is useful as stimulant and appetiser and also in dyspepsia, diarrhoea, leprosy, obesity and worms.
16	<i>Emblica officinalis</i>	Amla	Phyllanthaceae	Rich in Vit C, antiviral, excellent liver tonic. Fruits are reported to be good for diabetes, cough, asthma, bronchitis, dyspepsia, collic flatulence, peptic ulcers, skin diseases, leprosy, inflammations, diarrhoea, dysentery, cardiac disorders, intermittent fevers and greyness of hair.
17	<i>Mallotus philipinensis</i>	Indian Kamla	Euphorbiaceae	Glandular hairs on the fruits, which are reddish brown are reported to be used in constipation, flatulence, wounds, ulcers, cough, renal and vesical calculi, haemorrhages, poisonous affections, scabies, ringworm, herpes and other parasitic skin affections. This red powder is also used as vermilion by women.
18	<i>Mesua ferrea</i>	Nag-champa	Calophyllaceae	Spiritual, Ornamental & Medicinal. The flowers are astringent and are useful for asthma, cough, leprosy, vomiting, dysentery, ulcers, burning sensation of the feet, dyspepsia, impotency, fever and cardiac debility. The seed oil is used for

				skin diseases.
19	<i>Michelia champaca</i>	Champa	Magnoliaceae	Aromatic & Medicinal. Flowers are reported to be used in dyspepsia, nausea, fever and also useful as a diuretic in renal diseases. Flower oil used in cephalagia. Bark is a stimulant, diuretic and febrifuge. Dry roots are reported to be used as a purgative and immounogogue.
20	<i>Mimusops elengi</i>	Bakul	Sapotaceae	Aromatic & Medicinal. The bark, flowers and fruits are acrid, astringent, cooling and anthelmintic. Bark is reported to be used as a gargle. It is also useful in urethrorrhoea, diarrhoea and dysentery. Flowers are reported to be used for preparing a lotion for wounds and ulcers; powder of dried flowers is considered a brain tonic and is used as a smuff to relieve cephalagia. Unripe fruit is reported to be used as a masticatory help to fix loose teeth. Seeds are used for preparing formulations to treat constipation especially in children.

21	<i>Nothapodyyates ovata</i> (<i>Mappia foetida</i>)	Narkya	Icacinaeae	Recent research has identified presence of an antitumour compound, named "Camptothecin", in this species. This could be the reason for its large scale smuggling out of India.
22	<i>Oroxylon indicum</i>	Tetu	Bignoniaceae	One of the constituents of "Dashmoola". Roots are reported to be used to treat rheumatism, diarrhoea and dysentery. Seeds are reported to be used as a purgative. The leaves made into a decoction are reported to be given in stomach ache and rheumatism and are used externally for enlarged spleen. Tender fruits are refreshing and stomachic.
23	<i>Pongamia pinnata</i>	Karanj	Fabaceae	Its seed oil is useful as biodiesel and seed cake as excellent manure.
24	<i>Pterocarpus marsupium</i>	Bijasal	Fabaceae	It is coarse-grained, durable and strong but difficult to work. Termites (also known as white ant) do not easily attack it. It is used for ordinary building construction and for cart wheels.
25	<i>Pinus roxburghii</i>	Chir-Pine	Pinaceae	Pine wood is hard and tough except white pine which is soft. It decays easily if it comes into contact with soil. It is heavy

				and coarse grained. It is used for pattern making, frames for doors and windows, and for paving material. White pine is light and straight grained and is used in the manufacture of matches.
26	<i>Pterocarpus santalinus</i>	Rakta Chandan	Fabaceae	The heart wood is reported to be used for treating intrinsic haemorrhage, fracture, chronic fever, diarrhoea, and spider poisoning
27	<i>Rhododendron arboreum</i>	Buransh	Ericaceae	The bark and flowers are used to treat digestive and respiratory ailments. - Burans have excellent antioxidant, anti-inflammatory, and anti-diabetic properties making it not just appealing to the eye but potent for health too. - Burans is considered good for heart, liver, diabetes, and is used for treating diarrhea.
28	<i>Santalum album</i>	Chandan	Santalaceae	Medicinal & Cosmetic. It's wood is used to manufacture musical instruments like Guitars and Fengshui products. A paste of the wood and oil are reported to be used for treating burning sensation, skin diseases, cardiac debility, jaundice, cough, bronchitis cystitis, malaria.

				The bark is used for treatment of dysosoeia, cystitis (inflammation of bladder), gonorrhoea and cough.
29	<i>Sapindus emarginatus</i>	Soapnut	Sapindaceae	The roots and are expectorant and demulcent. The roots are good for hysteria and epilepsy. A decoction of the bark is good for cattle suffering from ulcers due to worm infestation after calving. The fruits are good for asthma, diarrhoea, cholera, verminosis and gastralgia due to dyspepsia. Its fruits are natural substitutes for chemical soaps and hair dyes.
30	<i>Shorea robusta</i>	Sal	Dipterocarpaceae	Sal is one of the most important sources of hardwood timber in India. The wood is resinous and durable, and is sought-after for construction, although not well suited to planing and polishing. It is used as an astringent in Ayurvedic medicine, burned as incense in Hindu ceremonies, and used to caulk boats and ships.
31	<i>Saraca asoca</i>	Sita Ashok	Fabaceae	An evergreen shady tree the bark is reported to be used in treating uterine affections and

				gynecological problems. The seeds taken with water are supposed to alleviate suppression of urine and calculus. The flowers are pounded, mixed in water and are used for treatment of dysentery.
32	<i>Schrebera swietenoidess</i>	Ghantifal	Oleaceae	Leaves are reported to be used in treating enlargement of spleen and urinary discharges. Roots reported to be used in leprosy. Bark is used against boils and burns. The fruits are digestive, purgative and stomachic and reportedly useful in flatulence, anorexia, colic anaemia and diabetes.
33	<i>Syzygium cumini</i>	Jamun	Myrtaceae	Spiritual, fruits anti-daibetic & liver stimulant
34	<i>Taxus wallichiana</i>	Talispatra	Taxaceae	Used in anorexia, rheumatism, cough catarrh. It also checks vomiting and diarrhoea. It is an ingredient of drug formulations used in treatment of haemoptysis, asthma, and bronchitis and as a tonic given after parturition.
35	<i>Tecomella undulata</i>	Marwar Teak,	Bignoniaceae	Excellent Timber. It attracts birds.
36	<i>Terminalia arjuna</i>	Arjun	Combretaceae	Bark is reported to be a cardiac tonic, used in bilious affections, for sores and as an antidote to

				poisons. Fresh leaves juice is used against earache.
37	<i>Terminalia bellirica</i>	Behada	Combretaceae	The bark is reportedly used in treating anaemia and leucoderma. Fruits are reported to be effective in curing cough, bronchitis, insomnia, dropsy, dyspepsia, flatulence, vomiting, skin diseases, leprosy, fevers, ulcers and general debility. The mature and dry fruit is constipating and is useful in diarrhoea, dysentery and rheumatic swellings.
38	<i>Terminalia chebula</i>	Hirda	Combretaceae	The fruits are laxative and reported to be used for treating wounds, ulcers, inflammations, gastropathy, flatulence, jaundice, skin diseases, leprosy, intermittent fever and cardiac disorders. The fruit pulp is used as dentrifice.
39	<i>Tectona grandis</i>	Teak (Sagaun)	Lamiaceae	Moderately hard, teak is durable and fire-resistant. It can be easily seasoned and worked. It takes up a good polish and is not attacked by white ants and dry rot. It does not corrode iron fastenings and it shrinks little. It is among the most valuable timber trees of the world and its use is limited to superior work only.

40	<i>Toona ciliyata</i>	Toon	Meliaceae	The timber is red in colour, easy to work and very highly valued. It was used extensively for furniture, wood panelling and construction, including shipbuilding, and was referred to as "red gold" by Australian settlers.
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Terminal Questions

- Q1. What do you understand from the indigenous tree species.
- Q2. What is exotic species? Explain.
- Q3. List out some indigenous tree species of India.
- Q3. Discuss the advantages and disadvantages of indigenous and exotic species.

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Unit 11: Herbarium Preparation

Unit Structure

11.0 Learning Objectives

11.1 Introduction

11.2 History of herbarium

11.3 Objectives of herbarium

11.4 Importance/role of herbarium

11.5 Herbarium sheet

11.6 Types of herbarium

11.7 Important herbaria of the World

11.8 Major herbaria in India

11.9 Specimen preparation

11.9.1 Field visits and specimen collection

11.9.2 Pressing

11.9.3 Drying

11.9.4 Mounting

11.9.5 Stitching

11.9.6 Labelling

11.10 Virtual herbarium

Summary

References

11.0 Learning Objectives

After completion of this unit, you will be able to:

- understand the concept and importance of herbarium;
- discuss the role and objective of herbarium;
- understand different types of herbarium;
- understand the method of preparation and processing of specimen;

11.1 Introduction

A herbarium is a collection of preserved plant specimens and is also called as herbaria. It is a collection of dried plants systematically named and arranged for ready reference and study. The word herbarium is a combination of two words herbar, means "plant specimens"

and arium, means "an artificial place". The essential details of which plants flourished where over time are found in herbarium specimens. They function as a permanent record that enables anyone to go back and verify the identity, resample, or do more research. They may have been used as a tool for systematic study and environmental survey. Thus, the creation of herbarium specimens is a crucial, yet frequently overlooked aspect of botanical research.

Plant specimens that have been conserved and are labelled with evidence are found in herbariums. Vascular plants, bryophytes, lichens, algae, and fungi can all be found in herbaria. A herbarium may focus on a specific locality, like a city, state or it may make an effort to cover an entire country, continent, or world. It might aim to compile all of the information that is known about a single taxon, like a species, or about a small number of taxa, belonging to genus or family, or it might try to include all of the different kinds of plants. It may also include wild and domesticated plants, or both.

11.2 History of herbarium

The practice of creating herbarium was solely done by Luca Ghini in 1556, when he began gathering specimens, drying them, and pasting them onto paper. Later, Ghini's student Gherardas Cibo started gathering and preserving plants from 1582 and carried on doing so until his passing. Herbarium sheets were bound into volumes back then, and these herbaria volumes were arranged vertically in libraries, just like books. But in the 18th century, Linnaeus developed a novel technique that is nowadays mostly used by all museums and herbaria worldwide. He mounted his specimens on single sheets and began preserving them flat horizontally.

11.3 Objectives of herbarium

The objectives of herbarium are to identifying any material, including novel taxa and to protect historically significant specimens. Herbarium makes it possible to prepare new floras and monographs and collect specimens in relatively permanent form, for comparative morphological or phylogenetic studies, as well as to supply material for specialized study such as molecular, plant anatomy, palynology, and

ethnobotany. Herbarium compile information in order to determine ecological distribution and ranges.

11.4 Importance/role of herbarium

- A herbarium is an essential repository for plant material acquired from various global locations. As a result, they serve as an essential place to research or study the flora and vegetation of various locations or regions.
- The labels on the specimens in the herbarium include important information and this information include habitat, habit, local names, colour, and other characteristics, as well as information about the species abundance or frequency and related plants. Data for botanical, ethnobotanical, and phytogeographical research are thus provided by a herbarium.
- In educational institutions where a herbarium is located, the teacher display different plant specimens to the students, that might not be readily available when the subject is being taught. Students can identify local plants they have collected with its assistance.
- Nearly all forms of taxonomic research employ preserved herbaria specimens. It is very important for accurate plant identification and nomenclature in biosystematics research nowadays.
- Additionally, the specimens maintained in the herbaria serve as a source of material for research related to anatomy, palynology, and chemo-taxonomy.
- The herbaria offer crucial information for studies in cytology, ecology, and embryology, including precise locations of occurrence, flowering and fruiting times, and related species. Since many of the native applications of plants are documented on the herbarium sheets, the herbaria have proven to be extremely valuable sources of information for ethno researchers.

11.5 Herbarium sheet

Herbarium sheet, measures 42 x 28 cm in general and the label, measuring 12 by 8 cm, is typically adhered to the mounting board's lower right corner. The specimen is glued into

the center of the herbarium sheet as much as feasible, with the field number in the center of the left border and the accession number or barcode at the top right.

11.6 Types of herbarium

Herbarium collections come in a variety of sizes, from modest personal collections that typically contain a few hundred specimens to huge collections held by government organizations, colleges, and universities. Herbaria comes in a variety of forms and are used for a range of purposes. Different types of herbaria are as follows:

- International herbaria (e.g. Royal Botanic Gardens, Kew)
- National herbaria (e.g. Central National Herbarium, Howrah)
- Regional herbaria
- University herbaria (e.g. Calcutta University Herbarium, Kolkata)
- Medicinal plant herbaria
- Economically important plant herbaria (e.g. Industrial section Indian Museum, Kolkata)
- Local herbaria (e.g. Malabar Botanical Herbarium, Calicut)
- Agricultural herbaria (e.g. Tamil Nadu Agricultural University Herbarium, Coimbatore)

11.7 Important herbaria of the World

Based on information published by the Index Herbariorum, there are currently about 3,000 herbaria worldwide. An estimated 350,000,000 specimens total from all of the world's herbaria record the vegetation of the planet over the previous 400 years. Below is a list of the world's largest herbaria along with an estimated number of specimens in each:

S. No.	Location	No. of specimen present
1.	Museum National d'HistorieNaturaelle, Paris	8,000,000
2.	Newyork Botanical Garden, New York, USA	7,800,000

3.	V.L. Komarov Botanical Institute Leningrade, Russia	7,200,000
4.	Royal Botanical Gardens, Kew	7,000,000
5.	The National Herbarium Nederland (NHN), The Netherlands	7,000,000
6.	Missouri Botanical Garden, St. Louis, USA	6,600,000
7.	Conservatoire et Jardin Botaniques de la Ville de Geneve, Geneva, Switzerland	6,000,000
8.	Harvard University Herbaria, Cambridge, USA	6,000,000
9.	Natural History Museum, London	5,200,000

11.8 Major herbaria in India

1. Central National Herbarium (CAL) is the nation's first herbarium, established in 1795 in Howrah is home to around 2,000,000 specimens.
2. There are 350,000 specimens in the Forest Research Institute at Dehra Dun (DD).
3. There are 260,000 specimens at the National Botanic Gardens in Lucknow (LWG).
4. There are 200,000 specimens in the Blatter Herbarium at St. Xavier's College in Fort Bombay (BLAT).
5. The Botanical Survey of India maintains herbaria linked to its regional centers and units throughout the nation.

S. No.	Name of herbarium	Place	No. of specimen present
1.	Central National Herbarium	Howrah	2,500,000
2.	Botanical Survey of India, Southern circle	Coimbatore	200,000
3.	Botanical Survey of India, Eastern circle	Shillong	100,000
4.	National Botanic Garden, Herbarium	Lucknow	100,000
5.	Industrial Section Indian Museum	Kolkata	20,000

11.9 Specimen preparation

The preparation of an herbarium involves: (a) Field visits and collection of specimens (b) Pressing and drying, (c) Mounting and stitching on a herbarium sheet, (d) Preservation, (e) Labeling and (f) Proper storage.

A specimen that is to be deposited in a herbarium needs to be carefully collected, pressed, dried, mounted and finally properly labelled, so that it can meet the demands of rigorous taxonomic activity. When specimens are prepared correctly, they can preserve their key characteristics for a very long time. This makes them incredibly valuable for further scientific research, such as the creation of taxonomic monographs, flora compilations, and even experimental studies, as seeds of some species can survive for years even in dry herbarium specimens.

11.9.1 Field visits and specimen collection

Every component, including the root system, flowers, and fruits, should be present in a whole specimen. As a result, frequent field trips are required to gather data about plant growth and reproduction at every stage. The primary equipment needed in the fields are polythene bag, an old newspaper, magazines, a field note book, scissors, and a knife for cutting twigs and roots. An additional item needed is a pole with a hook for collecting tree pieces. In order to prevent harm during transit and storage, several copies of the specimens had to be gathered. A field number needs to be attached to the collected specimen, and any relevant data needs to be entered into a field note book.

11.9.2 Pressing

Each specimen needs to be made of materials that will fit inside the 11.2 x 16.2 inch. standard herbarium sheet. It is best to gather enough tiny herbs at a time to fill a folded newspaper sheet and then a normal herbarium sheet. As soon as possible, the specimens should be put into the field press. This can happen just after collecting or occasionally after a little period of storage in a polythene bag. A bigger shrub or herb may have its main axis twisted into a "M," "V," or even a "N" to fit inside a paper fold. A tiny piece of cardboard called a flexo stat with a slit in the middle can be slipped over the bent stem to hold it in

place while it dries. To ensure that reserve specimens are accessible in case one or more are destroyed, it is important to gather a few specimens of each species from the location. Additionally, duplicates can be placed in various herbaria after being mounted on sheets. To study the underside of the leaves from a pressed leaf as well, it is helpful to invert some of the leaves. It is possible to slice the large fruits thinly and then press them.

11.9.3 Drying

Drying is a slow process if artificial heat is not employed and naturally specimens dry slowly; it can take up to a month for them to dry completely. Freshly picked plants are put in a press without corrugated sheets, and the press is locked for a full day. Plants lose some of their moisture during this sweating phase, and become floppy and readily rearranged. It is also essential to change the newspaper, and the plant has to be moved from one newspaper to another with caution. Every few days, the blotters or newspaper sheets are changed, until the specimens are completely dry. Depending on the specimens and local environment, the entire drying procedure could take ten days to a month.

11.9.4 Mounting

The specimen is attached to a mounting sheet along with a label after it has been compressed, dried, and poisoned. The mounting sheets are composed of solid, long-lasting white paper that measures 28 x 42 cm. The goal of mounting is to ensure that all of the plant's components are readily accessible for research and that the specimens are evenly and neatly spread out and secured on the sheet. Currently, the most often used method in our nation is to attach specimens to sheets. The typical animal glue used in bookbinding is sold in the market in the form of flakes or bits. To make the glue paste, slowly add small amounts of boiling water to glue flakes until a thin, syrup-like paste is formed. A tiny amount of copper sulphate or mercuric chloride is added to this glue to give it the appropriate amount of insect repellent. A glass or tin plate is covered with glue or paste. Using forceps, gently tap the specimen on top of the paste. Next, carefully move the plant to the appropriate location on the mounting sheet using forceps. Nowadays, artificial animal glue is also replaced with fevicol. For good sticking and drying, the mounting sheets with the specimens glued on them are left in the press for a whole day.

11.9.5 Stitching

On the lower side of the mounting sheet, the stitches should be small, independent, and free of thread that runs from one stitch to the next. A hole is made and a thread is put on both sides of the stem or twig. The thread is cut and a knot is tied at the back.

11.9.6 Labelling

An integral component of a permanent plant specimen is a herbarium label. It mostly includes the data entered in the field journal at the time of collection, along with the outcomes of any further identification procedures. The label is placed in the lower right corner of the herbarium sheet, and the relevant data is written either on the paper slips that are adhered to the sheets or on the pre-printed proforma. Typing the data is the best option. It should be written by hand in permanent ink. Ball pens should never be used since, after a few years, the ink tends to spread. Although there is no set size for a herbarium label, 4 by 6 inches is the recommended size. When an expert visits a herbarium, they could make corrections to identification. A tiny annotation or determination label, typically measuring 2 by 11 cm and placed to the left of the original label. This label not only includes the adjustment, but it also includes the name of the individual and the date the change was made. This kind of data is helpful, particularly when a herbarium sheet has multiple annotation labels attached to it. Most likely, the final label is the accurate one.

11.9.7 Preservation

For the preservation of herbarium, a 2% mercuric chloride solution is used as one of the fungicides applied on the mounted specimens.

