UTTARAKHAND OPEN UNIVERSITY
Teenpani Bypass Road, Transport Nagar, Haldwani - 263 139
Phone No. : (05946) - 286002, 286022, 286001, 286000
Toll Free No. : 1800 180 4025
Fax No. : (05946) - 264232, email : <info@uou.ac.in>
http://www.uou.ac.in

Plantation Forestry

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

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

FR 07

Plantation Forestry

Department of Forestry and Environmental Science
School of Earth and Environmental Science
Uttarakhand Open University

Board of Studies

Compilation by

Department of Forestry and Environmental Science, (SoEES),
Uttarakhand Open University

Cover page design

Krishna Kumar Tamta, Beena Tewari Fulara, H.C. Joshi

Printed at: Uttarayan Prakashan, Haldwani, Nainital (Uttarakhand)

Table of Contents

Unit 1: Plantation:

Unit Structure

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 Gershenzon 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 internationalisation 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 industry. Earning from export of plantation crops accounts to 27% 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-scaleindustrial 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, witheven age class and regular spacing. Usually smallscale 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:	Managed forest stand, established primarily to provide environmental stabilization or amenity value, by planting or/and

windbreaks, soil protection and erosion control, wildlife management, site reclamation or amenity	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.

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.

4) Planning site description:

a) **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.

b) **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.

c) **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.

d) 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.

You are not finished 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: (IIPO 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 organisation 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.

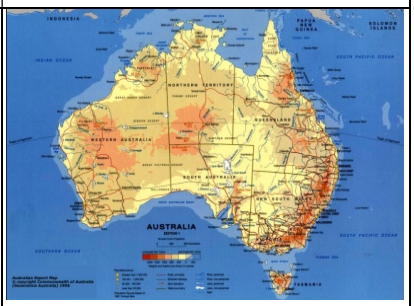
1.6.1: Characteristics of a map

1. All objects in the map are in the same relative position as on the ground.
2. All angles between the lines drawn on the map are equal to the angles between corresponding lines on the ground.
3. Each map has specific scale.
4. Information in the map is depicted in the form of signs or symbol.

1.6.2: Types of a Map

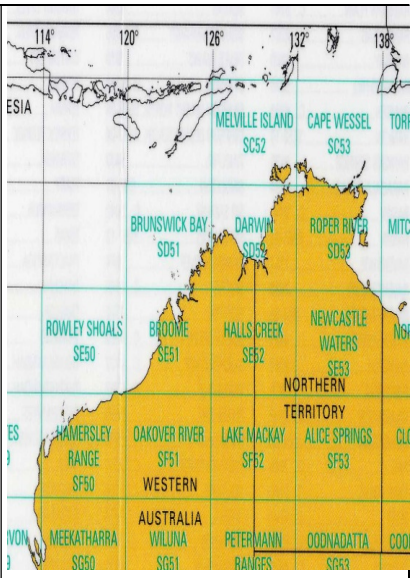
- There are many different types of maps, which are usually classified according to what they are attempting to show. However, it must be noted that there are many different ways to interpret the types of maps. One common point of view is that there are two main types of maps:

- 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).

Types of Map	Example
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.	

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.

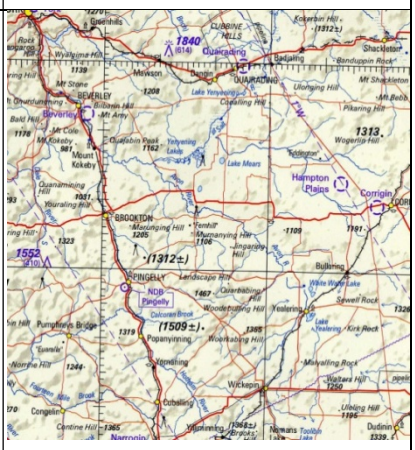
- They show elevation using contour lines.
- they have an emphasis on showing human settlement (roads, cities, buildings etc), but may include some thematic information such as vegetation or the boundaries of national parks
- they are typically produced by government agencies
- they have well defined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



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.

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 defence 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.



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 the 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.

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.

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).

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:

1) 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.

2) 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.

3) 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.

1.7. Summary

Table 3. Assessment by FSI:

Cycle of Assessment	Year	Data Period	Sensor	Spatial Resolution	scale	Minimum Mappable Unit (ha)	Mode of Interpretation
First	1987	1981-1983	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
twelth	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

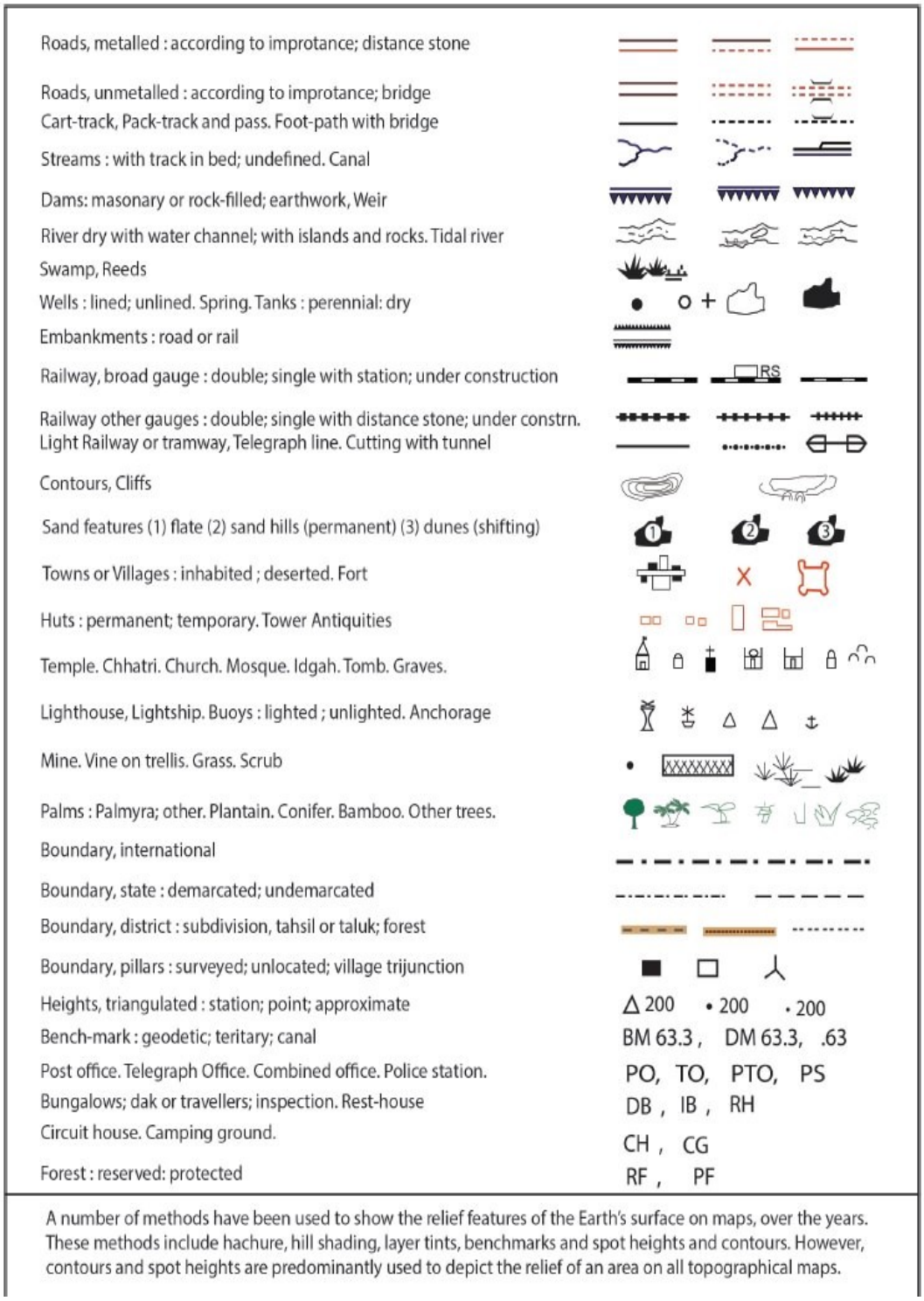


Figure 1: different conventional signs and symbols

References:

- Food and Agricultural Organisation of the United Nations (2005) Proceedings fao advisory committee on paper and wood products. Forty-sixth Session, Vancouver,Canada. http://www. fao.org/docrep/009/j7552e/j7552e00.htm , 2018.
- Food and Agricultural Organisation of the United Nations (2010) Global forest resources assessment 2010, main report. FAO forestry paper no. 163; Food and Agricultural Organisation of the United Nations, Rome, Italy, p 378. http://www. fao.org/docrep/013/i1757e/i1757e.pdf. Accessed on 29 Aug 2018
- Food and Agricultural Organisation of the United Nations (2016) Global forest resources assessment 2015. How are the world's forests changing? Second Edition, Food and Agricultural Organisation of the United Nations, Rome, Italy, p 56. http:// www.fao.org/3/a-i4793e.pdf. Accessed on 29 Aug 2018
- Clean India,"Tips on Tree Planting", [Online] Available: http://www.cleanindia.org/resoucewatch/tree_plantgtips. htm
- Clean Earth Movement,"Tree Plantation", [Online] Available: http://www.cleanearthmovement.com/index. php?option=com_content&view=section&layout=blog&id =5&Itemid=56
- Plant a Tree India, [Online] Available: http://plantatreeindia. org/
- "Economic Importance of the Plantation Sector in Kerala", Chapter 4, [Online] Available: http://shodhganga.inflibnet. ac.in/bitstream/10603/547/12/13_chapter%203.pdf
- Kishor Goswami, Jitu Saikia, Hari Kanta Choudhury, "Economic Benefits and Costs of Jatropha Plantation in North-East India", [Online] Available: http://ageconsearch. umn.edu/bitstream/109423/2/10-K-Goswami.pdf
- "Importance of trees", [Online] Available: http://newshopper. sulekha.com/tree-plantation-benefits.htm
- Julian Evans,"Plantation Forestry in the Tropics: Tree Planting for Industrial, Social, Environmental, and Agroforestry Purposes", Oxford University, 1992.

UNIT 2: SEED SOURCE AND SEEDLING ESTABLISHMENT:

Unit Structure

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.

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.

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.

1. 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 radicle and plumule which are enclosed in coleorizha and coleoptile respectively. The single cotyledon is known as scutellum. Aleurone 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.

2. Dicot seeds / Dicotyledons

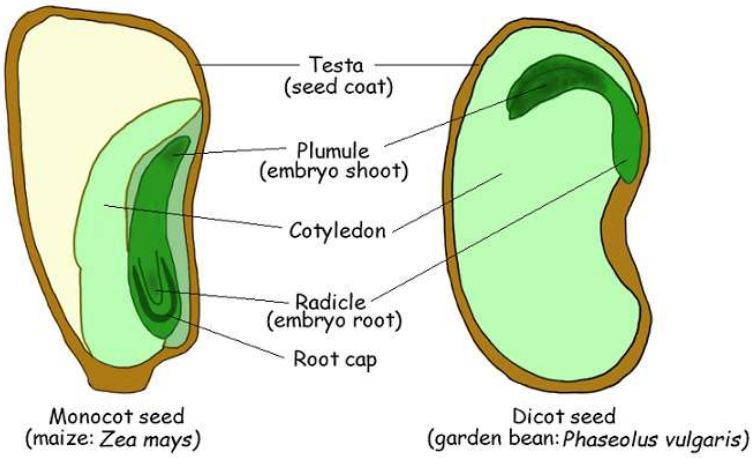
The dicot seeds consist of primary axis and a living storage tissue, the cotyledons which combine the embryo of the seed. This embryo is enclosed in the seed coat. Mostly dicots do not have endosperm which is fully utilized for the development of embryo. Sometimes they have well developed endosperm (castor, fenugreek) and mostly they are exendospermous or exalbuminous in natutre (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.

COMPONENTS OF SEED

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.



Seed structure

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, radicle and cotyledon. The plumule and radicle without the cotyledon is known as primary axis.

Radicle

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 coleorhiza.

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.

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.

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.

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.

Awn
The thorns like projection at tip of the seeds. (e.g) paddy- the bract tip is elongated into the awn.

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.

Micropyle
The point where the integuments meet at the nucellar apex is referred as micropyle.

Chalaza
A region of integumentary origin and attachment opposite to micropyle is called chalaza.

Raphe
The area between the micropyle and chalaza is the raphe. The raphe may be visible on the seed coat of some species.

Caruncle
It is the white spongy out growth of the outer integument in the region of the micropyle seen in some species e.g. castor, tapioca.

Aril
It is the coloured flesh mass present on the outside of the seed e.g. nutmeg.

Hairs
They are the minute thread like appendages present on the surface of the seed e.g. cotton.

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.

PARTS OF NORMAL SEEDLING

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

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.

Shoot
The part of the plant growing above the ground is known as shoot. It develops from the plumule of the embryo.

Epicotyl
The portion of the shoot above the cotyledons

Hypocotyl
The region of shoot below the cotyledon and above the root.

Coleoptile
It is the cover that protects the plumule and helps in its emergence. It also helps in elongation of the cotyledons in monocot.

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

The importance of seed is as follows:

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. **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.

3. The principal means to secure crop yields in less favourable 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.

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 seed zone 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 loses 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 specially 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, germplasm 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. weather 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, and
- 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 to select 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 labelling 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 (synchronised 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.

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.

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.

2.6.1. 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 .

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.

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.

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 generate much heat as well as thermophilic fungi that can kill the seeds.
- seeds should be completely dried and labelled before putting them for storage under speciesspecific 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 categorised into following three groups on the basis of their harvesting and collection behaviour:

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 speciesspecific 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 behaviour 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. 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 loose 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 :

Seed Lot

A seed lot is defined as a specified quantity of seeds of reasonably uniform quality from a particular geographic source.

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 X 100 = 80%

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 :

No. of seeds per kg. = 10,00,000 /1000 seed weight in gm.

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 overdrying can make them non-viable. It can be determined by drying of l0g 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.

MC% = Original wt. of seed - oven dry wt. of seed/ Original wt. of seed X 100

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 length-wise 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 destroys by insects, birds and rodents. The others germinate provided they are deposited on suitable soil. Germination of seed depend 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.