11.9.8 Storage

Plant specimens that have been properly dried, pressed, and identified are then inserted into thin paper folds, or specimen covers. Then kept together in thicker paper folders before being arranged in the herbarium cabinets in the appropriate locations in accordance with a well-established system of classification. Bentham and Hooker classification system is used in India and the type specimens are often kept in secure and isolated locations.

11.10 Virtual herbarium

A virtual herbarium is an online database that includes pictures of specimens from the Herbarium along with the textual documentation that goes with them. By directly connecting physical specimens to the internet and integrating all specimen data, together with the creation and retrieval of resources, it represents a significant leap in the use and design of herbariums. A virtual herbarium has various benefits over a physical herbarium, despite the fact that it cannot exist without the former. Virtual herbaria with searchable database have been developed by many major organizations like New York Botanical Garden (KE EMu), Royal Botanic Gardens Melbourne (AVH), Fairchild Tropical Garden (E-FTG), Australian Virtual Herbarium (AVH) and Royal Botanic Gardens, Kew (ePIC). The Virtual herbarium of New York Botanical Garden presently consists of digital collection of 8,50,000 herbarium specimens and 120,000 high resolution images, updated daily. Garden pursues the goal of digitizing all of its 7 million plant and fungi specimens.

Summary

This unit describes the importance, history and specimen preparation methods. Herbarium is a collection of dried plants systematically named and arranged for ready reference and study. A herbarium may focus on a specific locality, like a city, state or it may make an effort to cover an entire country, continent, or world. The objectives of herbarium is to identifying any material, including novel taxa and to protect historically significant specimens. Herbarium makes it possible to prepare new floras and monographs and collect specimens in relatively permanent form, for comparative morphological or phylogenetic studies. A herbarium is an essential repository for plant material acquired from various global locations. As a result, they serve as an essential place to research or study the flora and vegetation of various locations or regions. The preparation of an herbarium involves Field visits and collection of specimens, Pressing and drying, Mounting and stitching on a herbarium sheet, Preservation, Labeling and Proper storage.

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Unit 12: Species selection

Unit Structure

12.0 Learning Objectives

12.1 Introduction

12.2 Fast growing species

12.2.1 *Azadirachta indica*

12.3 Multipurpose tree species (MPTs)

12.3.1 *Acacia nilotica*

12.3.2 *Casuarina equisetifolia*

12.3.3 *Leucaena leucocephala*

12.3.4 *Sesbania grandiflora*

12.4 Indigenous Tree Species

12.4.1 *Cedrus deodara*

12.4.2 *Cupressus torulosa*

12.4.3 *Pinus roxburghii*

12.4.4 *Quercus leucotrichophora*

12.5 Exotic Tree Species

12.5.1 *Eucalyptus globulus*

12.5.2 *Populus deltoides*

Summary

References

12.0 Learning Objectives

After completion of this unit, you will be able to:

- understand the concept and importance of species selection;
- understand different types of nursery practice used for different tree species;
- understand planting technique of different tree species;

12.1 Introduction

Different types of tree species are used for plantation purposes. Some of them are fast growing, short rotational, multipurpose, indigenous and exotic species. All of these tree species are grown at different climatic as well as soil condition. This unit provides the information about the nursery and plantation techniques of different tree species. All of

these tree species prove to be very beneficial as they provide timber products, food, fodder and other useful products to the humans for various industrial and construction purposes. Numerous crops can be planted in a range of designs among different species of trees. For instance, fast growing tree species can be planted in fallow land or grown alongside agricultural crops.

12.2 Fast growing species

Fast growing tree species are a good source of timber products and can be grown in any land use system. Fast-growing tree species can achieve a mean annual increment of at least 10 cubic meters per hectare, under suitable site conditions. Plantations of fast-growing tree species have gained popularity recently because of their ability to meet the growing need for biomass for renewable energy sources. Fast-growing trees (FGTs) can be used for a variety of purposes, and establish rapidly and propagate easily from cuttings. The plantation techniques of some fast-growing tree species are discussed below:

12.2.1 *Azadirachta indica*

1. **Synonyms:** *Melia azadirachta*; *Melia indica* (**Family: *Meliaceae***)

2. **Common name:** Nim; neem; Margosa Tree 3. **Trade name:** Neem

4. **Distribution:** Neem occurs widely throughout the drier parts of India; in plains as well as hills up to 1830 m in Kumaun; in tropical dry deciduous and thorn forests of Uttar Pradesh, Haryana, Rajasthan, Bihar, Orissa, Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu. It is extensively cultivated for shade and ornament, in and around villages and along road side as avenue tree; also for afforestation in arid and semi-arid regions.

5. **Seed:** Neem flowers March to May; fruits June to August. Seeds profusely, right from an early age of about 5 years. Ripe seeds are collected off the trees during July-August, and sown within about a fortnight after rubbing, depulping, washing and drying. Seeds do not store well; lose their viability after about a couple of months. About 2000 to 3000 fruits and 4500 seeds (varying between 3000 to 5000) weigh a kilogram.

Germinative capacity of fresh seed is 70 to 90 percent; plant percent 20 to 60. Seeds do not require any special pre-sowing treatment.

6. Methods of propagation:**Natural Reproduction:** Mature neem trees seed profusely; seed is dispersed mainly by birds. regeneration hedges. is dispersed mainly by birds. Natural seedling regeneration is plentiful under the protection of thorny bushes and also regenerates well by coppice and root suckers.

Artificial Propagation: Neem can be easily propagated through several methods, viz., direct sowing, planting entire plants with a ball of earth (E.T.P.), root and shoot cuttings, etc.

Direct Sowing: Broadcast or by dibbling under bushes, in lines. on mounds or in trenches, are the common methods in forestry practice.

In Maharashtra, neem is being raised with agricultural crops by sometimes in taungya syste deep-rooted, competes very little, if at all, with agricultural crops for soil moisture.

Planting (ETP):One- or two-year-old nursery seedlings are planted out, with ball of earth, in pits 30 cm³, initially spaced 3 m x 3 m.

Stump Planting: Stumps prepared from 1- or 2-years old nursery seedlings can be planted .2.2 in pits, 3 m x 3 m, during rains.

7.Nursery practice:Depulped, dried seeds are sown in nursery raised beds, in lines 15 to 20 cm apart, seeds 2.5 to 5.0 cm apart and 1 cm deep. Nursery beds are watered sparingly; weeded and hoed, and protected against frost in winter. Germination starts in about a week and continues for about 3 weeks. Plantable size seedlings, 7 to 10 cm tall, are produced in 2-3 months, but are usually pricked out 15 cm x 15 cm in nursery beds, or in polythene bags and held for another year or two, if and when tall plants are required for roadside planting and other Social Forestry programmes.

12.3 Multipurpose tree species (MPTs)

Multipurpose tree species provide numerous/two or more products and several services like shade, habitat, soil protection and land sustainability of the land-use system.Different

factors should be kept in mind when selecting multipurpose tree species like environmental adaptation, ease of maintenance, farmers need and availability of genetic materials. In order to boost yields, diversify product lines, boost economic resilience, and enhance farm viability and sustainability over the long run, multipurpose trees are essential components of a whole agricultural system. Multipurpose tree species improves soil fertility and nitrogen fixation, control pest and soil erosion, acts as wind resistance. They also provide wildlife habitat, green manure, animal fodder, living fence, fuel wood, food, timber and medicinal plants. Multipurpose tree species are used in alley cropping, home gardens, other multistorey systems, living fences, windbreaks, and in stabilizing stream banks and gullies. The plantation techniques of some multipurpose tree species are discussed below:

12.3.1 *Acacia nilotica*

1. **Synonym:** *Acacia arabica* Var. indica (**Family:** Leguminosae - Mimosoideae)
2. **Common names:** Babul; Indian gum arabic tree
3. **Distribution:** Babul is indigenous to the Western part of the India-Gangetic plains and the northern part of Deccan plateau, including Andhra Pradesh, Maharashtra, Rajasthan and Gujarat. It is widely planted, or self-sown throughout the hot regions of India, viz., Punjab, Haryana, Uttar Pradesh, Madhya Pradesh and Karnataka. It is an important constituent of Southern dry mixed deciduous tropical forests, Northern and Southern tropical thorn forests of India; at an elevation range of 200-500 m.
4. **Seed:** Babul flowers June to September; Pods ripen April to June (earlier in Southern India); are collected from the ground or 5-7 year old trees, dried in the sun and seed separated by beating with stick, and cleaned by winnowing. Seed weight: 7000 to 11000 seeds/kg. Properly collected, dried, clean seed may be stored in gunny bags, tins or baskets, in a cool dry place; if stored in air-tight containers, there is little loss in germination for upto 3 years. Pre-sowing treatment is necessary to soften the hard seed coat; by (i) soaking the seed in water for 48 hours at room temperature; or (ii) immersing the seed in hot water at 80°C, and allowing it to soak until cool; or (iii) keeping the seed in moist cow-dung heap for 2-

3 days; or (iv) putting the seeds in concentrated sulphuric acid for 10-15 minutes; or (v) feeding the pods to sheep and goats and then collecting the seed from their droppings. Treated seed should be sown promptly (neither stored nor allowed to dry). Germination varies 30 to 92% (average 50%); Plant percent 1610 75% (average 25%).

5. **Methods of propagation:** Natural Reproduction: Babul reproduces naturally, mainly through seed and, to a limited extent by seedling coppice. Germination takes place during rains. Complete over-head light, freedom from weeds, sufficient moisture supply and well-drained porous soil are favourable conditions for its germination and establishment. Effective fencing for protection against domestic and wild animals is necessary.

Artificial Reproduction: (i) **By Direct Sowing:** Easy and most common method; this may be done by broadcasting (seed rate 2.5-3 kg per ha); dibbling in lines, patches or mounds in June (seed rate 1.0 kg/ha).

(ii) **By Planting Container-raised Plants:** Two or three treated seeds are sown in each polythene bag, about 1.5 cm deep in February-March; 3-5 months before transplanting. Avoid excessive watering in the first month; shading necessary to prevent surface drying. It is also a common method for planting along road side strips, for which one-year old seedlings are used,

6. **Nursery technique:** Babul seedlings are raised in polythene bags (5 cm x 22 cm, 150-200 gauge), filled with soil mix, (soil and compost in 2:1 ratio). Seeds are regularly watered, weeded and sown at 1.5 cm deep in February- March. Seedlings are fit for planting out in July-August of the same year (when 3-4 months old). For obtaining bigger plants, seed is sown in June-July in bigger bags and one year old seedlings are planted out.

12.3.2 Casuarina equisetifolia

1. **Synonym:** *Casuarina muricata* (Family: Casuarinaceae)

2. **Trade name:** Beafwood

3. Distribution: Casuarina is widely distributed along the coastal sands of India, and river bank sands of Peninsular India. It is at its best in wind swept sea sands where few other plants can survive. It has been extensively planted in the coastal region for checking erosion and sea-sand drift; inland for ornament and fuel.

4. Seed: There are generally two distinct flowering periods, viz.. February-April and September- October, and two distinct corresponding fruiting periods, viz., June and December, respectively. Ripe cones are collected off the vigorously growing trees in June and/or December by lopping branches, before the cones dehisce. These are spread out in the sun to dry; winged seeds are shed after 3-4 days, are then separated and clean seed is dried for 2-3 days.

Seeds are very minute; a kilogram of seed may contain 71/2 to 10 lakhs of seeds; average germination percent is only 50. No special pre- treatment is, ordinarily, necessary; however, seeds may be exposed to sun for 12-16 hours, or kept in hot water for a few hours, before sowing. Seeds are, generally, not stored for long; sowing is done as early as possible after seed collection. To protect against white ants and other insects, seeds mixed with ash and stored in earthen pots, with mouth cow dung or cloth, can be stored only for a few months.

5. Methods of propagation:

Natural Regeneration: Except in North Kanara natural regeneration from seed is poor, both in coastal and inland plantations in India. It sometimes produces root suckers. and also reproduces by coppice and natural layers from lower branches. (Karnatka),

Artificial Propagation: Direct sowing and coppice are not successful. The only reliable method is planting out of 6-18 months old nursery-raised seedlings. Seedlings are planted out with naked roots, when 35-60 cm tall, Seed 30 cm³, in moist weather. Plants/pits are spaced 1 m x 1 m on good soil and upto 4 m x 4 m on poor sites, on long rotation of about 15 years. When raised as a hedge, plants are spaced only 30 cm apart. For difficult areas, larger seedlings are produced in the nursery by sowing in February-April, pricking out 15 cm x 15 cm when 14-16 months old. Polythene bag container plants, and, sometimes,

brick plants, are also planted. After planting, watering is done as frequently as possible particularly during the dry season.

6. Nursery technique: Nursery soil should be inoculated with soil collected from under *Casuarina* plantation, and gammexane sprinkled around beds to prevent ant damage, Seed is sown broadcast about 10 gm/m², usually in November, and lightly covered. Beds are mulched with palm leaves or straw and watered daily till germination is complete, in 20-30 days, when mulch is removed. Beds are kept properly weeded. For more difficult sites, larger seedlings are produced by sowing in February-April, pricking out seedlings 15 cm x 15 cm in transplant nursery beds, or in polythene bags.

12.3.3 *Leucaena leucocephala*

1. Synonym: *Leucaena glauca* (Family: Leguminosae- Mimosoideae)

2. Common/English names: Lead Tree; Wild Tamarind; Horse Tamarind; White Babool; White Popinac.

3. Distribution: *Leucaena* is a native of Central America; has been introduced widely in many tropical countries, as in plains of India. The "Hawaiian Giant" variety is being widely cultivated in most states under Social Forestry and Agro-Forestry Schemes, for fodder, fuel, charcoal, small timber, poles, etc. Its best growth is upto 500 m altitudes; grows fairly well upto 800 m in the tropical belt.

4. Seed: It flowers and fruits at a very early age; in the very first or second year in the case of Hawaiian type. It seeds twice a year, July-November and February to May; the latter collection is better. Ripe pods are collected before they open, and spread to dry and stirred to separate seed. The seed is liable to insect and fungal attack; it has to be treated with fungicides/insecticides before storing in air-tight containers. Properly dried and treated seed can be stored for long, about 8- 10 years. Each pod contains 15-30 seeds; seed weight is about 20,000/kg. Seed coat being hard, seed requires pre-treatment by any one of the following methods:-

(i) Mechanical scarification of seed coat.

(ii) Acid treatment: by keeping seed in concentrated sulphuric or hydrochloric acid for 15 minutes.

(iii) Cold water treatment: immersion of seed in tap water for 24-48 hours.

(iv) Hot water treatment: The easiest and the most commonly used method is to pour seed into water heated to boiling point, leaving it to cool off and decant off water.

5. Methods of propagation

Natural Regeneration: *Leucaena* reproduces itself naturally through seed and coppice, freely. It seeds profusely (particularly the Hawaiian type) and seeds get dispersed after spontaneous splitting of pods. It coppices well; coppice growth is faster than that of seedling regeneration.

Artificial Reproduction: It can be raised artificially by direct sowing as well as planting out seedlings entire (ETP), from pots (containers) or nursery beds.

Direct Sowing: Successful plantations can be raised by simply ploughing contour furrows and sowing Rhizobium inoculated seed direct; if acidity is high, lime is added to the furrows. Seed may be sown either broadcast, or in drills or patches; depth of sowing about 1.5 cm. Seed rate may be 10-20 kg/ha for line or patch sowing, 20-25 kg/ha for broadcast sowing and 5-7 kg/ha for sowing in lines 2-3 m apart. Spacing varies with planting objective; closer spacing for soil conservation and forage production than for timber, for which 3 m x 3 m to 5 m x 5 m spacing may be adopted. For forage, furrows may be as close as 75 cm and seeds dibbled 10 cm apart.

Planting: Seedlings are planted out from nursery beds with ball of earth or from containers, at an optimum age of 2-4 months, in July-August, in pits 30 cm³, dug during summer and soil allowed to weather. Addition of two handfuls of farm yard manure and 50 g of superphosphate in each pit is beneficial; may be essential for good growth on poor sites.

6. Nursery practice: Seeds require inoculation with Rhizobium culture to ensure nodulation and nitrogen fixation. Plants may be raised in nursery beds or containers. Pre-treated and, preferably, inoculated seeds are sown in beds in March-April, in lines spaced

30 cm apart and seeds 5 cm apart in lines and about 1.2-1.5 cm deep. Nursery soil should be neutral to mildly alkaline. Beds are irrigated regularly but lightly. Germination commences in 4-6 days. Beds should be kept well weeded. Seedlings attain plantable size by July-August.

To raise the seedlings in containers, which may be polythene bags, bamboo pots, etc., 2 pre-treated (and preferably inoculated) seeds are sown in each, in March-April, at a depth of about 1.5 cm, and watered regularly but lightly. One gram of complete fertilizer may also be added to each container. Containers are kept well weeded; these are shifted after a month, to prevent roots penetrating through into the soil. If both seeds sprout, one seedling is transferred to another container.

12.3.4 Sesbania grandiflora

1. Synonym: *Agati grandiflora* (**Family:** Leguminosae - Papilionideae)

2. Common names: Swamp-pea; Sesban; Agathi

3. Distribution: It is a native of Malaysia; now extensively grown in many parts of tropical India, such as Punjab, Delhi, West Bengal, Assam South India and the Andamans.

4. Seed: Flowers October-January; pink, profuse, handsome; seed ripens April-May; pod long, containing about 40 seeds: collected off the trees. Seed weight about 16,000/kg; germination capacity about 90 %; can be stored for more than a year under ordinary conditions; needs no pre-sowing treatment.

5. Methods of propagation: The species can be raised successfully both by direct sowing and polythene bag planting; naked root planting has not given satisfactory results.

Direct Sowing: The site is burnt and patches well worked beforehand. Sowing is done in early June, at the break of monsoon rains. Seedlings are kept well weeded and thinned. For pulpwood plantations, patches may be as close as 0.9 m x 0.9 m.

Planting: Polythene bag plants are planted out in pits, 30 cm³, in June-July of the same year of sowing; optimum spacing is about 1.2 m x 1.2 m.

6. Nursery technique: Seeds are sown in polythene bags soon after collection in May. and watered regularly. Germination starts on the third day of sowing and is complete within a week to ten days. Seedlings grow very rapidly and are fit for planting out in about a month.

12.4 Indigenous Tree Species

Indigenous species occur naturally and are unique to geographic locations or ecosystem. These trees have lived long enough in their natural habitat to develop complex ties with the surrounding fauna, microorganisms in the soil, and other plant species. They have become an essential part of the local ecology as a result of their gradual adaptation to the soil and climate of their native area. The plantation techniques of some indigenous tree species are discussed below:

12.4.1 Cedrus deodara

1. Synonym: *Cedrus libani* Var. *deodara* (**Family:** Coniferae)

2. Distribution: Deodar is well distributed all over the Western Himalayas; from Kashmir in the west to Nepal in the east; between 1220 m and 3050 m altitude; most abundant between 1850 and 2600 m: altitudinal range being higher on the southern aspect than on the northern. It occurs extensively in the Himalayan moist temperate forests of Western Himalayas of Himachal Pradesh, Uttar Pradesh and Kashmir. Its main associates are *Abies pindrow*, *Picea smithiana*, *Quercus semicarpifolia* and *Juglans regia* on the higher altitudes, *Pinus wallichiana* and *Q. dilatata* on the lower, modified by the effect of aspect.