(a) Size of seed-The size of seed, aflects natural segeneration because while very minute seeds are washed away with the rain water, very big seeds do hot get properly covered) Viability-Viability is defined as' the potential capacity is a specific character and is decribed by the number of seeds gramme or kilogramme.

The size of the seeds varies not only from tree to tree in the same species bat 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) Germinative capacity and germinative 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 germinative capacity and germinative energy of the seeds of the species, Germinative capacity is defined as' the percentage, by number, of seeds in a given sample that actually germinate, irrespective of time '.

Germinative 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) '.

(**vili) 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. These are:

(i) Moisture: -An adequate quantity of moisture is very essential for germination. Moisture activates the dormant embryo and by softening the seed cost 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 radicle 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. Within this range, the higher the temperature the better the germination.

(iv) Light -Most species are indifferent to light conditions for their germination but some, e.g., Cassia fistula, *Albizzia 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.

Germination per cent: Germination percent is an estimate of the viability of a population of seeds. Germination percent is the ratio between total number of seed germinated to the total number of seed sown in all replications multiplies by 100. It is expressed in %.

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

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 then germination percent.

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 undecomposed 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.,

(i) Due to deficiency of air as is seen in case of teak whose seedlings die as a result of poor Soil aeration resulting from waterlogging, and

(ii) 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 temperature 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 monsoonic 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 favours 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 crosion 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.

Dying Back Of Seedlings:

In some species, the shoot portion of seedlings keeps on dying year after year while the root remains alive. Results in keeping back the progress of the seedlings towards establishment because 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. 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:

(i) 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.
(ii) Favorable conditions for the germination of seeds.
(iii) Favorable conditions for the development and establishment of seedlings.
(iv) 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.
(v) Protection against all kinds of injuries.
(vi) Tending! during most part of the life span of crop
(vii) Control over mixture

Summary

References

1. Beniwal, B.S. and Singh, N.B. (1985). Observation on flowering, fruiting and germination behaviour of some useful forests plants of Arunachal Pradesh. Indian Forester (4): 216-227.

2. Khullar, P., Thapliyal, R.C., Beniwal, B.S. Vakshasya,, R.K. and Sharma Ashok (1991). Forest Seed. Indian Council of Forestry Research and Education, Dehradun. 409 p.

3. Willium, R.L. (1984). A guide to forest seed handling with special reference to tropics. Danida Forest Seed Centre, Denmark. Erratum Back cover Altingia excelsa = Canarium strictum.

4. Khanna, L. S. 1981. Principles and Practice of Silviculture. Khanna Bandhu, dehradun.

UNIT 3: Nursery Management:

Unit Structure

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 seedlings produced 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 is 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.

Definition

"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 raising of seedlings for one or two years. It is non 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. Inspite 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 unfavourable the inspection may be difficult, the labour 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 favourable 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 unpliable 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 metalled and tarred roads have not been developed.
- The rab nursery or semi-rab nursery made generally for teak rootshoots is a kind of temporary nursery for small plantation area which also gives stock for casuality

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, labour 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. 27

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 which 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 resists 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 require 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.

3.4: 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 to 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.

3.4.1: 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.

3.4.2: Protection of the Nursery Area

Forest nurseries to be protected against outside influences such as grazing damage by domestic and wild animals. For this purpose. 30 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.

3.5: 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 labour or mali can reach up to the middle for weeding and other purpose. The standard beds are of size 12.2m ? 1.2 (40ft ? 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 sunked 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 2030 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 leas 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).

Figure 1: Two types of raised beds. Bed A is best suited to high-rainfall areas. Bed B has a lip around all 4 sides which helps prevents prevent water from running off (helpful in drier conditions).

(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.

Figure 2: A sunken bed. Depth shouldn't exceed about 4 cm.

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 let 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.

3.6: 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.

Different methods of Sowing

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;

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.

2. 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.

3. 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.

4. 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.

5. Planting

Planting is the placing of seeds or propagules firmly in the soil for germination and growth.

6. 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 a optimum depth of sowing for a combination of particular and soil which need to be determined by experiment.

3.7: 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.

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.

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.

3.8: 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^{0}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.

3.9: Shading

The shading over nursery beds are 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 (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.

3.10: Watering and damping off

3.10.1. 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. Over irrigation increases 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 a 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 45^0C. 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.

3.10.2. 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 *Phytophora, 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, increasing the soil temperature, application of high nitrogen doses and addition of raw undecomposed humus favour 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 an 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, Rhizoct onia, Cylindroclc lium* and *Sclerotiutn*. 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 :

1. **Proper selection of site.** The site should be slightly acidic and loamy. If the soil is neutral or alkaline, it may be acidifed by adding sulphur, aluminium sulphate, concentrated sulphuric acid or ammonium sulphate fertilizer.
2. Nursery soils should be maintained dry throughout. During sprouting watering should be kept to the minimum.
3. Sowing density should be reduced and seedlings should be thinned to create better aeration.
4. 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.
5. **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:

(a) By placing the nursery soil under running steam in an autoclave or closed container for few hours.

(b) The perforated pipes are laid through nursery beds and steam is allowed to pass through them.

6. **Use of chemicals :** The following chemicals are used to disinfect the nursery soil:

a) Formalin : A sloution of 38% formaldehyde diluted in water is prepared and 300 ml of formaline per sq. m. of seed bed is enough for controlling damping off. It should be applied 8-10 days before sowing of seed.

b) Methyl bromide : It is applied 15-20 days in advance of sowing. After applying the beds are covered with thick polythene sheets.

c) Brassicol : Fumigation with formaline is done in fir and spruce nurseries in Himachal Pradesh.

d) 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).

7. Overhead shade should be avoided on wet soils.

3.11: 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:

(i) Circular/square weeding

(ii) Strip weeding

(iii) Complete weeding.

The following kinds of weeding are recommended for the plantations:

I year plantation:

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

II year plantation

(a) First weeding - strip weeding (July - Aug.)
(b) 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 weedings are timely and properly done, the third is seldom necessary but it may always be beneficial to the plants. The weedings in the second year depend on the success of the first year weedings. The first weedings 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 labour for first year and second year plantations. If the same gang of labour 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.

3.12 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 though 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 is 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 pricking 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 showel. 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 transplanting 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.

3.13: Plant containers

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:

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.

Dona: Dona is made up of leaves which are larger in size like *Bauhinia vahalii*, *Techtona 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.

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 earthern 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. Earthern pots are heavy, fragile and expensive. They are rarely used now.

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.

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
Tub size pots	35	50	90.00

Polythene bags: Polythene bags has revolutionized the nursery production. It 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, 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.

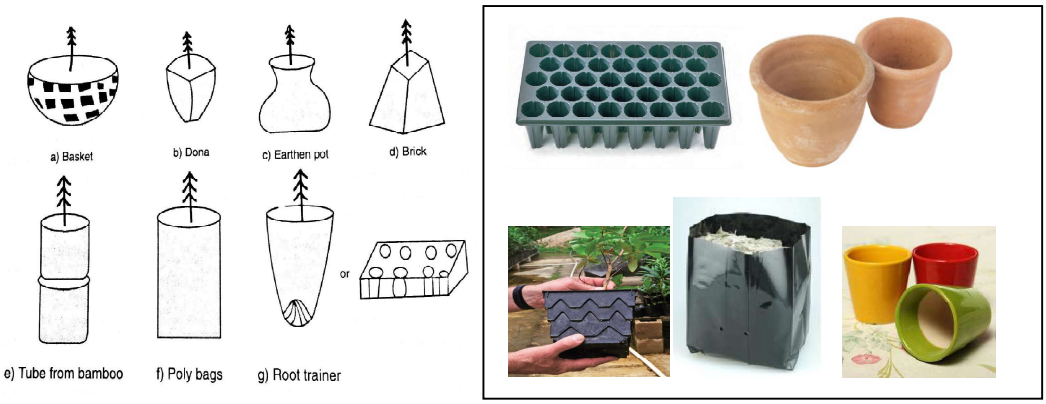
Root Trainers: In all the above mentioned containers a problem of root coiling is observed. This condition is not good for survival of seedlings when out planted in field. To overcome this, root trainers were designed. These can be cubical, cylindrical or of any desired shape. These are usually made 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.

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.

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.

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.



a) Root trainers b) Clay pots c) Root maker container d) Ploybegs e) Plastic pots

Figure 3: Different kinds of plant containers used in nursery

3.14: 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 respires, 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.

3.14.1. 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.

3.14.2. 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.

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.

1. Endosperm development
2. Embryogeny

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.

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 coleorhiza. A portion of the embryonic axis, which is located above the scutellum is called epicotyl. Epicotyl consists of shoot apex and coleoptiles.

3.14.3. 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.

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.

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.

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.

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.

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.

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.

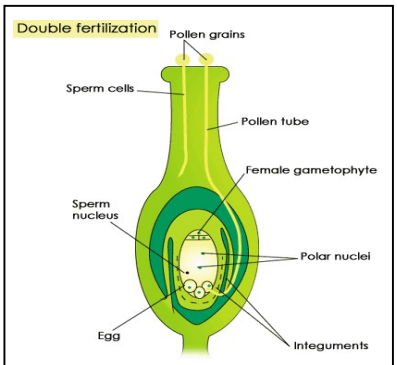


Figure 4: Double fertilization

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.

3.15: Micro-Propagation and Misting Units

3.15.1. 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**.

1. Selection of mother plant
2. Multiplication
3. Rooting and acclimatizing
4. Transfer new plant to soil

1. Selection of mother plant

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

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

2. 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.

3. 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 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.

Figure 6. Banana plantlets transferred to soil (with vermicompost) from plant media.

4. Transfer from culture

In the final stage of plant micropropagation, 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.

Methods

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 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]

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

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.

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.

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.

Advantages

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.

Disadvantages

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.

3.15.2. Mist chamber

Figure 8: 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.

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.

3.16. References

1. **^** *"Micropropagation - Definitions from Dictionary.com". dictionary.reference.com. Retrieved 2008-03-17.*
2. **^** *Chugh, Samira; Guha, Satyakam; Rao, I. Usha (2009-11-03). "Micropropagation of orchids: A review on the potential of different explants". Scientia Horticulturae.* ***122*** *(4): 507–520. doi:10.1016/j.scienta.2009.07.016. ISSN 0304-4238.*
3. **^** *"Frederick Campion Steward" (PDF). Cornell University Faculty Memorial Statement. Archived from the original (PDF) on 2012-04-02.*
4. **^** *Wilms, Hannes; De Bièvre, Dries; Longin, Kevin; Swennen, Rony; Rhee, Juhee; Panis, Bart (2021-09-15). "Development of the first axillary in vitro shoot multiplication protocol for coconut palms". Scientific Reports.* ***11*** *(1): 18367. doi:10.1038/s41598-021-97718-1. ISSN 2045-2322.*
5. **^** *Naing, Aung Htay; Kim, Si Hyun; Chung, Mi Young; Park, Soon Ki; Kim, Chang Kil (2019-04-13). "In vitro propagation method for production of morphologically and genetically stable plants of different strawberry cultivars". Plant Methods.* ***15*** *(1): 36. doi:10.1186/s13007-019-0421-0. ISSN 1746-4811. PMC 6461810. PMID 31011361.*
6. **^** *Salokhe, Shubhangi (2021-06-01). "Development of an efficient protocol for production of healthy sugarcane seed cane through Meristem culture". Journal of Agriculture and Food Research.* ***4****: 100126. doi:10.1016/j.jafr.2021.100126. ISSN 2666-1543.*
7. **^** Maciej Hempel, M. Хемпел & M. Хемпел (1986) Some Economical Aspects of Commercial Micropropagation, Biotechnology & Bioindustry, 1:5, 22-26, DOI: 10.1080/02052067.1986.10824247

Unit 4: Plantation establishment:

Unit Structure

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. Having selected the land the various

informations pertaining to land viz: soil type, soil depth, slope, site quality, neighbouring 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:

1. Decision regarding area to be planted and area to be left unplanted for protection, conservation, research or other purposes.
2. Selection of species for different patches or zones of area.
3. Determining type of site preparation required for different areas.
4. 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 abd approach roads etc.

(vi) Rights of access, grazing rights, collection of minor forest produce etc.

4.2: Selection of site

The selection of site are depending on the following criteria:

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

(iii) The participation of local labour should be enough facilities should be made available to the labour.

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 marketingof the nursery stock.

The selected site should preferably be near the highway orat 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: The 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 salinityand 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 soiland irrigation water leads to salt injury resulting in nutritionaldeficiencies, marginal browning of leaves and in acute cases deathof 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 oneper 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 landrequired 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 aboutone lakh mango grafts at least 2 hectares of nursery land is required.

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:

1. Allow equidistance for each tree for uniform growth.
2. Allow easy orchard operations like cultivation, intercropping, irrigation, spraying of plant protection chemicals and growth regulators, harvesting etc.
3. Proper utilization of orchard space avoiding wastage of land.
4. Help in proper supervision and management of the orchard.
5. Aloe 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. By doing 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 alsohave 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 theground 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

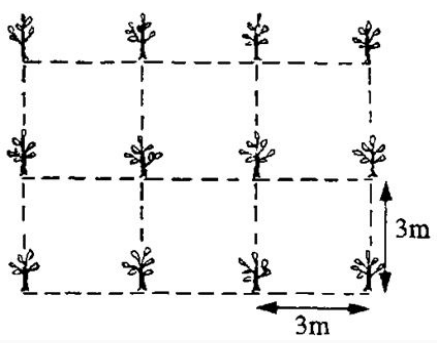
4.3.1.8: Potting Mixture and Potting Yard

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, vermicompost, 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



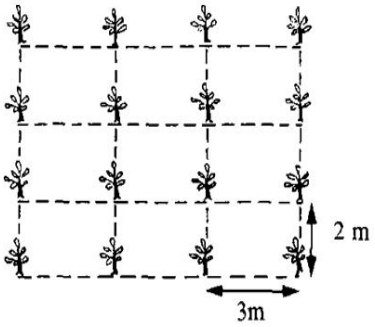
This system is considered to be the simplest of all the system and is adopted widely. In this system, the plot is divided into squares and trees are planted at the four corners of the square, in straight rows running at right angles. While laying out the plot a base line is first drawn parallel to the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

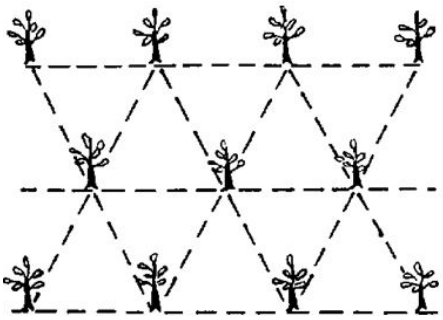
4.4.2 Rectangular system

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.