3. Seed: Male flowers appear in June and female flowers in August; pollen is shed mid September to mid-October; female cones (bearing seed) ripen in late October to November, 12 1/2 to 13 1/2 months after their appearance. These break up on the tree itself; scales and winged seeds fall on, the ground and only the persistent axis remains on the tree. Some of the seeds in a cone are infertile. Good seed years occur once in three years, on average. Cones are collected off the trees immediately before they open, end September to early October; placed in the sun for about a week till they open and break up. These are thrashed, cleaned and sieved to separate scales.

Seed is oily; it cannot be stored for long; it is best to sow fresh seeds before snowfall. At best, it may be stored in sealed tins till the following rains. Stratification method of storing and pre-treatment of the seed may be applied. 7000-9000 seeds weigh a kilogram; on an average 7900/kg Germination capacity is 65-80% and Plant percent 58.

4. Methods of propagation: Natural Reproduction: Under favorable conditions of snowfall, good seed year, well distributed rainfall, soil respect of raw humus and weed growth, adequate sunlight under properly opened up crop, profuse natural regeneration comes up, which may be tended to establish. Prolonged dry spell after germination, in May-June, may, however, prove disastrous; as also fire and/or uncontrolled grazing.

Artificial Reproduction: It is necessary to supplement natural Artificial Reproduction and/or to restock abandoned deodar and burnt regas, to introduce or increase proportion of deodar in spruce and kail areas. Deodar is both sown and planted.

Direct Sowings: It is done broadcast, or along contour lines 3 m apart in well-worked 30 cm wide continuous or broken. or in patches of various sizes, 1.5m * 0.5 m to 1.5m * 1.5m spaced 2 m apart. These patches can serve the temporary nurseries for the next year as surplus seedlings are available for planting out; for this, patches are made 3.8 m apart, edge to edge in the lines. Sowing is done in November.

Planting: Nursery-raised seedlings, 2 1/2 to 3 1/2 year old, are planted out in the field in auger-holes or in pits dug beforehand, in late June-July, when rains have well set in. Seedlings are packed in bur bundles, with wet moss round the roots, on a cloudy/rainy day; roots should not be exposed to sun. Planting spacemen will vary with various local factors; 2m * 2 m to 2.5 m to 2.5 m. for pure planting; 3m * 3 m to 3.8m * 3.8m for planting in a mixture.

5. Nursery practice: Nursery should be located in the optimum zone of deodar; on the northern aspect; soil to be thoroughly worked and mixed with leaf mould. Beds should be raised; size usually 2m * 1.2 m. Seed is sown in November-December just before snowfall, in drills 10-15 cm apart; 5 cm apart in drills and covered with thorny twigs to protect from birds. Germination occurs in March - May.

12.4.2 Cupressus torulosa

1. **Local names:** Devidiar; Surai (W. Himalayas) (**Family:** Coniferae)

2. **Distribution:** Fairly well distributed in outer ranges of Western Chamba to Nepal in Himachal Pradesh and Uttar Pradesh on calcareous/limestone soil between 1800-2700 m altitudes. It has been raised as an exotic in the Eastern Himalayas. It has been successfully raised in Dehradun and Saharanpur (U.P.), plains of Punjab and parts of Peninsular India. Himalayas,

3. **Seed:** Seeds ripen within the cones by April, even if cone scales are soft and green inside. Cones open and shed seed during rains, soft and strand continue till November-December. Cones are collected by lopping branches in June (April to July); are placed in the sun till they open; seeds are separated by gently threshing the cones.

Each cone contains 45-80 seeds, many of them being infertile. Trees start bearing cones at an early age; good seed years are quite frequent. Seed weight varies within a wide range. 1,65,000 to 3,00,000 seeds weigh a kilogram. Germination capacity is 50-60%. Germination starts in about 5 weeks and is complete in 3 months. Dried seed can be stored in a well-ventilated dry room for quite some time, but it is best to use fresh seed only. Pre-sowing treatment is not necessary, though cold stratification in moist sands for a few months may hasten germination.

4. **Methods of Propagation: Natural Regeneration:** Seed falls during August to December, remains in the ground till following rains and germinates round about July. In exposed situations, seedlings are likely to die in the ensuing hot and dry spell. Natural regeneration springs up in abandoned cultivation, landslips, exposed rock crevices, etc.

Artificial Propagation: For artificial propagation, nursery raised seedlings, not less than 23 cm in height, are planted out in 2nd or 3rd rains, with handful of earth around roots, in pits spaced 1.6 m x 1.6 m; at higher elevation spacing is increased to 2 m x 2 m. In West Bengal, spacing is kept close, 1.2 x 1.2 m so that plants grow slowly, to improve quality of timber. Direct sowing is not reliable, because of minute seeds and poor germination capacity.

5. Nursery technique: Seed is sown broadcast, thinly in shaded nursery beds in June, soon after collection, and covered with a thin layer of soil, and watered regularly. Germination starts in about 5 weeks and is complete in 3 months. Pricking out is generally not necessary. Seedlings are planted out when at least 23 cm tall in second rains; smaller ones are retained and planted out in third rains when about 60 cm tall. Shade is taken off the nursery beds about a fortnight before planting out.

12.4.3 Pinus roxburghii

1. Synonym: *P. longifolia* (Family: Coniferae - Pinaceae)

2. Distribution: Chir is found in the outer Himalayan ranges and on the ridges of Siwalik Hills, from 900-1800 m elevation; occasionally descending down to 500 m and ascending up to 2200 m. It occurs extensively in Jammu, Himachal Pradesh (Kangra) and Uttar Pradesh (Garhwal and Kumaun hills). It is a gregarious species, remarkably pure on quartzite. Towards its upper limit, it is found mixed with Kail, deodar and ban oak; and in its lower limits, sal, khair, Bauhinia, and other miscellaneous species occur with Chir. It is the most conspicuous and important constituent of Sub-tropical Himalayan Pine Forests.

3. Seed: Male flowers ripen and shed pollen from February to April; female flowers appear from early February onwards; pollination takes place from February to April; fertilization occurs during the second year. Ripe cones appear during April-May (sometimes March), open and shed seed in hot and dry weather; in cool localities, seed remains unshed till June. Dry cones remain on the tree for a year or longer. Fair seed year occurs every 2-3 years; a good seed year once in 4 or 5 years.

Cones are collected from healthy, tall, twist-free trees in March or April; or from trees felled during or after December, and stored till April; cones are then kept out in the sun to open, and seed is threshed or shaken out and cleaned. Seed is winged; number of seeds in each cone varies from 30 to 100, average being 40-50; seed weight varies from 8800 to 12500/kg. Seeds retain viability for over two years, if stored under proper conditions in sealed containers. Germinative capacity of fresh seed is 75-85%. Soaking of seed in water for 24 hours hastens germination.

4. Methods of propagation: Natural Reproduction: In nature, seed falls April to June; it germinates with break of rains. In a good seed year regeneration is profuse, provided the seed bearers are healthy and suitably spaced (about 20-25 m apart) and the area is protected against fire, grazing and careless grass cutting. Young seedlings are kept well weeded and cleaned for their proper establishment and growth.

Artificial Propagation: Direct sowing at the commencement of rains is quite easy and successful; this may be done in patches, or along contour lines.

Chir can also be successfully raised by planting out a year old nursery-raised entire plants with ball of earth, or container plants (in polythene bags), in pits 30 cm³, dug in advance, spaced 2 m x 2 m to 3m x 3m. This method is preferable, particularly in afforestation of degraded and heavily grazed hill slopes. Poorly drained soils should be avoided as the young plants damp off in excessively damp sites.

5. Nursery practice: Seed is treated with red lead before sowing in beds (to protect against pests), soon after collection; beds are irrigated regularly till break of rains. Seedlings are pricked out in transplant beds, or into polythene bags during the first rains; they are ready for planting out with a ball of earth in the second rains when 14-15 months old. As an alternative, seed is sown directly in Polythene bags, 2 seeds in each, at the break of rains; singling out the seedlings if both germinate and planting these out in the following rainy season. Seedlings are watered and weeded regularly in the nursery.

12.4.4 Quercus leucotrichophora

1. Synonym: *Quercus incana* (Family: Fagaceae)

2. Distribution: Ban oak occupies extensive areas in the Lower Western Himalayan Temperate Forests of the outer foothills of N.W. Himalayas, in Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh, extending eastward up to Nepal; between 800 m and 2400 m altitude, descending to as low as 600 m in moist localities and ascending up to 2400 m on southern aspect. Its best growth is on cool northerly aspects.

It is gregarious in habit; is frequently found associated with Conifers - deodar and kail at higher elevation, and Chir towards the lower limits- and/or other broad-leaved species, such as *Rhododendron*, *Pieris*, *Acer*, *Pyrus*, *Litsaea* and *Phoebe*.

3. Seed: Flowers (male catkins and female spikes) appear in April-May; pollination takes place in May-June; fruits (acorn) ripen in November-December of the following year, about 18 months after flowering, but remain on the tree till they start falling from February to May. Acorns are collected in December-January, preferably from the trees, dried in shade and stored in sealed tins, in cool dry place and protected against insects; they store well for about a year. Seed weight varies from 400 to 800/kg, average about 550/kg. Germinative capacity of fresh seed is about 95%; seed stored for a year gives only about 60% germination. Pre-treatment of seed is not necessary.

4. Methods of propagation: Natural Reproduction: Though seed is produced in fair quanta almost every year, but due to heavy damage to seed by bean monkeys, squirrels, rats and birds, which greedily eat them insect damage to seed; post-germination (in July) drought autumn and summer; damage due to cattle grazing, and fires, the resultant natural regeneration is very poor particularly in forests near and around habitations.

The other and the only reliable method of natural regeneration is by Coppice; this method has been successfully employed in Uttar Pradesh and Himachal Pradesh forests.

Artificial Propagation: Ban oak can be raised by direct sowing, as well as planting out nursery- raised seedlings.

In direct-sowing, seeds are dibbled in cultivated lines, or patches. About 10 kg of acorns are sufficient for sowing one hectare area. For line sowing, strips are laid 30 cm wide and 3 m apart (center to center); patches are prepared 45 cm² spaced 3 m x 3 m. Seeds are sown about 2 cm deep, before the onset of monsoon rains. On hot dry slopes, sowing is done under the shade of bushes. In Kangra (H.P.), broadcast sowing, after hoeing the soil without breaking the clods, has been quite successful.

Planting of 15-20 cm tall nursery-raised seedlings is done in pits, 30 cm³, dug in advance to allow weathering of soil, in the rainy season, and preferably completed by July.

Seedlings are uprooted with care and planted with a ball of earth. Roots are wrapped in gunny bags and kept moist during planting. Plants are spaced 2 m x 2 m to 3 m x 3 m.

Air-layering is also successful; application of auxin encourages rooting; however, this method cannot be employed for extensive planting.

5. Nursery technique: Seeds are dibbled 2 cm deep and 5 cm apart, in lines spaced 25 cm apart, in raised and well-manured nursery beds in February-March. Beds are provided with light shade as direct exposure to sun is harmful; they are also protected against rodents by wire mesh. Nursery beds are regularly watered till the break of rains. Germination starts in 10-12 days and is complete in 4-5 weeks. Seedlings are weeded and tended regularly in the nursery for 3-4 years, with one transplanting in the second rains, 10 cm apart in lines in nursery beds, or into large polythene bags (18 x 25 cm size). Seedlings, when 3-4 years old and 15-30 cm tall, are fit for planting out with a ball of earth, during the rains; winter planting succeeds only in moist areas.

12.5 Exotic Tree Species

Exotic tree species are also called as alien species and are introduced to an area or region where they do not occur naturally. Initially, these species must be planted, but later they are able to regenerate easily. The utilization of exotic tree species is also possible in energy, avenue, industrial and waste land plantations. These tree species are especially helpful for reclaiming alkaline and saline soil and for afforestation of open-pit coal mines. Since alien plants develop more quickly than native ones do, their productivity and yield are significantly higher. But occasionally, these invaders pose a threat to the indigenous species. The plantation techniques of some exotic tree species are discussed below:

12.5.1 *Eucalyptus globulus*

1. **Synonyms:** *E. cordata*; *E. diversifolia*; *E. glange*; *E. perfoliata* (**Family:** Myrtaceae)
2. **Distribution:** Blue gum is native to Australia; introduced in India, on an experimental basis, in Nilgiris in 1843 to meet firewood demand. Regular plantations in Nilgiris and Palni Hills, between 2000-2500 m altitudes, date back to 1856. Planted in Simla and

Darjeeling hills, with fair success; found unsuitable for plains. Best known of the Eucalypts, most widely distributed in its native home, Australia, and planted outside. It is now extensively planted in the Nilgiris and Palni Hills (1500 m-2400 m) for fuel, oil and as industrial raw material.

3. **Seed:** Flowers appear Feb.-March; fruits (capsules) ripen March-April; may be collected in May (in Nilgiris) from standing or felled trees, or by lopping branches, or from the ground. Fruits are dried in the sun, when they open. Seeds are separated by putting dried capsules in a bag and shaking, and then dried in the sun for 3-4 days before storing in sealed tins, if necessary; seeds can be stored for several years. Seeds are extremely minute; about 2,30,000 to 3,50,000 seeds weigh a kilogram. Germination capacity varies 50 to 80%; plant percent 10 to 30.
4. **Methods of propagation:** coppicing **Natural Regeneration:** Blue gum has extraordinary power, it is capable of naturally regenerating from coppice for coppice rotations of 10 to 15 years each. **Artificial Reproduction:** Blue gum is raised by planting out 5-7 months old. 25-45 cm tall polypot plants in May, or even earlier depending on rains. In Nilgiris South Division, plantations are replanted at the end of 5 rotations of 10 years (50 years); during pre-monsoon showers in May and completed by July, in pits 30 m³, spaced 2m x 2m. Pits are dug during December to March. Usually 60-75gm of Chemical fertilizer, NPK, is also mixed in each pit. Spacing varies: in some localities it is upto 3m x 3m. Casualties are beaten up in the first year. In areas where regeneration is by coppice, planting will be done only in gaps.
5. **Nursery practice:** Blue gum is raised in polythene bags for planting out entire. Seed is sown broadcast in raised and shaded nursery beds in April or from September to December; 75-100 gm seed per standard bed, 10 m x 1m; seed is mixed with ash, fine sand or earth to protect against being blown away. Insecticide is also added to the soil; about 100 gms of 5% Aldrex dust per bed to protect against insect and termite damage. Beds are covered with a thin layer of soil, and a layer of brushwood and grass, and watered lightly and frequently (with sprinkler or fine rose-can) to avoid damping off. Germination takes place in about a fortnight; then remove the cover.

Protect the beds from sun by low shade of about 0.5 m height, which is removed during rains to avoid drip damage. When seedlings are 5-10 cm high with 3 to 4 pairs of leaves, they are pricked into polypots, which are weeded regularly and shifted frequently to avoid their striking roots. Potted plants are fit for planting out when about 25-45 cm tall. They are kept under shade till about 2 weeks before planting.

12.5.2 Populus deltoides

1. **Common and trade name:** Poplar (Family:Salicacea)
2. **Introduction:** Poplars are fast-growing species which can be economically harvested on short rotations of 10-12 years, for their multiple uses for veneers, matches, fiberboards, light packing cases, paper pulp, etc. In view of the ever-widening gap between the demand and supply of wood, due to the rapid growth of population on the one hand and the wood-based industries on the other necessity of growing as much wood, and as quickly as possible is now fully realized.

A number of exotic poplar clones were tried in the hills and plains of Uttar Pradesh from about 1950 onwards. The best results were obtained in the Terai region with Australian clones of *P. deltoides* (mainly G-3) and American *P. deltoides* clones.

3. **Distribution:** *Populus deltoides* grows in North America; its clones have been cultivated outside its natural range, in a number of countries, such as Australia, Germany, France; and more recently in Middle East and Pakistan (West Punjab), with irrigation, and India (Punjab, Haryana, and U.P., mainly).
4. **Methods of propagation:** Poplars are reproduced primarily by vegetative means generally, by cuttings. By this means, a given specimen can be multiplied into an endless number of individuals having identical characteristics, the whole population constituting a Clone. Poplars can be planted out in the field by the following vegetative means :-
 - (i) **Cuttings:** Branch or preferably stem cuttings, 18-25 cm long, 1- 2.5 cm thick, having at least four buds, are directly planted in the field in well worked soil, keeping only one bud above the ground. Soil around the cuttings is thoroughly compacted.

They need more frequent weeding and watering; sin. For large scale plantations, this method is seldom adopted.

(ii) Sets: A set is a one-year-old cut-back plant without root; or a long stem cutting consisting of one year growth.

(iii) Barbatelles: These are produced by cutting back one year old plants in the nursery, so as to obtain in the following year a well developed new shoot; by this method, it is possible to obtain one year old stem on a 2 year old root.

(iv) Entire Transplants with Naked Roots (ETP): These are one year old plants raised from cuttings in the nursery. From the trials made during several years, it has been found to be the best method of planting; best time being during January-February, before the opening of new buds.

(v) Bag Plants: These are prepared in perforated polythene bags, 15 cm x 23 cm and of 150 gauge; bags are filled up with soil mix of local soil, sand and well rotten compost in the ratio of 4:2:1; 5% aldrex at 5 gm per 100 bags is also added. Cuttings are planted in the bags in February in the year of planting.

5. **Nursery technique:** Nursery soil should be sandy loam, deep, fertile well-drained, neither alkaline nor too acidic and rich in organic matter, with assured irrigation. One year old plants, harvested during the period of dormancy are preferably used for making cuttings, 18-25 cm long, each with four live buds. The entire length of the plants can be used. Except the terminal, soft, undignified part. Before planting, cuttings are soaked in water for 24 hours; this helps rooting.

Cuttings are inserted vertically into the soil leaving one bud above the ground, during February (late January to early March) at a spacing of 80 cm x 60 cm to 90 cm x 60 cm. Nursery beds have to be fertilized with plentiful of FYM, and suitable quantities of chemical fertilizers. At the time of planting cuttings, BHC 5% or gammexane 5% is added @ 20 gm/m² of the area. Regular weeding, hoeing and watering are done. Singling of collar shoots should be done during April-May; debudding of sprouted plants is done from June to October, by gently rubbing with gunny bag, upto 2/3 height from the base. The stools which supply cuttings for further multiplication are spaced 2

m x 2 m in stool beds; new shoots that come out are cut at 30 cm above ground, every year during February- March; a large number of pollard shoots are thus available for multiplication after one year.

Summary

Different types of tree species are used for plantation purposes. Some of them are fast growing, short rotational, multipurpose, indigenous and exotic species. All of these tree species are grown at different climatic as well as soil condition. All of these tree species prove to be very beneficial as they provide timber products, food, fodder and other useful products to the humans for various industrial and construction purposes. Numerous crops can be planted in a range of designs among different species of trees. For instance, fast growing tree species can be planted in fallow land or grown alongside agricultural crops. Fast growing tree species are a good source of timber products and can be grown in any land use system. Fast-growing tree species can achieve a mean annual increment of at least 10 cubic meters per hectare, under suitable site conditions. Multipurpose tree species provide numerous/two or more products and several services like shade, habitat, soil protection and land sustainability of the land-use system. Indigenous species occur naturally and are unique to geographic locations or ecosystem. Exotic tree species are also called as alien species and are introduced to an area or region where they do not occur naturally. Initially, these species must be planted, but later they are able to regenerate easily.

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Unit 13: Site Preparation

Unit Structure

13.0 Learning Objectives

13.1 Introduction

13.2 Area Demarcation

13.3 Site Clearing

13.4 Spacing

13.5 Pits Digging

13.6 Making the Soil Suitable on the Slops (Soil Preparation)

13.7 Plantation Methodology

13.8 Planting Patterns

13.9 Maintenance of the Site

13.10 Mulching

13.11 Types of mulches

13.11.1 Organic mulch

13.11.2 Non-organic mulches

13.12 Advantages of mulching

13.13 Disadvantages of mulching

Exercise-1

Exercise-2

Exercise-3

Summary

13.0 Learning Objectives

On completion of this unit you should be able to understand

- About the area demarcation, site clearing, pits digging for plantation
- Soil preparation on the slope for plantation
- About the different Plantation Methodology
- About the Maintenance of the plantation Site

13.1 Introduction

As far as offering a suitable habitat for the establishment of a new forest or plantation is concerned, the site's state can range from favorable to unfavorable. The planning of site

preparation is necessary after taking ecological, physiological, managerial, and social factors into account.

13.2 Area Demarcation

Everywhere the site's border line intersects a road, a well-traveled walkway, or another notable location. If a planting area is inside or close to an existing forest, it must be clearly marked on all sides where there is growth of shrubs or trees by a line that is three meters broad. Each border post must be marked with the name of the Block or locale, species, year of planted, and area. The plantation boundary must be properly surveyed. A 1:15,000 scale map (10 cms = 1.5 kms) of the proposed inspecting roads and paths must be created. This map will indicate the species to be planted and the treatments to be administered to each section of the particular area.

13.3 Site Clearing

Once the undesirable trees have been removed, the remaining standing growth and refuge must be felled and distributed evenly over the plantation area. It is important to make sure that all of the accessible waste material is piled between 0.1 and 0.4 meters above the ground. By the end of March at the latest, this job must be finished. After that, the stuff mentioned above has to dry for a week or two. As soon as the material is sufficiently dry to produce a clean, hot fire, burning will begin. Starting the fire up the wind and working it around the perimeter will ensure that the majority of the fire burns within and up the wind, posing the least amount of risk to any nearby plantations and forests. The process of burning and re-burning needs to be finished by the end of May, at the latest. A successful burn is a necessary condition for a good plantation. Intense soil working might make up for a poor burn.

13.4 Spacing

(A.) Closer spacing: The benefits of closer spacing include the ability to monitor weed growth, cleaner tree boles from natural pruning, straighter stems, easier thinning that yields short-term returns, etc. On the other hand, drawbacks include reduced growth of individual trees and increased work costs.

(B.) Wider spacing: Additionally, there are benefits and drawbacks to wider spacing, including the potential for soil deterioration due to the longer time it takes for the canopy to close, increased weed growth, and perhaps branching trees. However, broader spacing results in lower plantation costs.

All plants should be spaced 2 meters apart, unless a different amount is specified in a specific plan or by the operating plan. For instance, 5 m x 5 m or 5 m x 4 m will be the recommended spacing for bamboo plantations. In addition to the above spacing, the following plant counts per hectare will be needed:

Table 4. Number of plants at a different spacing per hectare

Spacing	No of plants per hectare
2 m x 2m	2,500
2.5 m x2.5m	1,600
3m x3.5m	1111
5m x 5m	400

Staking must be done at the designated intervals right after burning. Sections will be created inside the plantation area. When feasible, the final line on each of the block's four sides should be used. By doing this, the block's demarcation is improved, and the necessary block division against insect attack is mostly fulfilled. If it is not possible to plant a distinct species to mark the planting block, the planting block will be marked by posts that are 75 cm long, 15 cm square in cross section, and made of either stone or R.C.C. This post will be buried partially below ground. In situations in which the planting area exhibits irregularities in shape, the broadest portion of the area should have two bare lines for staking placed at right angles to one another. The sections from which the staking lines originate will be indicated on the plantation maps. Each block's specific area must be shown on the map.

13.5 Pits Digging

Pits must be dug in the winter before planting if the land is barren and there isn't any forest growth that will be cleared and burned. Pit digging must begin concurrently with stakes in

places where previous forest growth had been cut and burned, that is, as soon as the burning is done. The section of soil that is exposed to the sun and inside of the pit must be finished, ideally two months ahead of time, or at least one month before planting begins. Pits should not be dug out right before planting, with the exception of sandy coastal locations. When digging up, the top half of the pit's soil needs to be maintained apart. This half will be placed in the bottom of each hole after it has been filled, with the remaining soil at the top. Before replacing the soil in the pit, all roots, stones, and other debris must be removed. Pits should typically measure 30 cm³ on both normal and wet sites.

13.6 Making the Soil Suitable on the Slops (Soil Preparation)

Plantation should be done following contour trenches that are 45 feet wide at the base and 45 feet deep on the downhill side of a steep slope. When the slope is modest, a half-moon trench-ridge should be created on the downhill side next to each pit. There will be unworked sections of three meters between each of the seven-meter-long trenches. A trench along a slope shall be spaced five meters apart. The trench's dirt will be partially replenished within it, with the leftover material being piled on the side facing downward. Pick tools must be used beforehand to break the area of the hillside where this soil is piled. Staggered trenches are required. Digging the trenches early in the year before planting is the best practice. Let the trenches get partially filled with silt during rainy seasons and leave them open to the elements for approximately a year

13.7 Plantation Methodology

In areas without an established forest, the block planting technique is utilised to plant an entire area. Enhancement of an existing secondary forest can be achieved by the practice of enrichment planting, which also includes gap, under, and line conversion planting.

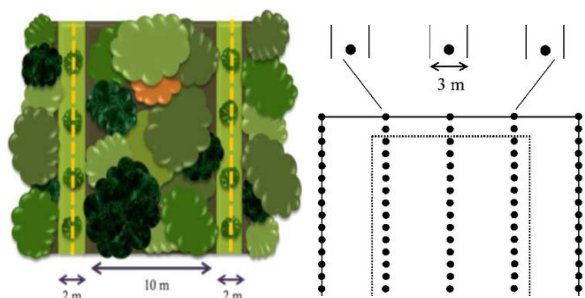
Table 5. Various Plantation Techniques Depending on the Final Product

Sl. No	End products	Plantation systems	Planting methods
1.	Timber	Large-scale industrial plantation Small-scale community plantation	Block planting, Enrichment planting
2.	Post boundry	Agro-forestry system	Trees planted individually or in line

3.	Food	Agro-forestry system	Trees planted individually or in line
4.	Fodder	Agro-forestry system	Trees planted individually or in line
5.	Medicinal products	Agro-forestry system	Trees planted individually or in line
6.	Shade	Planting along Road side / National Highways	Trees planted individually or in line
7.	Land reclamation	Large / small-scale non-industrial plantation	Block planting /Nitrogen fixing species
8.	Aesthetics / Biodiversity	Large / small-scale non-industrial plantation	Enriching planting

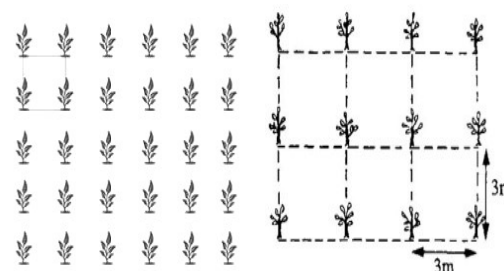
13.8 Planting Patterns

(i). **Line planting:** In line planting, plants are planted at some spacing in lines. Thus, the planted plants form rectangles.



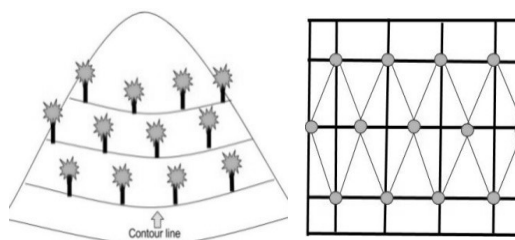
$$\text{Number of plants/ha} = \frac{100 \times 100m}{\text{Distance between plants in lines} \times \text{distance between the lines}}$$

(ii). **Square planting:** This system is considered to be the simplest of all the system and is adopted widely. In this system, the plot is divided into squares and tree seedlings are planted at the four corners of the square, in straight rows running at right angles.



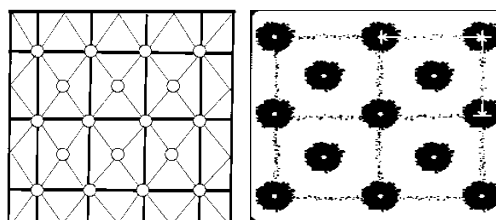
$$\text{Number of plants/ ha} = \frac{100 \times 100m}{(\text{Planting distance})^2}$$

(iii). **Triangular planting:** In this planting pattern plants are planted at equilateral triangles i.e. with plants occupying in three corners of each adjacent equilateral triangles.



$$\text{Number of plants/ha} = \frac{(100 \times 100 \text{ m}) \times 1.155}{(\text{Planting distance})^2}$$

(iv). **Quincunx planting:** This system of planting is similar to square system, except that a fifth tree seedling is planted at the centre of each square. As a result the tree



number in a unit area becomes almost double the number in the square system. The additional tree in the centre is known as “filler”. The fillers are usually quick growing and early maturing.

$$\text{Number of plants per ha.} = \frac{2 \times (100 \times 100\text{m})}{\text{Distance between plants in row or column}}$$

13.9 Maintenance of the Site

In addition to optimum availability of light and temperature conditions, plants need a certain amount of nutrients, air, and water for proper development. Certain basic requirements are not met by all soils. There are numerous factors that contribute to the extremely poor plant growing circumstances, including water logging, drought, salinity and alkalinity, acidity, low nutrient status, deteriorated physical conditions, and erosion. These create challenging situations for forest cultivation. A significant portion of the nation's overall landmass is made up of these challenging regions. Our natural forests contain these places as well. Site maintenance, whether artificial or natural, is required to support healthy regeneration and enhance the expansion of the current forest. Site maintenance is a vital component of silviculture. A well-established dense forest may take care of the property on its own.

Adopting an appropriate system for forestry practices is the only requirement. It is typically advised to use manures, fertilizers, nutrients for the soil and moisture conservation techniques to improve the soil's nutritional status, as well as its acidity, salinity, and alkalinity, and to prevent soil erosion.

13.10 Mulching

Mulching is one of the many protected cultivation techniques that can be used to completely or partially manage the microclimate surrounding the plant and shield it from unfavorable conditions. Among the materials that make up this protective layer of ground cover are natural materials like plastic sheets, sawdust, seaweed, manure, trash, sand, and gravel. Mulching refers to the act of applying these materials to the soil's surface in order to minimize moisture loss and stabilize significant fluctuations in soil temperature throughout the day, particularly below ground. By obstructing the ground's solar radiation, it reduces evaporation losses and the amount of energy supplied to the evaporating site. Mulching has several benefits, including lowering soil temperature, preserving seedling mortality, increasing crop stand, and limiting the initial stage of drying.

Moreover, it suppresses weed growth and reduces weed competition with crops for nutrients and water, increasing the availability of these resources for crop plants. Mulching also contributes to better water circulation downward. Generally speaking, mulches are more effective in retaining moisture in situations where there is more rainfall, a drought, or during the vegetative stages of crop growth when there is less canopy cover. Mulch can be utilized in a number of ways.

- To maintain the soil's fertility.
- To stop wind and water erosion of the soil.
- To retain the moisture content in the soil.
- To assist in the manufacture of healthy and high-quality goods.
- To shield the plant and its products from disease-causing insects and pests.
- To maintain a moderate soil temperature regime during the growing season.
- To stop the growth of weeds.
- To improve crop output.

13.11 Types of mulches

There are mainly two types of mulches: organic and non-organic:

13.11.1 Organic mulch

13.11.1.1 Manure/Compost

This type of mulching material is typically utilized for its visually attractive look and is spread in a 2 to 3 inch thick layer over soil or crop surfaces. Before applying manure, it must be thoroughly decomposed to prevent crop harm. For nursery, kitchen or backyard gardens, these kinds of mulching products are typically utilized. In addition, enhancing the organic carbon status of the soil by mulching these items will increase soil fertility. It is usually affordable and absent of weed seeds. Compost or manure can be made with readily available raw materials from commercial producers or households. Compost can be made with the supplies one has in his yard. It is not necessary to buy costly raw materials for mulching.

13.11.1.2 Mulching through Crop residue

These mulching products are becoming more popular since they are simple to handle. It takes a lot of chopping to generate crop wastes. Consequently, these are advised for regions that are prone to drought and should only be put in thin layers that are three inches or less deep. Additionally, these materials are favorable for medium-duration crops due to their susceptibility to micro fauna. You may also use grass clippings straight from the lawn mower and they work incredibly well as mulches. Applying these mulching materials in thick layers (4 to 6 inches) is required.

13.11.1.3 Sawdust

Sawdust that has partially decomposed is essential mulch that spans for a long period. It is prone to caking and has high levels of carbon and nitrogen. It is prone to caking and has a high carbon and nitrogen content. It takes longer to break down because of the high C:N ratio and nutritional state. It must not be utilized as mulch until worms are discovered in it and it has properly decomposed into brown "soil." Compared to hardwood sawdust,

softwood sawdust took longer to break down. Nitrogen can be applied externally to sawdust and applied two inches deep in the soil to speed up the decomposition process.

13.11.1.4 News paper

Newspaper sheets are utilised as an anchor by lightly covering them with mulch or grass clippings. These mulch materials' biggest drawbacks are that they blow away quickly and allow weeds to readily break them up or penetrate them once they get wet. But these mulch materials don't contain chlorine, and the ink doesn't pose a lead concern. Details furnished in Table 1.

13.11.2 Non-organic mulches

13.11.2.1 Mulches made of polyethylene

In general, non-organic mulches don't have the same ability to enrich soil, especially when it comes to aggregating soil particles, forming structures, and controlling soil responses. These mulches are the most popular among the various inorganic mulch materials because of their ability to control the hydrothermal regimes of the crop's microclimate, respond positively to weed control, shield soil from drying out and crusting, regulate soil moisture by preventing surface evaporation, prevent erosion of the surface soil, and decrease nutrient loss.

13.11.2.2 Aluminum-coated foil and plastic sheets

These mulching products are primarily used with vegetable crops. They help lessen viruses and aphids, two insect pests that affect vegetable production. Mulching in a single layer effectively inhibits weed growth. They are, however, highly costly and unpopular.

13.12 Advantages of mulching

Weed suppression, nutrition input, and protection are three main advantages of mulching. However, mulching offers numerous advantages when done properly.

Since the mulch shields the soil from the effects of weather, it can be considered as a protective covering. By covering the soil, the organic material helps to warm it in the winter

and cool it in the summer. Crops' growing season may even be extended by doing this. Furthermore, the organic material layer stops the water in the soil from evaporating. This reduces the amount of watering needed because the soil can hold onto water longer.

Furthermore, the presence of a mulch layer slows soil erosion since it shelters the soil from environmental factors like heavy rainfall. Because the mulch layer is made up of organic material that decomposes slowly, it adds to the inflow of nutrients. In this method, hard-working microbes break down the material and release the nutrients it contains for the plants to use. As a result, less fertilizer is required because the mulch layer gradually delivers nutrients to the plants. Furthermore, weeds can be suppressed by using mulch materials like bark mulch, which prevents weeds from growing through the mulch layer. An additional advantage of mulching is that trash from the garden, like leaves or grass clippings, can be recycled in a meaningful way by turning them into mulch.

13.13 Disadvantages of mulching

Mulching can have benefits but also drawbacks if it is not done correctly. First and foremost, selecting the right mulch material is essential, with the carbon to nitrogen ratio (C/N ratio) being a key factor. Straw is one of those materials that has a high carbon content but a low nitrogen content. Because of this, the microbes require more nutrients to break down the straw than are eventually supplied to the plants. Even more nutrients are used by the microbes, limiting the plant of them. Plants with yellow leaves and limited growth can be identified as such. For this reason, it's critical to provide supplementary fertilizer to mulch materials with low nitrogen content. Horn shavings or an organic fertiliser that releases nutrients gradually are good choices for this kind of fertilizer. In this manner, you can be certain that the plant won't suffer any harm from your mulch. If the mulch is overly damp, more issues can surface. Both mould development and slug infestation are exacerbated by this. In humid conditions, mould and snails just feel right at home. Finally, until you remove the mulch, mulching has the drawback that once applied, the soil below the mulch layer cannot be worked.

Exercise-1

Objective: To determine number of plants in 10 hectares of plantation under different planting pattern with spacing of:

- (a) 2 x 2 meter (b) 2.5x2.5 m
(c) 3 x 3.5 m apart (d) 5 x 5 with a plant in center of each square

Requirement: Measuring tape, field book, notepad etc.

Principle: Number of plants required per hectare under different planting patterns can be calculated by the formulae given below (Kumar, 2011), but in actual practice 10 to 20% of plants have to be arranged extra for providing mortality of plants in extraction from nursery, transport to the planting site or at the time of planting.

Methods:

(a) In Line planting with spacing of 2x2 m

$$\text{Number of plants in 10 ha} = \frac{10 \times (100 \times 100\text{m})}{\text{Distance of plants in lines} \times \text{distance between the lines}}$$

$$\text{Number of plants} = \frac{10 \times 100 \times 100}{2 \times 2\text{m}} = 25,000 \text{ plants}$$

(b) In Square planting with spacing of 2.5x2.5 m

$$\text{Number of plants in 10 ha} = \frac{10 \times (100 \times 100\text{m})}{2.5 \times 2.5\text{m}} = 16,000 \text{ plants}$$

(c) In triangular pattern with 3 x 3.5 m spacing

$$\text{Number of plants in 10 ha} = \frac{10 \times (100 \times 100\text{m}) \times 1.155}{3 \times 3.5\text{m}} = 11,000 \text{ plants}$$

(d) Quincunx planting with 5 x 5m spacing with a plant in center square

$$\text{Number of plants in 10 ha} = \frac{10 \times 2 \times (100 \times 100\text{m})}{5 \times 5\text{m}} = 8000 \text{ plants}$$

Results: Estimated number of plants in 10 ha area for line planting is **25000 plants**, square planting **16,000 plants**, for triangular planting **11000 plants** and quincunx planting **8000 plants**.

Exercise-2

Objective: To explain the strategy for the preparation of site of plantation.

Requirement: Measuring tape, field book, notepad etc.

Methodology for site preparation: See the section 13.2 to 13.9

Exercise-3

Objective: To explain the methodology of mulching in the plantation.

Requirement: Measuring tape, field book, notepad etc.

Methodology for site preparation: See the section 13.10 to 13.13

Summary

- As far as offering a suitable habitat for the establishment of a new forest or plantation is concerned, the site's state can range from favourable to unfavourable. The planning of site preparation is necessary after taking ecological, physiological, managerial, and social factors into account.
- Everywhere the site's border line intersects a road, a well-traveled walkway, or another notable location. If a planting area is inside or close to an existing forest, it must be clearly marked on all sides where there is growth of shrubs or trees by a line that is three meters broad.
- Once the undesirable trees have been removed, the remaining standing growth and refuge must be felled and distributed evenly over the plantation area. It is important to make sure that all of the accessible waste material is piled between 0.1 and 0.4 meters above the ground.
- The benefits of closer spacing include the ability to monitor weed growth, cleaner tree boles from natural pruning, straighter stems, easier thinning that yields short-term returns, etc. On the other hand, drawbacks include reduced growth of individual trees and increased work costs.