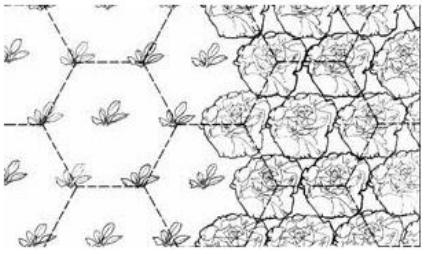
4.4.3 Triangular system

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

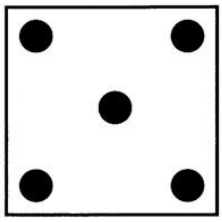
In this system, the trees are planted at the corners of an equilateral triangle and thus, six trees from a hexagon with the seventh tree at the centre. This system is generally followed where the land is costly and very fertile with ample provision of irrigation water. Though 15 per cent more trees can 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

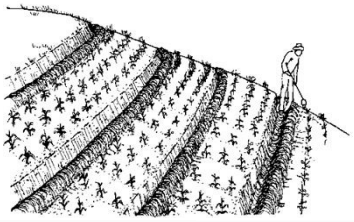
position of a tree in the second row. This row is then used as the base line and pegs are set in the third row. In this way entire plot is laid out.

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

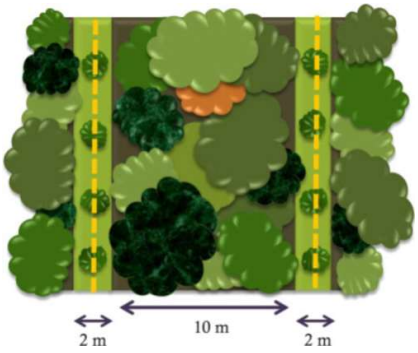


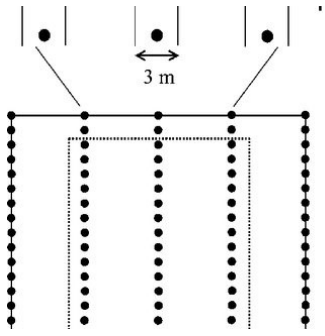
It is generally followed on the hills with high slopes. It particularly suits to a land with undulated topography, where there is greater danger of erosion and irrigation of the orchard is difficult. The main purpose of this system is to minimize land erosion and to conserve soil moisture so as to make 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. Number of Plants Required in Different Pattern of Planting:

Number of plants required per hectare under different planting patterns can be calculated by the formulae given below, 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.

Line planting: In line planting, plants are planted at some spacing in lines. Thus, the planted plants form rectangles.





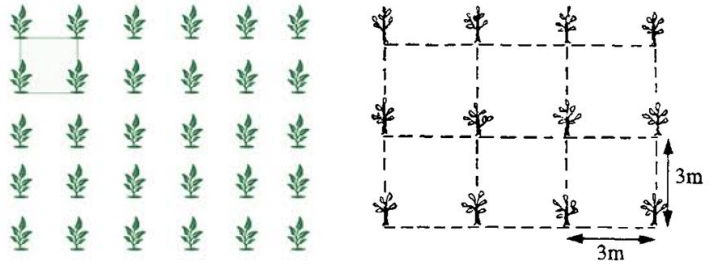
Number of plants = $\frac{100 \text{ X } 100}{Distance\ of\ plants\ in\ lines \text{ X } distance\ between\ the\ lines}$

In Line Planting (2x4 meter)

Number of plants = $\frac{100 \text{ X } 100}{Distance\ of\ plants\ in\ lines \text{ X } distance\ between\ the\ lines}$

Number of plants = $\frac{10\ X100\ X\ 100}{2x4}$ = 12,500 plants

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 trees are planted at the four corners of the square, in straight rows running at right angles.



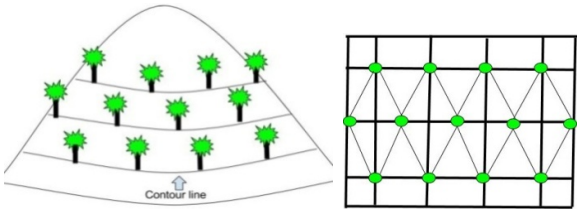
Number of plants = $\frac{100 \text{ X } 100}{(Planting\ distance)2}$

In Square planting (2.5x2.5 m)

Number of plants = $\frac{10\ X100\ X\ 100}{2.5\ X2.5}$ = 16,000 plants

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.

Number of plants = $\frac{100 \text{ X } 100 \text{ X}1.155}{(Planting\ distance)2}$

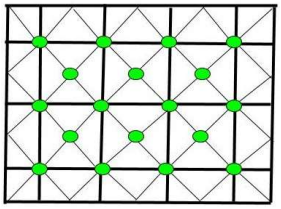


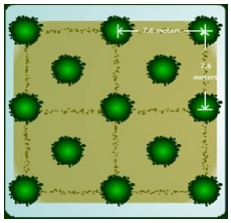
In triangular pattern 2.5 m apart

Number of plants = $\frac{10\ X100\ X\ 100X1.155}{2.5\ X2.5}$ = 18,480 plants

Quincunx planting: This system of planting 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 and early maturing.

Number of plants = $\frac{2\ X\ 100\ X\ 100}{Distance\ \ between\ plants\ in\ row\ or\ column}$





Quincunx planting (2. 5 x 2.5 with a plant in center of each square)

Number of plants = $\frac{10\ X\ 2\ X\ 100\ X\ 100}{2.5\ X2.5}$ = 32,000 plants

4.6. 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.

Season of Planting:

Planting seasons varies with the species and the commencement of monsoon, Teak and sisso 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:

i. **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.

ii. **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.

iii. **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.	*Shorea robusta, Tectona grandis Acacia catechu, Dalbergia sisso, Eucalyptus spp. Populus spp.*	Maize, paddy, sorghum, pigeon-pea, soyabean, wheat, barley, chick-pea, rape-seeand miscellaneous
Andhra Pradesh (AP)	*Anacardium occidentale, Tectona grandis, Bombax ceiba, Bamboo, Eucalyptus spp.*	Hill paddy, groundnut, sweet potato
Kerala	*Tectona grandis Bombax ceiba Eucalyptus spp.*	Paddy, tapioca, ginger, turmeric, etc.
Assam	*Shorea robusta, S assamica*	Paddy
Tamil Nadu	*Tectona grandis, Santalum album Tamarindus indica, Acacia nilotica Acacia mearnsii ,Ceiba pentandra Cashew, Rubber, Bamboo*	Millet, pulses, groundnut, cotton
Andaman and Nicoba Islands	*Pterocarpus dalbergioides*	Sugar-cane, maize
Maharashtra	*Tectona grandis, Acacia nilotica*	Sunhemp, jute, mesta, sunflower, castor etc.
Tripura	*Shorea spp., Schima spp., Michelia spp.*	Paddy, maize etc
West Bengal	*Tectona grandis, Shorea robusta Schima wallichii, Cryptomeria*	Paddy, maize, millets,

	japonica, Quercus spp. Michelia doltsopa	turmeric, ginger, lady's, finger, pineapple, sunhemp
Karnataka	*Tectona grandis, Santalum album, Cassia siamea*	Paddy, tapioca, etc.