- Additionally, there are benefits and drawbacks to wider spacing, including the potential for soil deterioration due to the longer time it takes for the canopy to close, increased weed growth, and perhaps branching trees. However, broader spacing results in lower plantation costs.
- Pits must be dug in the winter before planting if the land is barren and there isn't any forest growth that will be cleared and burned. Pit digging must begin concurrently with stakes in places where previous forest growth had been cut and burned, that is, as soon as the burning is done.
- Plantation should be done following contour trenches that are 45 feet wide at the base and 45 feet deep on the downhill side of a steep slope. When the slope is modest, a half-moon trench-ridge should be created on the downhill side next to each pit.
- In areas without an established forest, the block planting technique is utilised to plant an entire area. Enhancement of an existing secondary forest can be achieved by the practice of enrichment planting, which also includes gap, under, and line conversion planting.
- In addition to optimum availability of light and temperature conditions, plants need a certain amount of nutrients, air, and water for proper development. Certain basic requirements are not met by all soils. There are numerous factors that contribute to the extremely poor plant growing circumstances, including water logging, drought, salinity and alkalinity, acidity, low nutrient status, deteriorated physical conditions, and erosion.
- Mulching is one of the many protected cultivation techniques that can be used to completely or partially manage the microclimate surrounding the plant and shield it from unfavorable conditions. Among the materials that make up this protective layer of ground cover are natural materials like plastic sheets, sawdust, seaweed, manure, trash, sand, and gravel.
- Mulching refers to the act of applying these materials to the soil's surface in order to minimize moisture loss and stabilize significant fluctuations in soil temperature throughout the day, particularly below ground. By obstructing the ground's solar

radiation, it reduces evaporation losses and the amount of energy supplied to the evaporating site. Mulching has several benefits, including lowering soil temperature, preserving seedling mortality, increasing crop stand, and limiting the initial stage of drying.

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Unit 14: Energy Plantation

Unit Structure

14.0 Learning Objectives

14.1 Introduction

14.2 Energy Plantation

14.3 Fuel wood and its properties

14.4 Advantages of Energy Plantations

14.5 Disadvantages of Energy Plantations

14.6 List of Plants Consider Suitable for Energy Plantations

Summary

14.0 Learning Objectives

On completion of this unit you should be able to understand

- About the fuel wood and its properties.
- About the Energy Plantation
- About the different fuel wood species
- Advantages and disadvantage of energy plantation

14.1 Introduction

The present unit deals with basic understanding of energy plantation and on site management. However it is also explained in the unit 09 which deals with definition of energy plantation, scope of energy plantation and suitability of species for firewood/fuel wood/ energy plantation for different regions. In the present unit developed the basic understanding about fuel wood and its properties, different fuel wood species, advantages and disadvantage of energy plantation and also list of plants consider suitable for energy plantations.

14.2 Energy Plantation

A plantation that is produced only for its fuel yield rather than its fiber content is known as an energy plantation. The ecological productivity of solar energy produced by the

traditional silvicultural techniques involving vast spacing and extended rotations will make them unfeasible for maintaining crops. Fast-growing plants with very close spacing—less than one meter—and short rotations—three to four years—must be selected for energy plantations.

This idea depends on the idea that the dry matter yield of some rapidly spreading forest species is independent of spacing. When compared to conventional silvicultural techniques that utilize wide spacing, such a strategy produces more dry matter per unit area since canopy closure happens quickly at a very early stage. Using trees that develop quickly in their initial few years and coppicing or cropping them often at intervals of fewer than five years is the principle behind this strategy. After researching the concept, Smith (1972) discovered that red alder stumps on suitable locations may be kept at a density of 17,000 per hectare for up to eight years, yielding eight tonnes of yearly output.

The global economic development of the planet depends significantly on energy. It is now more important than ever to create and manage energy sources due to the oil crisis and the quick depletion of fossil resources. Since the beginning of human civilization, fuel wood for light and heat production has come from natural energy sources, such as forests and tree bases. The material wood was the primary energy source for both industrial and residential use worldwide just a few decades ago. In light of the increased focus on plantations as a dependable source of renewable energy, biomass—a renewable organic matter produced by biological transformation of solar energy—is expected to play a significant role in future developments. In most developing nations' rural areas, fuel wood is the most often used energy source until now.

14.3 Fuel wood and its properties

The primary factors that determine a wood's worth as a fuel are its calorific value, or heating power, and its combustibility, or how easily it ignites and burns until only ash is left behind. The amount of heat released by a certain weight of wood during burning is known as its calorific value. All types of wood can be used since they are comparable and provide almost equal amounts of heat; their effectiveness will vary based on their density, dryness, and the efficiency of the stove, oven, or furnace in which they are burned.

Although the nation's planned agricultural expansion has given us enough food to feed ourselves, no conscious or long-term effort has been made to generate enough fuel to cook the food. The devastation of trees in rural areas is indicative of one of the worst outcomes of human planning. The lack of standing trees has led to villagers in many locations digging up the roots of fallen trees to suit their own fuel needs. Even worse conditions exist on the mountain regions. The rate of unchecked felling has caused landslides, floods, dust storms, and droughts, disrupting the ecology. A few years ago, gathering fuel wood could have taken an hour or two, but now they must dedicate a whole day to the task. However plantation management techniques can offset fuel wood shortages and usage.

14.4 Advantages of Energy Plantations

There are several clear benefits of using forest resources for energy. They consist of

- i. A consistent supply of energy derived from the renewability of forest resources; a distributed implementation of developmental initiatives by reforestation of marginal lands; and the creation of job possibilities, especially in rural regions.
- ii. Energy plantations, primarily planted to fix solar energy, will provide greenery, control climatic fluctuations, function as windbreaks and belts, maybe as soil conservation measures, and shield lower-lying agricultural areas.
- iii. In addition to minor forest goods like bark and fruits, the trees that are cultivated may also provide cattle feed.
- iv. Since all vegetable matter contains less than 0.1% sulphur, the fuel from energy plantations is almost sulfur-free.
- v. Manure may be made from the ash.
- vi. The earth's carbon balance is unaffected by the use of fuel from energy plants. When they burn, the trees take in the same amount of carbon dioxide that they emit. Burning fossil fuels increases atmospheric carbon dioxide, which produces an increase in oxygen concentration.
- vii. In comparison with commercial energy sources, handling and disposing of byproducts is safe.

- viii. In comparison to nuclear energy systems, plantation fuels emit 25% less thermal pollution per unit of useful energy produced.
- ix. The technology required to burn plantation fuels for energy is accessible. There are commercial wood-burning boilers that can produce up to 800,000 pounds of steam per hour at 950°F. About 80 megawatts of power can be supported by such a boiler.
- x. Unlike solar energy gadgets, the sun's energy may be readily retained through photosynthesis.
- xi. Compared to photovoltaic and photothermal processes, photosynthetic energy methods are less expensive.

Thus, the plantations that produce energy are therefore significantly more sound investments from an ecological and sociological standpoint.

14.5 Disadvantages of Energy Plantations

The biggest drawbacks of energy plantations include the huge areas needed for cultivation, higher maintenance expenses, the unpredictable nature of weather patterns, and the significant amounts of wood required, which provide transportation challenges. On the other hand, the decentralised installation of modest energy plantations around the nation could significantly help in lowering fuel transportation expenses. Energy plantations are still in the conceptual stage and need much research to be profitable. Bulky biomass must be transformed into effective, high-energy fuels in order to take the position of phytomass as the world's main energy source.

At present, the productivity of forestry as a solar energy-based sector is quite poor. Less than 1% of the incoming radiation is utilised by commonly used tree species, however photosynthesis may reach several times higher efficiency at its highest level. There is little doubt that the process of photosynthesis in plants will be utilised more and more as a possible source of clean energy; yet, energy plantations are given less attention since photosynthesis is naturally less efficient at converting solar energy. Therefore, identifying and maintaining species and types that convert solar energy more effectively is a major hurdle for modern genetic research. It is especially important to optimise methods in the

tropics, where significantly more solar radiation is available, making them environmentally ideal for energy production.

14.6 List of Plants Consider Suitable for Energy Plantations

The following trees, shrubs, legume, aquatic and hydrocarbon products producing plants are consider suitable for energy Plantation:

Table 1. List of Plants Consider Suitable For Energy Plantations (Source: Luna, 2006)

Trees	
<i>Ailanthus excelsa</i> Roxb	<i>Eucalyptus globulifera</i>
<i>Anogeissus latifolia</i> Wall	<i>Ficus bengalensis</i> Linn.
<i>Aleurites moluccana</i> Willd.	<i>Ficus glomerata</i> Roxb.
<i>Aguilaria agallacha</i> Roxb.	<i>Ficus religiosa</i> (Linn.)
<i>Abies Pindrow</i> Royle	<i>Ficus elastic</i> (Roxb.)
<i>Butea monosperma</i> (Lam.) Taab	<i>Givotia rottleriformis</i> Griff.
<i>Cedrela toona</i> Roxb.	<i>Grevellia robusta</i> A. Cun.
<i>Casurina equisetifolia</i> L.	<i>Moringa tinctoria</i> (Roxb.)
<i>Duabanga sonnerioides</i> Buch-Ham	<i>Millingtonia hortensis</i> L.F.
<i>Dipterocarpus indicus</i> Bedd.	<i>Odina odies</i> (Roxb.)
<i>Dendrocalamus strictus</i> (Roxb.) Nees	<i>Stereospermum angustifolium</i> Haines.
<i>Dolicahandrone falcate</i> (Wall) Seem	<i>Treni orientalis</i> B1 (Roxb.)
<i>Erythrina indica</i> Lam.	<i>Terma orientalis</i> B 1
Shrubs	
<i>Atlantia monophylla</i> (Roxb.) DC.	<i>Jetropha glandulifera</i>
<i>Clerodendron inerme</i> (L) Gaertm.	<i>Kydia calycina</i> Rox.
<i>Crewia latifolia</i> F. Muell. Ex Benth.	<i>Memecylon edule</i> Roxb.
<i>Dodonaea viscosa</i> Jacq.	<i>Macaranga Peltata</i> (Roxb.) Muell.
<i>Ipomaea carnea</i> Jacq.	<i>Tecoma gracillis</i>
Legumes	
<i>Cyamopsis tetragonoloba</i>	<i>Bambusa aurmdinaria</i> Willd.
<i>Canvalia ensiformis</i> DC.	<i>Cucumis melo</i> Linn.
<i>Crotolaria jumcea</i> L.	<i>Alternanthera sessilis</i> (L) R. Br.
<i>Ghracidia maculata</i> HB.	<i>Amaranthus Panicuatus</i> (Linn.)
<i>Phaseolus trilobatus</i> Linn.	<i>Sesbania aegyptiaca</i> Buch-Ham ex Wall

<i>Prophocarpus terragonoloba</i> DC.	
Aquatic Plants	
<i>Eichornia crassipes</i> (Mart) Solms.	<i>Typha latifolia</i> Linn.
<i>Juncus indicus</i> (Royle, ex) D. Don.	<i>Polygonum glabrum</i> Willd.
Hydrocarbon Products	
<i>Thevetia nerifolia</i> Fuss ex stud.	<i>Argemone mexicana</i> Linn.
<i>Calotropis procera</i> Ait.	<i>Givorta rottalariformis</i> Griff.
<i>Vitis quadrangularis</i> Wall.	<i>Ceropegia tuberosa</i> Roxb.
<i>Sansevieria</i> Sp.	<i>Pedaliium murex</i> Linn.
<i>Aloe vera</i> Linn.	<i>Agave americana</i> Linn.
<i>Euphorbia antiquorum</i> Linn.	<i>Euphorbia hirta</i> L.
<i>Euphorbia nerifolia</i> Linn.	<i>Euphorbia royleana</i> Boiss.
<i>Jatropha curas</i> Linn.	<i>Pedilanthus tithymaloides</i> Poit.
<i>Wrightia tomentosu</i> Roem & Schult.	<i>Tabernaemontana coronaria</i> R. Br
<i>Plumeria alba</i> Linn.	<i>Plumeria acutifolia</i> Poir.
<i>Allamanda cashartica</i> Linn.	<i>Nerium odorum</i> Soland.
<i>Calotropies gigantea</i> R.Br.	<i>Asclepias curassavica</i> R. Br.
<i>Daemia extensa</i> R. Br.	<i>Calotropis procera</i> R. Br.
<i>Cryptostegia grandiflora</i> R. Br.	<i>Stapelia grandiflora</i> Mass.
<i>Artocarpus integrifolia</i> Linn.	<i>Artocarpus incisa</i> Linn. f.
<i>Bassia latifolia</i> Roxb.	<i>Mimusops elangi</i> Roxb

Summary

- A plantation that is produced only for its fuel yield rather than its fibre content is known as an energy plantation. The ecological productivity of solar energy produced by the traditional silvicultural techniques involving vast spacing and extended rotations will make them unfeasible for maintaining crops. Fast-growing plants with very close spacing—less than one meter—and short rotations—three to four years—must be selected for energy plantations.
- The global economic development of the planet depends significantly on energy. It is now more important than ever to create and manage energy sources due to the oil crisis and the quick depletion of fossil resources. Since the beginning of human

civilisation, fuel wood for light and heat production has come from natural energy sources, such as forests and tree bases.

- The primary factors that determine a wood's worth as a fuel are its calorific value, or heating power, and its combustibility, or how easily it ignites and burns until only ash is left behind. The amount of heat released by a certain weight of wood during burning is known as its calorific value.
- Although the nation's planned agricultural expansion has given us enough food to feed ourselves, no conscious or long-term effort has been made to generate enough fuel to cook the food.
- The devastation of trees in rural areas is indicative of one of the worst outcomes of human planning. The lack of standing trees has led to villagers in many locations digging up the roots of fallen trees to suit their own fuel needs. Even worse conditions exist on the mountain regions.
- The rate of unchecked felling has caused landslides, floods, dust storms, and droughts, disrupting the ecology. A few years ago, gathering fuel wood could have taken an hour or two, but now they must dedicate a whole day to the task. However plantation management techniques can offset fuel wood shortages and usage.

Terminal Questions / Exercises

- Q.1. What do you understand Fuel wood?
- Q 2. What do you understand by Energy Plantation?
- Q 3. List out some important Fuel wood Species of India.
- Q 4. List out some tree species suitable for energy plantation.
- Q 5. List out some some shrubs and legumes suitable for energy plantation.
- Q 6. List out some hydrocarbon producing species.

References

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Unit 15: Industrial Plantation

Unit Structure

15.0 Learning Objectives

15.1 Introduction

15.1.1 Managerial aspects

15.1.2 Silvicultural aspects

15.2 The Importance and Advantages of Industrial Planting

15.2.1 Economic Growth and Development

15.2.2 Increased Productivity and Efficiency

15.2.3 Technological Innovation and Development

15.2.4 Infrastructure Development

15.2.5 International Trade and Market Expansion

15.2.6 Resource Utilisation and Efficiency

15.2.7 Social and Community Benefits Skill Development:

15.2.8 Environmental and sustainability considerations.

15.3 Paper and Pulpwood Plantations

15.3.1 Tree species in paper industries

15.4 Matchwood Plantations

15.4.1 Species in the Matchwood Industry

15.5. Plywood Industry

15.5.1 Species used in Plywood industry

15.0 Learning Objectives

After you have studied this unit, you should be able:

- To have basic understanding of industrial plantation.
- To understand about paper and pulpwood plantation.
- Understand about Matchwood plantation.
- Understand about Plywood plantation

15.1 Introduction

Industrial plantations have recently become recognized as a vital component of Indian forestry in order to fulfill the industry's growing needs as the population and living standards rise. The demand for forest products in India, as in other parts of the world, is fast increasing, and the gap between demand and availability is increasing. It has been expected that the demand for industrial wood in 1985 will be around 30-35 million cubic meters.

The most important forest-based businesses are pulp and paper, plywood, particle and fiber board, sawmilling, rosin and turpentine, and tanning. Aside from these, there are other important end uses for timber, including building construction, matches and splints, packaging, furniture and paneling, pit props, railway coaches and truck bodies, textile accessories, sports products and pencil-making. Shoe lasts, bullock carts, agricultural implements, handcraft items, marine applications, etc. It is thus evident that with the rising gap between supply and demand of raw materials, it is not enough to raise large-scale plantations, but also to obtain maximum yield from such plantations by silvicultural and management techniques, to reduce waste in harvesting and processing, and to create new resources in and outside of conventional forest areas.

Several criteria distinguish large-scale industrial plantations from smaller operations like community plantations. Although flexibility for the selection and improvement of species, spacing, tending, and adoption of various means to increase yield and quality can be manipulated to a great extent in such plantations, the risks and disadvantages of monocultures, variation in the quality of artificially planted trees, and large investments and costs require the adoption of a sound and proper approach to the problems of raising industrial plantations, and thus their planning must be given. Some of the elements influencing the establishment and maintenance of industrial plantations include:

15.1.1 Managerial aspects

1. Land availability: is a serious barrier in today's society due to its conflicting uses. Increasing population equals more homes, food grains, and roadways, which reduces availability for the forestry sector. As a result, land use in one location cannot be evaluated in isolation because it has an impact on future land use. Large expanses are required for the creation of forest plantations.

2. Labour: Industrial plantations require a huge workforce. On-the-job training for inexperienced workers is necessary, but can be time-consuming.

3. Market Trends: End-use is crucial for plantation development as market conditions might fluctuate significantly throughout the establishing phase. For example, the use of wooden sleepers has reduced significantly, and they are being replaced with those

made of other acceptable materials. Farmers in Punjab and Haryana abruptly ceased planting Eucalyptus since there is no market; no paper mills have been created, and the promises of high profitability have not been met.

4. Social and environmental factors: Plantations, like other developmental activities, have a significant impact on the surrounding population. This includes increased employment opportunities, financial revenue, and cultural and social life.

5. Forestry enterprise: it requires enormous land areas and long-term investment, which the private sector lacks. Therefore, the public sector is responsible for managing large-scale plantations.

6. Plantation size and layout: Due to the bulky nature of wood, transportation, logging, and extraction costs (which make up a significant portion of harvesting expenses) should be carefully considered during the planning stage, especially for industrial plantations. Terrain, topography, accessibility, and proximity to consumption areas are all essential location considerations. The plantation should be large enough to supply the industrial unit's overall wood requirements, and the minimum size can be calculated by considering the capacity, rotation, and expected yield of the species. For integrated industries, a significantly bigger area may be required. For example, a paper mill with a capacity of 200 tonnes based on Eucalyptus pulp may require an annual planting area of around 2000 ha. or 5000 acres for raw material production on a 10-year rotation in medium quality areas. The plantation size may be even smaller in irrigated plantations.

15.1.2 Silvicultural aspects

Choice of species: The selection of species is the most significant consideration when designing industrial plantations. The major factors for selecting a species include:

- (i) Suitability for the end-use,
- (ii) Compatibility with the site's soil and climate, and
- (iii) Rapid growth to efficiently produce the desired raw material.

As a result, species play a different role in industrial plantations than in afforestation to

cover barren ground. Fast-growing species can only reach their full potential if the site is productive enough.

As a result, species play a different role in industrial plantations than in afforestation to cover barren ground. Fast-growing species can only reach their full potential if the site is productive enough. *Eucalyptus*, *Populus*, *Tropical pines*, *poplars*, *wattles*, *Gmelina*, *Cedrella*, *Anthocephalus cadamba*, *Cryptomeria japonica*, *Schima wallichii*, *Bombax ceiba*, *Acacia catechu*, and other species are often used in industrial plantations for a variety of purposes.

Seed Source: Availability of certified seed with known provenances. Growth rates, ecological requirements, and tolerance vary across provenances in plants with a wide geographical distribution, such as eucalypts. Variations may exist in terms of frost, drought, and soil adaptability, pest and disease resistance, and even wood qualities.

Spacing: Close initial spacing enhances taper, but wider spacing increases production of large-sized material, volume production, and lowers planting costs. For all productivity classes, tight spacing is assumed to result in better yields in the early years, whereas broader spacing leads to higher yields subsequently. Thus, if a smaller size of material is required, such as pulp, closer spacing is appropriate. However, greater spacing is required when working with large materials such as plywood, veneers, matches, and saw milling.

Fertilizers: However, the effectiveness of fertilization during the rotation is debatable. Fertilizer treatment at the beginning of planting and during the early stages is really beneficial. It is also necessary to adopt appropriate techniques of application, dose, and type of fertilization.

Rotation: Aside from the goal of maximal volume production, the most essential factor in industrial plantations is the technological properties of wood obtained at various ages. For pulp production, a lower density and a lower proportion of wood are preferred; therefore pulpwood plantations often have shorter rotations ranging from 6 to 50 years.

15.2 The Importance and Advantages of Industrial Planting

Industrial planting refers to the construction and operation of large-scale facilities for manufacturing, processing, and other industrial purposes. This industry is critical to

modern economies and provides numerous benefits in addition to economic growth. The importance and advantages of industrial planting are as follows:

15.2.1 Economic Growth and Development

Job Creation: Industrial plants create jobs, helping to reduce unemployment and strengthen local economies.

Economic Stimulus: The creation and operation of industrial plants stimulates local businesses and services, hence increasing economic activity and growth.

Revenue Generation: Industrial facilities contribute to the government's revenue by paying taxes and other fees.

15.2.2 Increased Productivity and Efficiency

Scale of manufacturing: Industrial plants allow for large-scale manufacturing, resulting in economies of scale and lower per-unit costs.

Technological advancements: The use of new technology and automated systems boosts manufacturing efficiency and product quality.

Process optimization: Industrial plants are intended to streamline processes, reduce waste, and improve operational efficiency.

15.2.3 Technological Innovation and Development

Many industrial plants lead the way in research and development (R&D), resulting in improvements in goods, processes, and technology.

Adoption of Cutting-Edge technology: Industrial facilities frequently include cutting-edge technology such as automation, robotics, and data analytics, which fuels technological advancement.

15.2.4 Infrastructure Development

Improved Infrastructure: Establishing industrial units can result in improved infrastructure such as transportation networks, utilities, and communication systems.

Urban and Rural Development: Industrial plants can spur expansion in adjacent communities, resulting in the construction of new residential and commercial districts.

15.2.5 International Trade and Market Expansion

Export Opportunities: Industrial plants can create goods for export, improving trade balances and opening up new markets for local businesses.

Competitive advantage: Advanced industrial facilities help a country or area compete in the global market.

15.2.6 Resource Utilisation and Efficiency

Optimal Resource Use: Industrial operations are built to make the best use of available resources, such as raw materials, energy, and labour.

Waste Reduction: Modern industrial facilities frequently employ waste management and recycling systems to reduce their environmental impact.

15.2.7 Social and Community Benefits Skill Development:

Industrial plants offer workers training and development chances to improve their skills and career prospects. Community Support: Many industrial facilities participate in corporate social responsibility (CSR) efforts, which benefit local communities through a variety of programs and investments.

15.2.8 Environmental and sustainability considerations.

Sustainable Practices: Industrial plants are increasingly using sustainable practices, such as energy-saving technologies and renewable energy sources.

Regulatory Compliance: Modern facilities follow strict environmental rules, lowering their ecological footprint and encouraging environmental stewardship.

A. Terminal questions: MCQ

1. What is the primary goal of industrial planting?

- A) To enhance the aesthetic value of landscapes
- B) To produce raw materials for large-scale industrial use
- C) To provide recreational areas for the public
- D) To conserve endangered plant species

Answer: B) To produce raw materials for large-scale industrial use

2. Which of the following is NOT a common type of industrial plant?

- A) Automotive manufacturing plant

B) Textile and apparel plant

C) Residential housing plant

D) Chemical processing plant

Answer: C) Residential housing plant

3. In industrial planting, which factor is crucial for site selection?

A) Proximity to public transportation

B) Availability of raw materials

C) Proximity to tourist attractions

D) Aesthetic appeal of the site

Answer: B) Availability of raw materials

4. Which tree species is most commonly used in the production of paper in the industrial sector?

A) Oak

B) Eucalyptus

C) Cherry

D) Maple

Answer: B) Eucalyptus

5. What type of plywood is typically made from hardwood species like oak and maple?*

A) Structural plywood

B) Decorative plywood

C) Marine plywood

D) Utility plywood

Answer: B) Decorative plywood

6. In the context of industrial planting, what does "resource management" involve?

A) Maximizing profits from resource extraction

B) Efficiently utilizing resources such as energy and water

C) Increasing the amount of waste produced

D) Minimizing the quality of raw materials used

Answer: B) Efficiently utilizing resources such as energy and water

7. What type of industrial plant would you expect to find a facility dedicated to the manufacturing of heavy machinery?*

A) Automotive manufacturing plant

B) Machinery and equipment plant

C) Food and beverage processing plant

D) Textile and apparel plant

Answer: B) Machinery and equipment plant

B. Assertion and Reasoning Question

Assertion (A): Industrial planting is crucial for the supply of raw materials to various manufacturing industries.

Reason (R): Industrial planting focuses on growing tree species and crops that can be processed into essential products, reducing the need for importing raw materials.

Options:

A) Both Assertion and Reason are true, and the Reason is the correct explanation for the Assertion.

B) Both Assertion and Reason are true, but the Reason is not the correct explanation for the Assertion.

C) Assertion is true, but the Reason is false.

D) Assertion is false, but the Reason is true.

Answer: A) Both Assertion and Reason are true, and the Reason is the correct explanation for the Assertion.

Explanation:

Assertion (A): This is true because industrial planting provides the necessary raw materials such as wood, fibers, and crops that are essential for various manufacturing processes. These materials support industries like paper, plywood, and chemicals.

Reason (R): This is also true as industrial planting focuses on cultivating specific tree species and crops designed for industrial use. This reduces the dependence on imports by ensuring a steady and reliable supply of raw materials.

The Reason correctly explains why industrial planting is crucial for supplying raw materials to industries, making both statements true and the explanation accurate.

15.3 Paper and Pulpwood Plantations

Paper is the most important commodity in the developed world today. In fact, the per capita use of paper in a country can be used to objectively measure its advancement level.

Forest raw resources account for approximately 55% of the current production of paper and allied products. In the paper business, wood accounts for 30 to 50 percent of the entire production cost. Other elements influencing paper production costs include capital, chemicals, and power. According to reputable estimates, this industry requires a modest labour force, of which 35 to 45 percent are qualified workers. The cost of transportation can be significantly decreased if plantation forestry is moved to industrial catchments.

When we look at the history of the Indian pulp and paper business, we can see that in the early years (1882-1911), the raw materials used were Sebai grass (*Eulaliopsis binata*), waste paper, rags, and imported pulp. Later, the introduction of the fractional technique by Sir William Rait at the Forest Research Institute in Dehradun demonstrated that the domestic raw material of bamboos could be used to produce paper.

Because of the unique characteristics of hardwoods, forest planning for future raw material requirements must be done in such a way that both the required pulpwood grades and technical processes complement one another. The process of converting raw material into paper requires several processes.

The first critical process is to separate cellulose fibres, which are then transformed into paper mat. More than half of the material in chemical separation fibres dissolves. This spent liquor comprises raw chemicals and organic materials, the majority of which is lignin. This spent liquor is treated in an integrated mill to recover cooking chemicals and heat, which are used to calculate the overall process economics. Paper's physical

strength and runnability are determined by its fibre properties. As a result, it is clear that the physical and chemical qualities of raw materials have a fundamental impact on the quality of the finished product and overall processing. The homogeneity of raw material is critical for pulp manufacture.

In the present day, man-made plantations of rapidly growing pulpwood species can provide essential raw materials for the pulp and paper industry. Forest genetics can ensure high-quality breeding material by using carefully selected seedlings and tilling and fertilizing the soil. Plantations can provide up to ten times the growth of natural forests. The transition to essentially agro-technical methods offers numerous benefits, including easier selection of species and rotation periods, a more homogeneous crop suited to mass production, removal and processing techniques, reduced supervision and transportation costs through concentration, and the freedom to plan the sequence of age groups for orderly harvesting.

Several factors influence the amount of production in a paper mill vs the forests.

1. Forests' proximity to mills
2. Forests' terrain condition.
3. The extractable tree population density, and thus the total volume of accessible pulpwood.
4. Quality of the wood.
5. Forest management and operating practices.
6. The government's product cost policy for pulpwood.

Choice of species:

Poplars and Eucalyptus are the most promising plantation-grown raw materials for pulp and paper production due to their remarkable growth and, in the case of Eucalyptus, flexibility to a wide variety of climatic and soil conditions. Eucalyptus is said to have various advantages over standard long-fibred pulps, including:

They produce more paper per weight of wood.

Lower-cost pulping processes can be adopted.

Shorter fibres have reduced flow resistance and are better suited for pulps with high fiber-to-fiber binding strength.

Eucalyptus may be used to make a variety of papers, including writing, printing, typing, wrapping, packaging, and newspaper. Pulping methods can be chemical or semi-chemical, and paper can be created using both traditional and modern procedures. Eucalyptus wood has been discovered to be acceptable for rayon grade pulp. Eucalyptus pulp/paper is expected to have good formation, high opacity, high bulk, medium tensile strength, and high tear due to its fibre properties.

Eucalypts are a well-known raw material for the production of chemical-mechanical pulps appropriate for blending in newsprint supplies. Eucalypts develop a dark colour beginning in the fifth year and have a higher wood chip density than poplars.

15.3.1 Tree species in paper industries

In the paper industry, numerous tree species are used to produce fibres that are then processed into paper goods. Fibre quality, availability, and geographical suitability are all factors that influence tree species selection. Here's an overview of the main tree species utilized in the paper industry.

Softwood species

Softwoods are valued for their long fibres, which add strength and durability to paper products. They are widely utilised in the manufacture of newsprint, tissue paper, and packaging materials.

Pine trees (Pinus spp.): Pine are widely used as softwoods. Their long, robust fibres yield high-quality paper. It includes:

- **Loblolly Pine:** *Pinus taeda*
- **Scots Pine:** *Pinus sylvestris*
- **Eastern White Pine:** *Pinus strobus*
- **Southern Yellow Pine:** *Pinus palustris* and *Pinus echinata*

Spruce (Picea spp.)

Spruce trees provide long fibers that are ideal for producing strong and lightweight paper. They are used in making newsprint, kraft paper, and packaging materials.

- **Norway Spruce:** *Picea abies*
- **Sitka Spruce:** *Picea sitchensis*

- **White Spruce:** *Picea glauca*

Fir (Abies spp.)

Fir trees are used for their long fibers, which contribute to the strength and smoothness of paper products.

- **Douglas Fir:** *Pseudotsuga menziesii*
- **Grand Fir:** *Abies grandis*
- **Balsam Fir:** *Abies balsamea*
- **Noble Fir:** *Abies procera*

Cedar (Cedrus spp.)

Cedar wood is used for its strong fibers and resistance to decay. It is often used in specialty papers and products.

- **Western Red Cedar:** *Thuja plicata*
- **Eastern Red Cedar:** *Juniperus virginiana* (Note: Despite the name "cedar," it is actually a juniper.)

HARDWOODS:

Hardwoods are valued for their shorter fibers, which contribute to a smooth texture and better printability in paper products. They are commonly used in fine papers, writing papers, and certain specialty papers.

Eucalyptus (Eucalyptus spp.)

Eucalyptus trees are popular in the paper industry for their fast growth and high yield of short, strong fibers. They are widely used in producing fine papers and tissue products.

- **Blue Gum:** *Eucalyptus globulus*
- **Rose Gum:** *Eucalyptus grandis*
- **Sugar Gum:** *Eucalyptus cladocalyx*

Poplar (Populus spp.)

Poplar trees are used for their fast growth and the ability to produce short, clean fibers. They are often used in the production of newsprint and other paper products.

- **Eastern Poplar:** *Populus deltoides*
- **Hybrid Poplar:** *Populus x canadensis*
- **Trembling Aspen:** *Populus tremuloides*

Birch (*Betula* spp.)

Birch trees provide shorter fibers that contribute to smoothness and brightness in paper products. They are often used in specialty papers and high-quality printing papers.

- **Paper Birch:** *Betula papyrifera*
- **River Birch:** *Betula nigra*
- **Silver Birch:** *Betula pendula*

Aspen (*Populus tremuloides*)

Aspen trees offer short fibers that help in producing smooth and high-quality papers. They are often used in specialty papers and some types of printing paper.

Alder (*Alnus* spp.)

- **Red Alder:** *Alnus rubra*
- **Black Alder:** *Alnus glutinosa*

These species are chosen according to the required attributes of the paper, such as strength, smoothness, and durability. Softwoods are often selected for their long fibres, which contribute to the paper's strength, although hardwoods can provide a variety of textures and properties.

TERMINAL QUESTIONS

Multiple choice question

1. Which part of the wood is most commonly used to produce paper pulp?
 - a) Bark
 - b) Roots
 - c) Wood Chips
 - d) Leaves

Answer: c) Wood Chips

2. What chemical is commonly used in the paper bleaching process to produce white paper?

- a) Hydrogen Peroxide
- b) Chlorine Dioxide
- c) Sodium Hydroxide
- d) Ammonia

Answer: b) Chlorine Dioxide

3. What is the purpose of the "calendering" process in paper manufacturing?

- a) To bleach the paper
- b) To remove ink from recycled paper
- c) To smooth and compact the paper surface
- d) To add color to the paper

Answer: c) To smooth and compact the paper surface

4. What term is used for the process of recycling paper to produce new paper products?

- a) Papermaking
- b) Pulping
- c) Reprocessing
- d) Repulping

Answer: d) Repulping

True and False

1. The process of pulping wood for paper involves separating cellulose fibers from the lignin.

Answer: True

2. Recycled paper cannot be used to produce high-quality paper products due to its lower strength.

Answer: False

3. Bleaching in paper production is done to remove lignin and improve the whiteness of the paper.

Answer: True

4. Newsprint paper is typically made from high-quality wood fibers to ensure durability.

Answer: False

5. The paper industry is a major contributor to global deforestation.

Answer: False

15.4 Matchwood Plantations

Matchwood is one of India's oldest wood-based businesses, with two separate sectors emerging since 1920: mechanized and non-mechanized. Six factories are strategically positioned in the mechanized sector, while more than 1000 non-mechanized units with capacities ranging from one million to 80 million boxes of 50 sticks each are essentially centered in Southern India, primarily in Tamil Nadu. Cottage businesses have grown rapidly in the non-mechanized sector, with approximately 5500 units currently located in the Southern states, as shown below (Luna 2006).

Tamil Nadu	65%
Kerala	18%
Andhra Pradesh	7%
Other states	10%

The primary basic components required for the production of safety matches are wood, red phosphorus, sulphur, potassium chlorate, and match paper. Wood is the primary controlling factor in match manufacture. Since a few years, the match industry has had problems meeting its match log obligations. The primary characteristics of a match log include:

1. Ensure the wood is spherical, soft, straight-grained, light in weight, and devoid of knots and fissures.
2. For peeling thin match veneers, the wood density should be homogeneous, with minimal variance between sapwood and core.

3. Additionally, veneer logs must have good fissility. In terms of strength, highly strong, hard, and heavy wood is undesirable.
4. Ensure logs are almost cylindrical, as fluted or eccentric logs are wasteful to peel.
5. The market prefers white wood for matches, therefore a dark core is less desirable.
6. Match logs should be fresh and peelable when delivered to the plant.
7. Proper transportation arrangements and proximity between plantation and manufacturing are crucial for ensuring timely delivery.
8. Matchwood plantations produce 100 cubic meters of appropriate logs per hectare over a 30-year rotation.
9. To meet the demand for matches, at least 6000 ha of plantations should be undertaken year.
10. Several species are suitable for producing veneers, boxes, and splints. *Bombax ceiba* is the most suitable matchwood species, which may be grown over the Indo-Gangetic plains and eastern India.

15.4.1 Species in the Matchwood Industry

In the match industry, wood species selection is critical since different types of wood affect match ignition and burning properties.

- Matchstick wood should be easily fractured and have a uniform grain for consistent performance.
- Chemical treatments are commonly employed to improve the ignition and burning capabilities of matchstick wood, regardless of species. This includes applying chemicals to the match head and matchstick itself. Using the right wood provides consistent size and performance of matchsticks, leading to high-quality results.
- The choice of species may vary based on regional availability and specific requirements of match production.
- Species selection varies by area and fit production needs.
Some common tree species utilized in the match industry are listed below:

Some common tree species used in the match industry are as follows:

Softwoods:

Aspen (*Populus tremuloides*): Aspen wood is preferred for its ease of splitting and uniform grain, making it ideal for matchsticks.

Poplar (*Populus spp.*): Poplar is also used for similar reasons as aspen, due to its lightweight and ease of processing.

- **Eastern Poplar:** *Populus deltoides*
- **Hybrid Poplar:** *Populus x canadensis*

Pine (*Pinus spp.*): Pine is sometimes used, particularly in regions where it is abundant, due to its availability and processing properties.

- **Loblolly Pine:** *Pinus taeda*
- **Scots Pine:** *Pinus sylvestris*

Fir (*Abies spp.*): Fir wood is also used for its characteristics that make it suitable for matches.

- **Douglas Fir:** *Pseudotsuga menziesii*
- **Grand Fir:** *Abies grandis*

HARDWOODS:**Boxwood (*Buxus spp.*)**

Boxwood was historically used due to its fine grain and hardness, which allowed for a smoother surface and better performance in matches.

15.5. Plywood Industry

Plywood is a phrase used to describe glued wood construction made up of veneers with the grain of each veneer running at right angles to the grain of the adjacent veneer. The most major advantage of plywood is its dimensional stability, which solid wood lacks. Plywood is durable and easy to shape.

The plywood sector has a high need for timber in the form of logs of good girth, and their scarcity is becoming increasingly apparent; as a result, the overall capacity utilisation of the existing plywood plants has recently declined.

Veneers can be made from almost any wood, depending on the requirements. Woods with a close strong grain are ideal.

The Indian Standards Specification lists more than 49 kinds of tea chest plywood.

The more important woods used for veneering in plywood manufacture are as follows *Dipterocarpus macrocarpus*, *Terminalia myriocarpa*, *Acrocarpus fraxinifolius*, *Mangifera indica*, *Vateria indica*, *Ailanthus* spp., *Boswellia serrata*, *Canarium* spp., *Toona ciliata*, *Dillenia* spp., *Holoptelia integrifolia*, *Lannea coromandelica*, *Machilus macrantha*, *Syzygium cumini*.

Decorative veneer comes from *Dalbergia latifolia*, *Dysoxylum malabaricum*, *Swietenia* spp and *Tectona grandis*.

Recently some more timbers have been tested and found suitable for making general purposes plywood are: *Araucaria cunninghamii*, *Butea monosperma*, *Kayeu assamica*, *Pinus roxburghii*, *Populus deltoides*, *P. ciliata*.

15.5.1 Species used in Plywood industry

SOFTWOODS

Douglas Fir (*Pseudotsuga menziesii*): Known for its strength and stability, making it a popular choice for structural plywood.

Southern Yellow Pine (*Pinus* spp.): Used for its strength and availability, often found in construction-grade plywood.

- **Loblolly Pine:** *Pinus taeda*
- **Longleaf Pine:** *Pinus palustris*
- **Shortleaf Pine:** *Pinus echinata*

Western Red Cedar (*Thuja plicata*): Valued for its natural resistance to decay and its lightweight properties.

Spruce (*Picea* spp.): Provides a good balance of strength and weight, often used in higher-grade plywood.