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.

DISADVANTAGE OF THE 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:

1. Frequent flowering.
2. Easy nursery handling.
3. High germination rate.
4. Fast height growth in early stages.
5. Tolerant to drought and site competition.
6. High survival rate.
7. Naturally self pruning.
8. Normally free from all types of insect and diseases.
9. Rapid growth in girth.
10. Producer of timber of high quality.

4.9. Nurse and cover crops

NURSE CROP:

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.

4.10. 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.

References:

Unit 5: Choice of species for plantation on ecological aspects:

Unit Structure

5.0 Learning Objectives

On completion of this unit you should be able to understand

- 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 silvic6ultural 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, panelled products, hardboards, plywood, packing cases, furniture, match sticks, lac cultivation, tussor silk production etc.

(b) Domestic uses: Poles, Fuelwood, 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:

1. Selection of species according to ecological zones.
2. Technique of plantation viz. polypot planting, root shoot planting etc.
3. Influence of wind breaks on crop production.
4. Silvipastoral systems to create grazing reserves. etc.
5. Yield of timber, fuelwood, resins, gum, lac, bamboo, rubber, etc.
6. Management of species for leaf fodder, fruits, flowers etc.

7. Ease of establishment and growth rate.
8. Coppicing ability.
9. Resistance to pests and diseases.
10. 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, Albizzia 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.

1. To meet the needs of fuel wood, fodder, small timber and other minor forest produce.

2. To release the cow-dung as a manure for increasing agriculture production.

3. To provide gainful employment opportunities to the rural masses.

4. To develop cottage industries in rural areas.

5. To utilize all available land according its productive capacity to the best advantage.

6. To provide efficient soil and water conservation.

7. To improve the aesthetic value of the area and to meet recreational needs of the people.

8. 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 belowfreezing 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 m 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, Poplus alba, P. ciliata, P. deltoides, P. nigra, Purnus persica, P. domestica, P. padus, Quercus species, Salix species, Toona serrata and Ulnus 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. polycarpos, 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 totalclimate February to combinedabout rainfall is 6250mm with is equitableand typically a and well or its even distributed the seasonal is driest more. conditioned month. rainfall The distributionsouth-west Rainfall from by the both monsoon varies varies mountain the monsoons. fromconsiderably.gives situation1500mmrain 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 zoneisroughly 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.

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 varia- tion is from 15^0C to about 25^0C. 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 pennisular 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 22^0C to 27^0C. In north India temperature goes down to 10^0C compared with a typical 2000mm figure of to 16^0C 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, Schleichera 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, Albizzia amara, A. lebbek, Azadirachta indica, Cassia fistula, C. siamea, Dalbergia sissoo, Emblica officinalis, Ficus species, Leucaena leucocephala, Pongamia pinnata, Santalum album, Syzygium cumini, Terminalia belerica, Techtona 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 50^0C, 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.

Soil Preperation:

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.

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, Albizzia lebbek, Holoptelia integrifolia, Ailanthus excels', Ziziphus, Pongamia, Cassia fistula, C. siamea, Azadirachta indica, Casuarina, Eucalyptus, Prosopis juliflora, P. cineraria, Anacardium, Pterocarpus santalinus, etc.

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.

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 mdeep 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.

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 ehak 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 thebottom and 30 cm deep. The trenches are about 27 m lo ng, 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 dug out 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.**

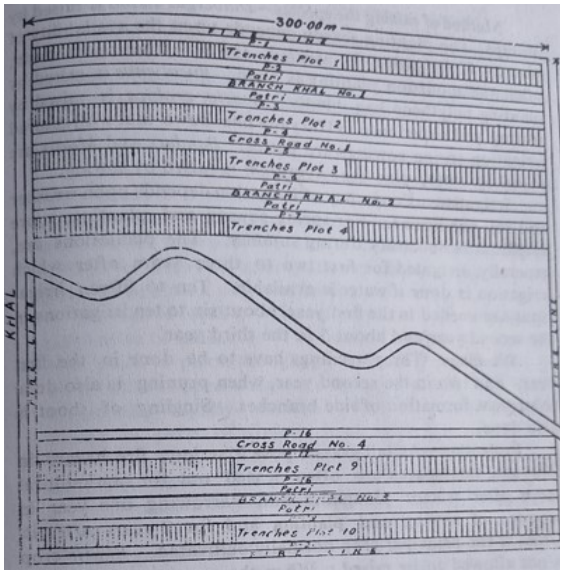


Fig. 1. Plan of irrigation channels in a compartment. Pi, P2, etc., stand for pasel serial numbers.

Choice of species— It depends upon climatic and soil conditions. The existing vegetation gives a good indication of the soil condition ana 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 planta-tions. It would be better to raise mixed plantations of *Acacia arabica, Bornbax ceiba, Morus, Syzygiuni, Eucalyptus*.

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.

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.

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 hactare (active ingredient) effected complete control of all above ground vegetation for the season. The weedicides were applied by Backpak 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 is 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 spread-ing or not, there are indications of fresh depositions of sand in the north east. It is, therefore, necessary not only to con-tain the movement of the desert sand to north east but also to immobilize it inside for the betterment of the people Factors of Locality—Ciimate is characterized by great of the area. m extremes of temperature. During the sumer,

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 ram 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

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 bard vesicular structure make it unfavourable for plant growth. Pressure of grazing is heavy.

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 labour. 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.

Choice of species -The most suitable species are *Acacia auriculaeformis, Eucalyptus hybrid, Madhuca latifolia, Pteros carpus marsupium, Shorea robusta and 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 affeeted 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 can not 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 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) max-imum retentivity 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

Height increment (cm) of different species on sodic soil

Soil treatment	*Acacia arabica*	*Albizzia lebbek*	*Eucalyptus* hybrid	*Prosopis juliflora*	*Terminalia arjuna*
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

mounds are made. On the basis of an experiment on calcareous lkali 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. Application of a small doze of nitrogenous and phosphatic fertilizers was found to improve the results further.

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 K 8 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 succesfully affores-ted by planting suitable species in pits with soil amendments like gypsum or farm yard manure. Such areas can serve as good firewood and foddar reserves. But soil with pH varying from 8.5 to 11 usually associated with poor drainage and a kankar pan, 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.

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.

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.

Soil preparation—As the so iA 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 in X 1 .8 m to 3.6 m x3.6 ru 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 espacetnent is reduced to even 1 m m with the definite object of creating a shelterbelt. Though pitting is the usual practice, tractor ploughing is also done in certain areas of Tamil Nadu.

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 pallisade 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, Ipornea, etc. If sane di tit 1 • not a problem, as in areas behind an old plantation or a created sheiterbeit, pallisading or immobilization of sand is not necessary. Casuarina is usually planted with naked roots, but some-times, 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 tem-porary

wells per hectare are dug in the plantation area. The watering is generally done from December to June, once or twice a week.