- **Sitka Spruce:** *Picea sitchensis*
- **White Spruce:** *Picea glauca*

Hemlock (*Tsuga* spp.): Used in various plywood applications for its strength and versatility.

- **Western Hemlock:** *Tsuga heterophylla*
- **Eastern Hemlock:** *Tsuga canadensis*

HARDWOODS

Birch (*Betula* spp.): Birch plywood is valued for its durability and smooth finish, commonly used in furniture and cabinetry.

- **Silver Birch:** *Betula pendula*
- **Yellow Birch:** *Betula alleghaniensis*

Maple (*Acer* spp.): Maple plywood is used for its strength and fine grain, suitable for cabinetry and furniture.

- **Hard Maple:** *Acer saccharum*
- **Soft Maple:** *Acer rubrum*

Oak (*Quercus* spp.): Oak plywood is valued for its strength and appearance, commonly used in high-quality furniture and architectural applications.

- **Red Oak:** *Quercus rubra*
- **White Oak:** *Quercus alba*

Teak (*Tectona grandis*): Known for its resistance to water and decay, used in marine and outdoor applications.

Mahogany (*Swietenia* spp.): Mahogany plywood is prized for its rich color and finish, often used in high-end furniture.

- **Honduran Mahogany:** *Swietenia macrophylla*
- **African Mahogany:** *Khaya ivorensis*

Cherry (*Prunus* spp.): Cherry plywood is valued for its rich color and smooth finish, commonly used in fine furniture and cabinetry.

- **Black Cherry:** *Prunus serotina*

TERMINAL QUESTIONS:

A. Multiple choice questions

1. Which of the following chemicals is commonly used in the head of safety matches to aid ignition?

- a) Sulfur
- b) Potassium Chlorate
- c) Calcium Carbonate
- d) Sodium Bicarbonate

Answer: b) Potassium Chlorate

2.. In which year was the first friction match invented?

- a) 1827
- b) 1830
- c) 1840
- d) 1850

Answer: a) 1827

3. Which type of match requires a specific striking surface to ignite?

- a) Safety Match
- b) Strike-anywhere Match
- c) Wooden Match
- d) Phosphorus Match

Answer: a) Safety Match

4. What type of wood is commonly used in the production of matchsticks due to its ease of splitting and uniform grain?

- a) Maple
- b) Cherry
- c) Poplar
- d) Walnut

Answer: c) Poplar

5. Which company is known for being one of the largest match manufacturers in the world?

- a) Reckitt Benckiser
- b) UPM-Kymmene Corporation
- c) Diamond Match Company
- d) Georgia-Pacific

Answer: c) Diamond Match Company

6. What is the main environmental concern associated with the production of matches?

- a) Deforestation
- b) Water Pollution
- c) Air Pollution
- d) Chemical Waste

Answer: d) Chemical Waste

7. Which chemical compound used in match production is known for being highly toxic and was eventually phased out?

- a) Potassium Chlorate
- b) White Phosphorus
- c) Sodium Chloride
- d) Calcium Sulfate

Answer: b) White Phosphorus

Assertion and Reasoning Question

Assertion (A): The use of white phosphorus in match production has been largely discontinued due to its health hazards.

Reason (R): White phosphorus is highly toxic and can cause severe health issues, including bone necrosis, when exposed to it over prolonged periods.

Choose the correct option:

- a) Both Assertion and Reason are correct, and the Reason is the correct explanation for the Assertion.
- b) Both Assertion and Reason are correct, but the Reason is not the correct explanation for the Assertion.

- c) The Assertion is correct, but the Reason is incorrect.
- d) The Assertion is incorrect, but the Reason is correct.
- e) Both Assertion and Reason are incorrect.

Answer: a) Both Assertion and Reason are correct, and the Reason is the correct explanation for the Assertion.

Explanation: White phosphorus is extremely toxic, and exposure can lead to serious health issues such as phosphorus necrosis of the jaw (phossy jaw), which is why its use in match production has been discontinued in favor of safer alternatives. The Reason provides a valid explanation for why the Assertion is true.

C. True and False

1. Safety matches require a specific striking surface to ignite, while strike-anywhere matches can be ignited on any rough surface.

Answer: True

2. The primary wood species used for making matchsticks is oak due to its strength and durability.

Answer: False

3. The use of white phosphorus in match production has been discontinued due to its severe health hazards.

Answer: True

4. The production of matchsticks involves a process where the match heads are coated with a mixture of chemicals, including phosphorus and potassium chlorate.

Answer: True

5. In the match industry, the wood used for matchsticks is often treated with preservatives to extend shelf life.

Answer: False

Unit 16: Plantation at different Problematic Sites

Unit Structure

16.0 Learning Objectives

16.1 Wastelands

16.1.1 Ecological Status of Waste land

16.2 Dry and Arid Areas

16.2.1 Tree Species suitable for plantation in Dry and Arid Areas

16.3 Wetlands and Waterlogged Areas

16.3.1 Species suitable for plantation in Waterlogged Areas

16.4 Coastal Areas

16.4.1 Species suitable for plantation in Coastal Areas

16.5 Ravine Lands

16.5.1 Tree Species used for plantation in Ravine lands

16.6 Shelter Belts and Windbreaks

16.6.1. Tree Species for Shelter Belts and Windbreaks

16.7 Sand Dunes

16.7.1 Species suitable for Sand dune region

16.8 Land Slips and Land Slides

16.8.1 Species suitable for Land Slips and Land Slides region

16.0 Learning Objectives

After you have studied this unit, you should be able:

- To understand about different problematic sites.
- To understand about Wasteland.
- Plantation at different sites, Ravine land, Water logged areas, dry and arid areas, Sand dunes,
- To understand how the value of several oil yielding species has been enhanced.

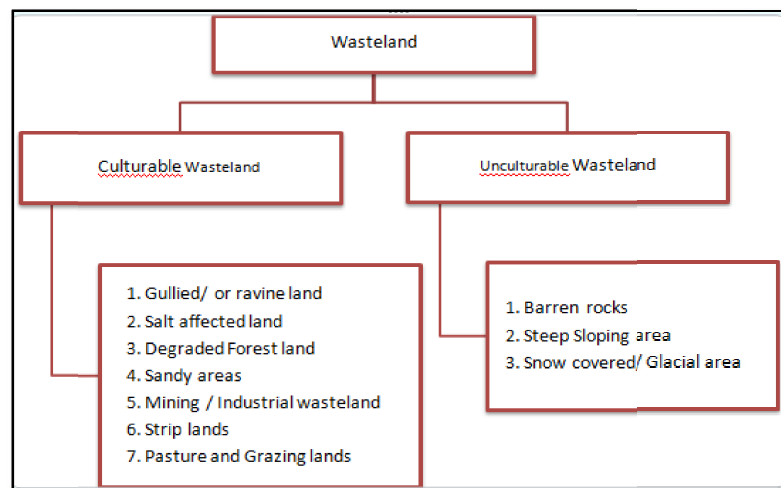
16.1 Wastelands

The term wasteland in common usage means the degraded, unused, uncultivated and common land. The waste land survey and reclamation committee, 1963, included under wastelands

- a) Lands not available for cultivation, barren and uncultivable wastes
- b) Ether uncultivated land excluding fallow, culturable waste, permanent pastures and land under miscellaneous trees.
- c) Fallows

The wastelands are ecologically unstable. Over the years of human settlements, these lands have been subjected to different degrees of biotic or ecological interference as a result, rendering them degraded, infertile and unculturable. National Wastelands Development Board (NWDB) defined wasteland as “that land which is degraded and is presently lying unutilized (except as current fallow) due to different constraints. NWDB also suggested that any land which is not producing green biomass consistent with the status of soil and water must be treated as wasteland”.

Generally, the wastelands are those areas which are not used for cultivation for the one reason or the other. Other areas which are generally included in the wasteland are saline and alkaline soils, water logged areas, common grazing lands, panchayat lands, land lying vacant along the railway lines, roads, canal strips, denuded and barren rocky hills, ravine lands, flood plains, lands infested with thick weeds



16.1.1 Ecological Status of Waste land

Before putting the waste lands into any use the existing ecological status of waste land and improving the same by possible means and planting with suitable species for the twin objects of fuel and fodder production are to be considered.

1. Wastelands are situated in the drier parts of the country.
2. Annual rain fall may not be more than 700 mm.
3. The dry period will not be more than month in a year.
4. The soil will be either sterile or alkaline or saline.
5. In slopy topography they must have been subjected to soil erosion and barren rocks, are exposed and scattered and strewn with boulders and gravels.
6. Added to that the region might be subjected to illicit grazing, over grazing and heavy browsing.
7. The regions are surrounded by rich population of poor people and therefore subjected to illicit-hacking of all available growth and unauthorized encroachment.
8. Water logged areas are also available as waste lands.

Keeping these existing adverse conditions in mind a five point formula is put forth which is as under.

- i. Provision of complete protection from man and his animals.
- ii. Existing people's participation to the maximum
- iii. Application of modern scientific techniques.

Planting trees or crops in problematic sites can be challenging, but with the right approach, it can be successful. Here are some strategies for dealing with various types of problematic sites:

16.2 Dry and Arid Areas

Dry rocky and Murramy areas are the major wastelands occurring mainly in the peninsular India to the extent of 2.4 million ha. They are generally termed as skeletal soils, designated so because of very shallow thickness of soil, and lack of profile development. The soils are coarse, poor, eroded with a mass of dry loose stones and gravel overlying the bed rock. In

high rain fall regions, steep hilly slopes have almost become necked due to serious soil erosion leaving behind the unproductive subsoil and therefore need immediate afforestation. The soil should only be managed for pasture development and afforestation.

For dry and arid areas, choosing plant species that are adapted to low water availability and high temperatures is crucial. Here's a list of species



across different categories that can thrive in such conditions:

16.2.1 Tree Species suitable for plantation in Dry and Arid Areas

In the dry and arid areas of Uttarakhand, which are often characterized by low rainfall and high temperatures, it's essential to choose tree species that are drought-tolerant and well-adapted to the local soil and climate conditions. Here are some tree species suitable for plantation in such regions of Uttarakhand:

S.No.	Botanical name	Local name	Description	Benefits
1.	<i>Zizyphus mauritiana</i>	Indian Plum	Drought tolerance and edible fruit.	Provides shade, has medicinal properties, and is useful for erosion control
2.	<i>Prosopis cineraria</i>	Khejri	A native tree of arid regions in India, known for its deep root system and ability to thrive in dry conditions	Fixes nitrogen in the soil, provides shade, and has multiple uses including as fodder and for timber.
3.	<i>Pongamia Pinnata</i>	Karanj	A drought-tolerant tree that grows well	Produces seeds that can be used for

			in arid conditions	biofuel, improves soil fertility, and provides shade.
4.	<i>Acacia nilotica</i>	Babool	A hardy, drought-resistant tree that is native to dry regions.	Offers shade, provides fodder for livestock, and its pods can be used for medicinal purposes.
5.	<i>Acacia senegal</i>	Gum Arabic Tree	Known for its gum-producing capabilities and resilience in dry environments.	Produces gum Arabic, which has various industrial and medicinal uses, and improves soil fertility.
6.	<i>Eucalyptus species</i>	Eucalyptus	Many species of Eucalyptus are drought-tolerant and can handle a range of soil conditions.	Fast-growing, provides shade, and is used for timber and medicinal purposes.
7.	<i>Ziziphus jujuba</i>	Jujube	A hardy tree that is well-suited to arid conditions.	Produces edible fruits and has medicinal uses.
8.	<i>Azadirachta indica</i>	Neem	A versatile tree known for its drought resistance and wide range of uses.	Offers shade, has medicinal properties, and its seeds can be used for pest control.
9.	<i>Olea europaea</i>	Olive Tree	Well-suited to dry climates and poor	Produces olives and olive oil, provides

			soils.	shade, and is ornamental.
10.	<i>Bambusa spp</i>	Bamboo	Certain bamboo species are adaptable to dry conditions and can help with soil erosion control.	Fast-growing, can be used for construction, and helps with soil stabilization.
11.	<i>Moringa oleifera</i>	Moringa	Known for its ability to grow in dry and poor soil conditions.	Highly nutritious leaves, fast-growing, and used for medicinal purposes.
12.	<i>Phoenix dactylifera</i>	Date Palm	Adapted to desert environments	Provides edible fruit

By selecting the right species and implementing water-conservation practices, we can create a thriving landscape even in the harshest dry and arid environments.

TERMINAL QUESTIONS:

A. Multiple Choice Questions

1. Which of the following trees is most suitable for plantation in arid regions?

- A) Oak
- B) Pine
- C) Date Palm
- D) Maple

Answer: C) Date Palm

2. What is a common method used to conserve soil moisture in dry and arid regions?

- A) Drip irrigation
- B) Flood irrigation

C) Surface irrigation

D) Hydroponics

Answer: A) Drip irrigation

3. Which plant adaptation is commonly found in vegetation suited for arid regions?

A) Broad leaves

B) Shallow roots

C) Succulent tissues

D) High water content in leaves

Answer: C) Succulent tissues

4. Which of the following is a challenge in plantation in arid regions?

A) Excessive rainfall

B) High soil fertility

C) Water scarcity

D) High humidity

Answer: C) Water scarcity

B. True/False Statements

1. Cacti are well-suited for plantation in dry and arid regions.

Answer: True

2. Mulching helps in reducing evaporation and maintaining soil moisture in arid regions.

Answer: True

3. Desertification is a process that leads to the increase of fertile land in arid regions.

Answer: False

C. Assertion-Reasoning Questions

1. Assertion: Drip irrigation is an effective method for water conservation in dry regions.
Reason: Drip irrigation delivers water directly to the roots of plants, minimizing evaporation and runoff.

Answer: Both the assertion and the reason are true, and the reason is the correct explanation for the assertion.

2. Assertion: High salinity in soil is beneficial for most dryland plants.
Reason: Many plants adapted to arid conditions have developed mechanisms to tolerate high salinity.

Answer: The assertion is false, but the reason is true. High salinity is generally harmful to most plants, although some arid plants are adapted to tolerate it.

3. Assertion: Soil conservation techniques are unnecessary in arid regions because of their low rainfall.

Reason: Soil erosion is less of a problem in dry regions due to low water runoff.

Answer: The assertion is false, and the reason is also false. Soil conservation techniques are crucial in arid regions to prevent erosion and maintain soil health.

16.3 Wetlands and Waterlogged Areas

Extent of water-logged areas is not known, however, it is estimated that about 1 million ha. of such land is found in the different states of India. Water-logged conditions are generally met within the high rainfall areas where drainage is poor. Water logging conditions can be categorized into :

1. Water-logging conditions caused by stagnant water
2. Water-logging caused by impeded but mobile water
3. Swampy areas



Source: https://commons.wikimedia.org/wiki/File:Waterlogged_area_near_Abbots_Well-geograph.org.uk_-_951493.jpg

4. Marshy areas and saline muddy areas.

Water-logging conditions are also caused by excessive and faulty canal irrigation in areas adjoining agricultural fields. Such conditions are found in Punjab and Haryana. Water-logging conditions are also found in the depressions or borrow pits, along canals, roads, railway tracks etc. during rainy season. Owing to refractory characteristics, these areas become difficult to afforest mainly due to physiological drought, defective aeration, excessive salt accumulation and poor nutrient availability. Under natural conditions, nothing grows except tall grasses such as *Saccha spontaneum*, *Vetiveria zizanioides*, *Themeda spp*, *Phragmites karka* and *Avistida spp*. Among the tree species *Salix alba*, *Barringtonia acutangula*, *Syzigium cumini* only can grow.

Afforestation of such lands need special treatments which include drains excessive water, reduction of excessive salinity and then planting with suitable species. In areas where water depth is less than one meter ridge and furrow method give good results, the height of the ridges can be amended according to the depth of water. Plantation of Water logged areas can only be achieved by:

- Choosing species that can handle excess moisture, such as cattails, willows, or certain types of ferns.
- Improve drainage by adding sand or organic matter to the soil.
- For gardens, consider creating raised beds to improve root health and drainage.
- If possible, improve drainage around planting areas to prevent long-term water logging issues.
- Regularly monitor water levels to avoid prolonged water logging that can impact plant health.
- Choose species based on their tolerance to local soil and water conditions.

16.3.1 Species suitable for plantation in Waterlogged Areas

For wetlands and waterlogged areas in Uttarakhand, it's important to select tree species that can thrive in consistently moist or waterlogged soils. These species should be able to

tolerate high moisture levels and occasional flooding. Some suitable tree species for such environments are:

S.No.	Botanical name	Local name	Description	Benefits
1.	<i>Salix spp</i>	Willow	Willows are well-adapted to wet soils and are commonly found in wetlands.	Effective in stabilizing soil and controlling erosion, provides habitat for wildlife.
2.	<i>Bambusa spp</i>	Bamboo	Certain bamboo species thrive in wet conditions and can help with soil stabilization.	Fast-growing, provides excellent erosion control, and can be used for construction and crafts.
3.	<i>Populus spp</i>	Poplar	Poplar trees are tolerant of wet soils and can grow quickly.	Provides fast-growing shade, can be used for timber, and helps with soil stabilization.
4.	<i>Swietenia mahagoni</i>	Mahogany	Adapted to tropical and subtropical wetlands, this tree can tolerate moist conditions.	Valuable hardwood, provides shade, and contributes to biodiversity.
5.	<i>Acer saccharinum</i>	Silver Maple	Thrives in wet soils and can handle occasional flooding	Provides shade, has attractive foliage, and supports local wildlife.
6.	<i>Acer rubrum</i>	Red Maple	Prefers moist soils and can tolerate waterlogged	Offers vibrant fall color, provides habitat, and supports

			conditions.	wildlife.
7.	<i>Salix nigra</i>	Black Willow	Known for its adaptability to wet conditions and high water tables.	Excellent for erosion control, provides habitat, and can be used for basketry and crafts.
8.	<i>Conocarpus erectus</i>	Buttonwood	Suitable for wetlands and can tolerate periodic flooding.	Used for landscaping, provides habitat, and helps with erosion control.
9.	<i>Tamarindus indica</i>	Tamarind	While typically found in drier regions, it can tolerate moist conditions and occasional flooding.	Provides edible fruit, offers shade, and is used in various culinary applications.
10	<i>Terminalia catappa</i>	Indian Almond	Tolerates wet soils and can handle waterlogged conditions	Provides shade, has edible nuts, and is used in traditional medicine.

TERMINAL QUESTION:**A. Multiple Choice Questions**

1. What is a common challenge in planting trees in waterlogged areas?

- A) High soil salinity
- B) Lack of sunlight
- C) Excessive soil aeration

D) Poor drainage

Answer: D) Poor drainage

2. Which plant adaptation is typical for vegetation in waterlogged areas?

A) Deep taproots

B) Floating leaves

C) Air-filled cavities in stems

D) Thick waxy coatings

Answer: C) Air-filled cavities in stems

3. Which of these practices can help manage water levels and improve plantation success in wetlands?

A) Installing drainage systems

B) Using drought-resistant crops

C) Applying chemical fertilizers

D) Frequent tillage

Answer: A) Installing drainage systems

B. True/False Statements

1. Mangroves are adapted to thrive in saltwater and brackish water environments.

Answer: True

2. Waterlogged soils generally have high oxygen levels, which supports root health.

Answer: False

3. Floating aquatic plants, like water lilies, are well-suited for environments with standing water.

Answer: True

c. Assertion-Reasoning Questions

1. Assertion: Mangrove forests help protect coastal areas from erosion.
Reason: The complex root systems of mangrove trees stabilize the soil and reduce the impact of waves.

Answer: Both the assertion and the reason are true, and the reason is the correct explanation for the assertion.