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

INLAND RIVER SAND

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

Factors of locality—The soil is sandy, unstable, and deficient iv 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. 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.

Soil preparation—Soil preparation consists of digging trenches and pits.

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

Method of raising plants—As the soil is shifting loose sand, it has first to be immobilized by planting grasses; Eulaliopsis binata (baib grass), and Saccharurn 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.

5.5. Summary

Unit 6: Plantation maintenance:

Unit Structure

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 galvanised 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, butis 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 m^3 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 m^3 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 tresspass. 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 thisproblem baffle walls are retained within the trench at appropriate intervals, so as to help arrest the sudden flow of rain water and thereby minimising its adverse scouring effect. The TCM also serves as a water-trap on slopy areas. The baffle walls are made triangular in cross section having height of 0.30 m, but it should not allow cattles 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 in 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 preplanting 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 recoupe 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 the rubbles 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.

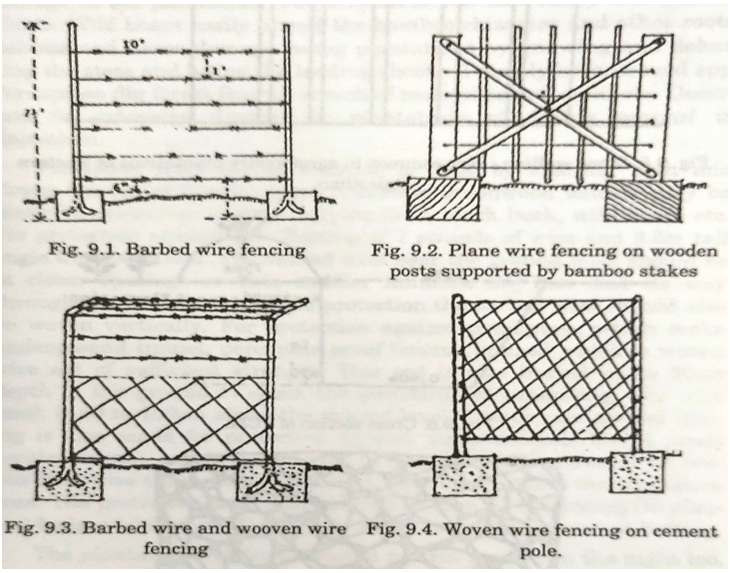


Fig. 9.1. Barbed wire fencing

Fig. 9.2. Plane wire fencing on wooden posts supported by bamboo stakes

Fig. 9.3. Barbed wire and wooven wire fencing

Fig. 9.4. Woven wire fencing on cement pole.

Fig. 1: Different kinds of fencing

(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.

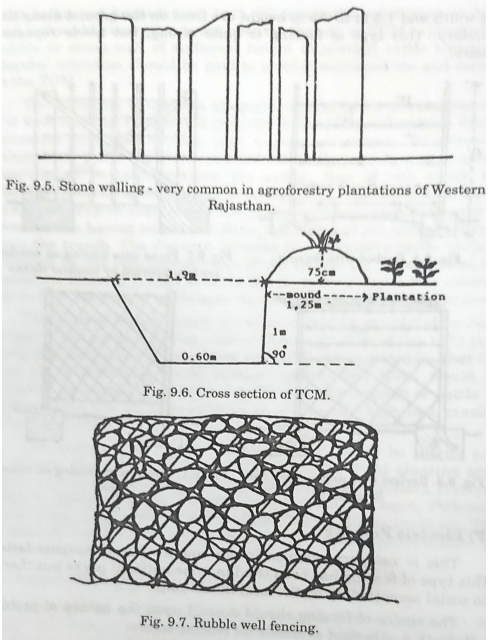


Fig. 9.5. Stone walling - very common in agroforestry plantations of Western Rajasthan.

Fig. 9.6. Cross section of TCM.

Fig. 9.7. Rubble well fencing.

Fig. 2: Different kinds of fencing

(G) Combined Fencing

Such type of fencing is node by combining two or more types of fencing e.g. (1) TCM and barbed wire(ii) live hedge andstone (iii) barbed wire, live hedge and TOM 6v) barbed wire and wooven 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:

(a) 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.

(b) Saucer Pit

For making saucer pit, the pit is dug but the area around pit is scrapped to form a shallow saucer of lm 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.

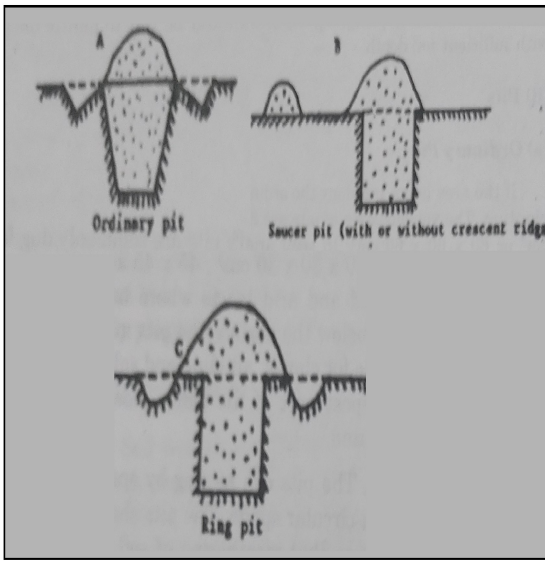


Fig. 3 Types of Pits

(c) 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 maxim[Type a quote from the document or the summary of an interesting point. You can position the text box anywhere in the document. Use the Text Box Tools tab to change the formatting of the pull quote text box.]

um 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. Irrigati 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 utilisation 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.

FERTILIZER APPLICATION IN PLANTATION

Application of fertilizer to plantations are a costly affair. Application 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, *Casurina, Techtona* 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. Gene-_ rally 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,ms was found to boost up considerably the firs: year teak plantation raised in lateritic soil in Central Chancla division of Maharashtra. In the first year of plantation two or three doses of urea each of 10 grns 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, phosph-orous or potassium etc. some preliminary trials are necessary.

6.4. 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 both 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 i also impr-oved. 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. scrappin.g, 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 elimi-nated by cutting. The various implements like spade, sickle, axe, lihurpi etc. are used for this purpose. The different types of weeding are

(i) Circular/square weeding

(ii) Strip weeding

(iii) Complete weeding

The following kinds of weedings 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 weedings 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 weedings are timely and properly done, the third is seldom necessary but it may always be beneficial to the plants. The weedings in the second year depend on the success of the first year weedings. The first weedings 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 labour for first year and second year plantations. If the same gang of labour is employed in the first year and second year work the success of second year works suffer.

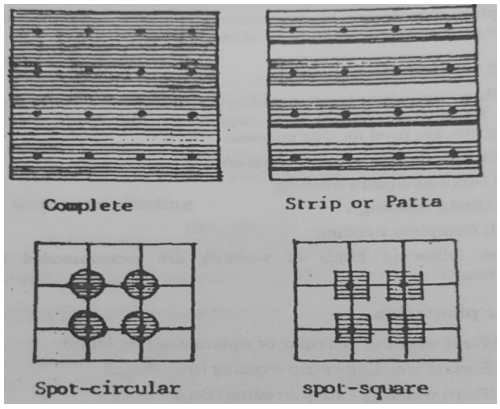


Fig. 4: Four patterns of Weedings

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 soil the weed growth is heavier.