2. Assertion: Plants with air-filled cavities in their stems are not suitable for waterlogged areas.

Reason: Air-filled cavities help these plants float and access oxygen in oxygen-poor environments.

Answer: The assertion is false, and the reason is true. Air-filled cavities actually help plants survive in waterlogged areas by providing access to oxygen.

3. Assertion: Waterlogged soils are generally nutrient-rich, which supports plant growth.
Reason: The anaerobic conditions in waterlogged soils often limit nutrient availability and microbial activity.

Answer: The assertion is false, and the reason is true. Waterlogged soils can often have reduced nutrient availability due to anaerobic conditions.

16.4 Coastal Areas

A coast, also known as the coastline, shoreline, or seashore, is the land adjacent to the sea or the line that separates the land from the ocean or a lake. Coasts are influenced by both the surrounding landscape's topography and water-induced erosion, such as waves. Coasts are significant zones in natural ecosystems, and they frequently support a diverse spectrum of wildlife. On land, they support key habitats like



Source: https://commons.wikimedia.org/wiki/File:Coastal_Land_for_the_Public,_Ilsham_Marine_Drive_-_geograph.org.uk_-_2047270.jpg

freshwater or estuarine wetlands, which are vital to bird populations and other terrestrial creatures.

Coastal areas gather a considerable amount of sand as a result of strong tides and winds. The strong winds transport vast amounts of sand to productive regions and settlements. Coastal soil is made up entirely of sand, is unstable, and has minimal water retention ability. Because of the salty breezes and brackish coastal waters that inundate the area, the soil has a strong alkaline reaction. The afforestation of these lands is urgently needed to minimize wind erosion and supply the increasing demand for firewood and small timber for local usage.

16.4.1 Species suitable for plantation in Coastal Areas

Some tree species that are suitable for saline or coastal areas and can be considered if such conditions are present:

S.No.	Botanical name	Local name	Description	Benefits
1.	<i>Avicennia marina</i>	Indian Mangrove	A true mangrove species that can tolerate saline conditions and is suitable for coastal areas.	Helps stabilize coastal soils, provides habitat, and supports biodiversity.
2.	<i>Casuarina equisetifolia</i>	Casuarina	Known for its tolerance to saline soils and coastal conditions.	Fast-growing, used for windbreaks, and provides timber and fuel.
3.	<i>Azadirachta indica</i>	Neem	While not a true coastal species, neem can tolerate some level of soil salinity and is versatile.	Offers shade, has medicinal properties, and its seeds are used for pest control.
4.	<i>Cocos nucifera</i>	Coconut Palm	Prefers coastal and saline conditions, though it may be less common	Produces edible fruit, has a variety of uses, and is highly adaptable to coastal

			in Uttarakhand.	conditions.
5.	<i>Terminalia catappa</i>	Almond	Can tolerate saline conditions and is used in tropical and coastal regions.	Provides shade, produces edible nuts, and has various medicinal uses.
6.	<i>Bambusa spp</i>	Bamboo	Some bamboo species can tolerate saline conditions and are useful in coastal stabilization.	Fast-growing, helps with soil erosion control, and has various uses in construction and crafts.

TERMINAL QUESTIONS:**A. Multiple Choice Questions**

1. What is the primary driver of tides in coastal areas?

- A) Wind patterns
- B) Ocean currents
- C) Gravitational pull of the Moon
- D) Temperature changes

Answer: C) Gravitational pull of the Moon

2. The term "estuary" refers to:

- A) A place where freshwater meets saltwater
- B) A type of coastal erosion feature
- C) An area of high wave energy
- D) A man-made coastal defense structure

Answer: A) A place where freshwater meets saltwater

B. True/False Questions

1. Tides are caused primarily by the wind.

Answer: False

2. Coral reefs are typically found in cold, nutrient-rich waters.

Answer: False

3. Deltas form where rivers deposit sediment into a standing body of water, like a sea or lake.

Answer: True

4. The term 'sand dune' refers to a coastal landform created by wind deposition.

Answer: True

C. Assertion and Reasoning Questions

1. **Assertion:** Coastal mangrove forests are critical for preventing coastal erosion.

Reason: Mangrove trees have extensive root systems that stabilize sediment.

Answer: Both the assertion and the reason are correct, and the reason is the correct explanation for the assertion.

2. **Assertion:** Coastal areas are more affected by climate change than inland areas.

Reason: Coastal areas experience more frequent and severe weather events, such as hurricanes and storm surges, due to their proximity to the ocean.

Answer: Both the assertion and the reason are correct, and the reason is the correct explanation for the assertion.

3. **Assertion:** Coastal areas with high biodiversity are often less resilient to environmental changes.

Reason: High biodiversity can indicate a more delicate ecological balance that may be disrupted more easily by environmental changes.

Answer: The assertion is incorrect, but the reason is correct. Coastal areas with high biodiversity are generally more resilient to environmental changes.

16.5 Ravine Lands

The word "ravine" means a deep gorge and is associated with a system of gullies, running more or less parallel to each other, in deep alluvium and draining into a major river or its tributary, which is flowing much lower than the surrounding table lands. Ravines represents the last stage of water erosion.

Ravine formation is the cumulative result of indiscriminate destruction of forests or vegetation, unplanned cultivation, destructive grazing and severe water erosion. Unprotected lands from grazing for a long time in the absence of soil conservation measures hasten the gully formation especially along the stream banks and get converted into deep ravines rendering the land unsuitable both for agriculture and forestry.



Source:

https://commons.wikimedia.org/wiki/File:Ravine_beside

Planting in ravine lands, which are often characterized by steep, eroded landscapes, requires species that can stabilize the soil, improve fertility, and thrive in challenging conditions. The choice of species depends on the specific climate, soil type, and other local conditions of the ravine area. Here are some commonly used species for plantation in ravine lands:

16.5.1 Tree Species used for plantation in Ravine lands

1. Acacia Species: These species are known for their ability to improve soil fertility and stabilize erosion-prone areas.

- *Acacia nilotica* (Gum Arabic Tree)
- *Acacia catechu* (Catechu Tree)

2. Eucalyptus Species: Eucalyptus trees are fast-growing and can help in soil stabilization due to their extensive root systems.

- *Eucalyptus camaldulensis* (River Red Gum)
- *Eucalyptus globulus* (Blue Gum)

3. Casuarina: Casuarina species are used for their deep root systems which help in preventing soil erosion and improving soil structure.

- *Casuarina equisetifolia* (Common Ironwood)
- *Casuarina junghuhniana* (Mountain Sheoak)

4. **Willow:** Willows are excellent for stabilizing riverbanks and ravines due to their high water uptake and extensive root systems.

- *Salix alba* (White Willow)
- *Salix babylonica* (Weeping Willow)

By selecting appropriate species and planting methods, ravine lands can be rehabilitated effectively, improving their stability and productivity.

16.6 Shelter Belts and Windbreaks

Shelter belts serve a significant function in preventing wind erosion and sand drift. Shelter belts minimize wind velocity and control dunes on the leeward side. A shelter belt is a wide belt of trees, shrubs, and grasses planted in rows across the land at right angles to the



direction of the prevailing winds to deflect air current, reduce wind

velocity, and provide general protection to cultivated areas from wind erosion and the desiccating effect of hot winds. Shelter belts in coastal areas prevent coastal sands from blowing onto cultivated lands, making them less productive in the long run. Shelterbelts in coastal areas minimize wind velocity. Shelterbelts in coastal areas minimize the wind velocity of storms that hit the coast and have the potential to reverse the trend of tidal forest degradation for the benefit of humanity.

Shelter belts and windbreaks are planted to protect crops, reduce soil erosion, and create a more favorable microclimate. They typically consist of rows of trees and shrubs designed to block or reduce wind speed. The choice of species for these purposes depends on local

climate, soil conditions, and the specific goals of the windbreak or shelter belt. Here are some commonly used species for these applications:

16.6.1. Tree Species for Shelter Belts and Windbreaks

1. **Poplar (Populus spp.):** Fast-growing and effective at reducing wind speed. Good for areas with ample water supply.
 - *Populus deltoides* (Eastern Cottonwood)
 - *Populus nigra* (Black Poplar)
2. **Pine (Pinus spp.):** Pines are often used in windbreaks due to their dense foliage and adaptability to a range of soil types.
 - *Pinus nigra* (Black Pine)
 - *Pinus sylvestris* (Scots Pine)
3. **Thuja (Thuja spp.):** Thuja species are evergreen, providing year-round wind protection and privacy.
 - *Thuja occidentalis* (American Arborvitae)
 - *Thuja plicata* (Western Red Cedar)
4. **Cedars (Cedrus spp.):** These trees are effective at reducing wind speed and can add an attractive aesthetic to the landscape.
 - *Cedrus atlantica* (Atlas Cedar)
 - *Cedrus deodara* (Deodar Cedar)
5. **Willow (Salix spp.):** Willows are useful in windbreaks and shelter belts, especially in areas with high moisture.
 - *Salix alba* (White Willow)
 - *Salix babylonica* (Weeping Willow)
6. **Eucalyptus (Eucalyptus spp.):** Eucalyptus trees are fast-growing and provide good wind protection. Be mindful of their water needs and potential invasiveness.
 - *Eucalyptus camaldulensis* (River Red Gum)

- *Eucalyptus globulus* (Blue Gum)

16.7 Sand Dunes

The word 'Dune' is derived from the English word 'Dun' meaning hilly topographical features. In the dry and areas, the moving wind dislodges soil particles and transport to considerable long distances particularly in the absence of vegetational cover. Particles with diameters ranging from 0.05 to 2.00 mm are classed as sand. Sand sized particles after being transported



Source:
[https://commons.wikimedia.org/wiki/File:Shifting_Dunes.j](https://commons.wikimedia.org/wiki/File:Shifting_Dunes.jpg)

by wind accumulate as dunes of different shapes

and sizes. Bagnold (1941) suggested three types of movement in the transport of sand: suspension, saltation and surface creep.

- Suspension process is not very effective in the transport of sand because vertical velocities needed to lift sand grains are rarely attained.
- Saltation is a bounding movement, resulting from impact and rebound of windblown sand.
- Bigger particles move by surface creep.
- Wind power and its duration are the principal factors that control the formation and shape of dunes. Local barriers like hills, vegetation, water and other factors which deflect the blowing wind modify the form of dunes.

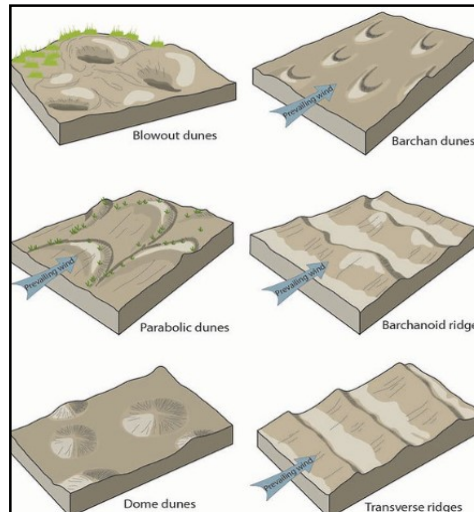
Types of dunes:

Dunes are generally called active and fixed dunes. The term active dunes include all types of edifices made up by Aeolian material regardless of the particle size and their mineralogical nature. The edifices formed by pavement composed of sand particles with grain sizes greater than those which are mobilized by trade winds are termed as **fixed dunes**.

Crescent dunes formed by one dominant wind direction. They are further divided into:

Barchens: It has a convex crescent form on the windward side and concave on the leeward side. Barchens have four major forms:

- Cake like sand dunes
- Juvenile crescent sanddunes
- Crescentic sand dunes
- The Barchen



Parabolic dunes: these are sandy crescents which are concave to the windward direction.

Linear Dunes: Linear dunes are elongated sand structures of unequal sizes parallel to the wind. Fixed linear dunes are called **sandridges**.

Star dunes: they are also known as pyramid dunes as sand mount is often pyramidal in form, from the top of which 3 or more arms stretch in all possible directions.

Traverse dune: These kinds form long lines of ridged dunes that are at right angles (perpendicular) to the direction of the wind. They commonly occur in areas with bountiful supply of sand and less plant life.

Blowout dunes: Their shapes are exactly opposite of barchans dunes. In blowout dune, the slip face and crescent-shaped curve faces away from the wind.

Dome Dunes: Dome dunes are rounded or dome-shaped. They are usually smaller in size and form in areas with limited sand availability or where wind speeds are relatively low. Dome dunes are more stable compared to other types of dunes because their shape helps distribute the sand more evenly.

16.7.1 Species suitable for Sand dune region

Species suitable for dune fixation must be highly drought resistant, have a well developed root system (preferably fibrous), capable of deep vertical penetration to reach the lower

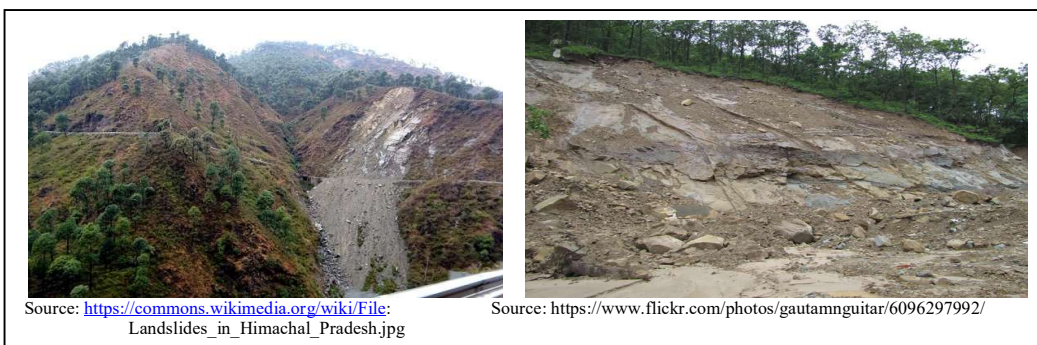
moisture layers of soil, should be wind firm, not exacting in moisture and nutrient requirements. For the sand dune stabilization different species are used:

1. **Casuarina (Casuarina equisetifolia)** - Known as Australian pine, it's widely used for coastal stabilization due to its tolerance to salt and sandy soils.
2. **Acacia (Acacia spp.)** - Various species are drought-tolerant and can help improve soil quality while stabilizing dunes.
3. **Pine Species (Pinus spp.)** - Species like Eastern White Pine (*Pinus strobus*) and Ponderosa Pine (*Pinus ponderosa*) are effective in sandy soils.
4. **Black Locust (Robinia pseudoacacia)** - Fast-growing and nitrogen-fixing, it can enhance soil fertility and stabilize the sand.
5. **Sand Pine (Pinus clausa)** - Particularly suited to sandy soils, it is commonly found in coastal dune areas.
6. **Myrtle (Myrtus communis)** - Thrives in well-drained sandy soils and can provide good ground cover.
7. **Salt Cedar (Tamarix spp.)** - While it can help stabilize dunes, it's important to manage this species due to its invasive potential in some areas.
8. **Eastern Red Cedar (Juniperus virginiana)** - A hardy tree that helps prevent erosion and can adapt to sandy soils.
9. **Coastal Live Oak (Quercus virginiana)** - Provides habitat and stabilization, suitable for sandy coastal areas.
10. **Cypress (Taxodium spp.)** - Some species can tolerate sandy soils and provide good stabilization.

16.8 Land Slips and Land Slides

Land slide or slip is defined as downward and outward movement of slope forming material composed of soil, natural rocks, artificial fills or a combination of these materials. Other factors which are responsible for causing landslides are classified as geological, hydrological, seismic and developmental. Thin beds of clayey limestones and highly

jointed sedimentary beds etc are the weak zones causing landslides. If these are accompanied by structural deformities like steep dips, folds, faults etc. then there is more danger of landslides. Among the hydrological causes water seeping through disturbed slopes, toes cutting by rivers and torrents are responsible for landslides. The landslides mostly take place after rain fall because the water increases the weight of material due to saturation and lubricating the sliding planes. Among the seismic factors, intensity and frequency of earthquakes are responsible for causing landslides.



16.8.1 Species suitable for Land Slips and Land Slides region

The suitable species are: *Acacia catechu*, *Pinus longifolia*, *Boehreria regulosa*, *Erythrina suberosa*, *Dalbergia sissoo*, *Salix alba*, *Morus alba* etc. are some of the species depending upon the elevation of the site. Some important species used for plantation in landslide area are as follows:

1. **Willow (*Salix spp.*)** - Known for their extensive root systems, willows are excellent for stabilizing stream banks and landslide areas.
2. **Alder (*Alnus spp.*)** - These trees can improve soil stability and are nitrogen-fixing, enhancing soil fertility.
3. **Black Locust (*Robinia pseudoacacia*)** - Fast-growing and with a strong root system, it helps stabilize disturbed soils.
4. **Pine Species (*Pinus spp.*)** - Species like Eastern White Pine (*Pinus strobus*) and Loblolly Pine (*Pinus taeda*) have strong roots and can thrive in various conditions.

5. **Birch (*Betula* spp.)** - Fast-growing and adaptable, birches help improve soil stability.
6. **Maple (*Acer* spp.)** - Certain species, like Silver Maple (*Acer saccharinum*), can thrive in moist conditions and help stabilize the soil.
7. **Eucalyptus (*Eucalyptus* spp.)** - Known for their deep root systems, they can help control erosion in some regions.
8. **Sweetgum (*Liquidambar styraciflua*)** - This tree has a strong root system and can grow well in disturbed soils.
9. **Cypress (*Taxodium* spp.)** - Particularly useful in wet areas, cypress trees have extensive root systems that stabilize soil.
10. **Coastal Redwood (*Sequoia sempervirens*)** - In appropriate climates, their deep roots can help with stabilization.

TERMINAL QUESTIONS

A. Multiple Choice Questions

1. Which of the following species is commonly used for stabilizing sand dunes?

- A) Oak (*Quercus* spp.)
- B) Australian Pine (*Casuarina equisetifolia*)
- C) Birch (*Betula* spp.)
- D) Maple (*Acer* spp.)

Answer: B) Australian Pine (*Casuarina equisetifolia*)

2. What is the primary purpose of planting trees in landslide-prone areas?

- A) To provide shade
- B) To enhance soil fertility
- C) To stabilize the soil with deep root systems
- D) To increase wildlife diversity

Answer: C) To stabilize the soil with deep root systems

3. Which tree is often used in shelterbelts to reduce wind erosion?

- A) Eucalyptus (*Eucalyptus* spp.)
- B) Red Maple (*Acer rubrum*)
- C) Black Locust (*Robinia pseudoacacia*)
- D) Douglas Fir (*Pseudotsuga menziesii*)

Answer: A) Eucalyptus (*Eucalyptus* spp.)

4. What is a key benefit of shelterbelt plantations?

- A) They are only decorative
- B) They prevent soil erosion and protect crops from wind
- C) They attract pests
- D) They require high maintenance

Answer: B) They prevent soil erosion and protect crops from wind

B. True/False Statements

1. *Casuarina* trees are suitable for planting in coastal sand dune areas.
Answer: True
2. Trees planted in landslide areas do not contribute to soil stabilization.
Answer: False
3. Shelterbelts can enhance biodiversity by providing habitat for various species.
Answer: True
4. All tree species are effective in preventing erosion in sand dune areas.
Answer: False
5. Eucalyptus trees can be used in shelterbelts due to their rapid growth and ability to withstand wind.
Answer: True

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1. ["coast". *The American Heritage Dictionary of the English Language* \(5th ed.\). HarperCollins. Retrieved 2024-07-19.](#)
2. [^ "coastline". *Merriam-Webster.com Dictionary*. Merriam-Webster. Retrieved 2024-07-19.](#)