(ii) Season: The warm and wet conditions help in weed growth.

(iii) Size of plants: When the plants are smaller more weedling is required.

(iv) Light requirement of species: The shade bearer plants can tolerate certain heavy weed growth better than the light demander species.

6.5. Climber cutting

Climber cutting should be carried out as a part of tending opearation. 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., Milletia auriculata, Smilex spp Ipornaea spp., Combreturn spp., Afikanin rordata etc. In the conifer forests. themon interfering climherq ore Maw-wren 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 creepen5 during rainy season. All climbers should be cut during monsoon period.

6.6. 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.

6.7. Singling and pruning

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 stern 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.

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 boled, 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 he 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 .

(i) Dry Pruning: Pruning of dead branches, and

(ii) 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 autornatically when the density of the crop is high. Te 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 practised. 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 tlu-ee-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 , t the basal portion is not. In thinning out the entire twig, can or shoot is removed.

Bud Prunning 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 occuladed early. This is also practised in case of Salix alba (willow) which produces timber for cricket bats. This is also practised to some) extent in conifers too. After bud-pruning the saplings which become lankly are liable to be affected by wind.

6.8. Summary

Unit 7: Protection of Plantations:

Unit Structure

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:

Frost tender - *Acacia nilotica, Azadirachta indica, Boswellia serrata, Shorea robusta, Tectona grandis, Terminalia arjuna,T. tomentosa, Dendrocalamus strictus, Callygonum polygonoides* etc.

Frost hardy - *Acacia catechu, Acacia tortilis, Anogeissus pendula, Dalbergia sissoo, Albizzia 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 tearings 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 bywind.Cold winds are responsible

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

The fast winds do considerable damage by uprooting the trees, rupturing the branches, shaking of roots, bending oftrees andkilling of branches. Winds are responsible for forming elliptic stems, wolf trees and short statured tree forms. The bamboo 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 or tuly 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 severly affected by hot sun when the temperature goes above 45?C. High temperature accompanied by drying wind in April and May is resonsible 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 stagheaded. 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 stagheadedness 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 waterlogging and high soil salinity. e.g. *Eucalyptus spp ., Syzygium cumini, Prosopisjuliflora, 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 (NH), Carbon monoxide (CO), Hydrocarbon (HC). **Secondary group** - Sulphate (SO4), Ozone (03). 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). the 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.*
Flouride indicator - *Cassia fistula, Dalbergia sissoo*.
Sulphur-di-oxide indicator - *Adina cordifolia, Buchnania lanzan, Diospyros melanoxylon.*
Combination of pollutants - *Aegle marmelos, Diospyros melanoxy lon, 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 can entirely ruinthe plantation. 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 spacings 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 tunnelling. 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 through out planting, may kill seedlings directly, or stunt or malform 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. Formation of gall, burls or tumours, abnormal swellings, hairs on leaves, witch-brooms etc.

VI. Epicormic branches - Dying of top due to fungal infection.

VII. Exudations - caused due to bacteria, gummosis, excessive out flow of resin (resinosis) etc. and

VIII. Leaf rusts.

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 excreta ions 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 are affected. The fungi Ganoderma lucidium 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.Itis also controlled by changing planting time and taking mixedplantations of susceptible and resistant species.

Similarly a sound knowledge of silviculture is necessary to select suitable site. For example, 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 clayloam 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 ie. 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 are-tectol in teak. But these extractives may degenerate due to oxidative enzymes or micro- organisms and become ineffective latter 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, Myllocerus 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.

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 todying 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 beesoni. The trees are grease-banded before March to stop breeding.

Dalbergia sissoo

It is for severly a considerable defoliated part by Placoptera of the year, reflexa hampering which makes growth or even death may occur to the tree.

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) Bettles 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.

CAUSES OF FOREST FIRE

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. Themenace 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 causesresult from human activity as well as methods of forest management. These can be intentional or unintentional, for example:

- graziers 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 inparts 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 minorforest produce. It has been estimated that 90% of forest fires in India are man-made

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.

Types of Forest Fire

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

1. 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 andit 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.

2. 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 arunning 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.

3. Crown Fire

The crown fire are deadly and occur mostly in combination with surface fire. It is of two are 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.

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 loss 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.

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.

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

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 behaviour. 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 personnels. The trained staff should keep the map of the forest area and equipments for fire fighting.

The prophylactic or preventive measures against fire includes

1. 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.
2. Selection of fire resistant species and avoiding pure stands.
3. Controlled and planned grazing to check the ability of undergrowth from catching and spreading fire.
4. 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.
5. Use of herbicides such as 2, 4-D; 2, 4,5-T
6. 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.

7. Planting of evergreen species as firebreaks. Such species are *Syzygium, Sesbania* etc.

8. 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.

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 organisation of fire fighting crew. (v) Skill in attacking and fighting the fire.

(vi) Mopping up and sufficient patrolling to check and stop the new outbreaks of fire.

If the fire is small it can beput 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 commodity, (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 triange 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 behaviour of any two forest fires are seldom alike. Each fire poses different problems due to variation in fuel types,

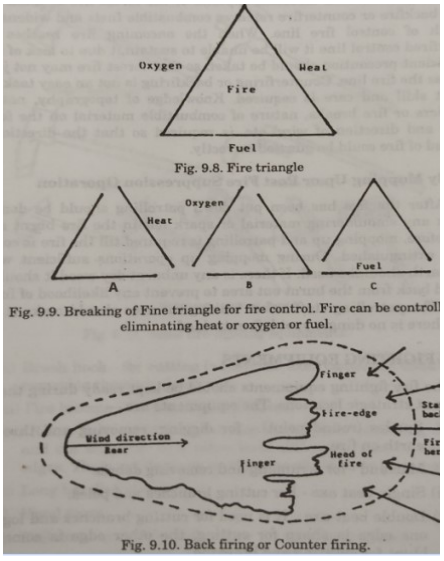


Fig 1. Back Firing or counter firing

weather, slope, nature of terrain, 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 labour 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 bushesoi 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 Counterfiring or Back-Firing:** The counterfaing 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 smouldering 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 trips are used for catching insects. To check climbing of band is tied on the tree

trunks• larvae up the tre 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• mai-formed, diseasea, wind nc,ibroken, fire damaged etc. should be removed., Resistant species such be planted. Certain species support the parasites of the erects, fame on a species should be grown to harbour parasites. The trees growing Should °u1c1 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 birder are encouraged. This method is difficult to practise because of insufficient knowledge and other constraints.

(iv) Chemical Control

Many chemicals like insecticides andpesticides are used to control the insects. They are categorised as unders:

(a) Contact poison : Lime-sulphur, MIC,Aldrex, Dieldrine, thimet, paramor, termax, Rogor, Dimecron, Aldrin.

(b) Stomach poison: Calcium arsenate, Sodium fluride etc.

(c) Fumigants-Creosote, nepthalene, bordeux mixture etc.

(d) Systemic insecticides.

7.9: Summary

Unit 8: Thinning:

Unit Structure

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 ieta) 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 fellings and also pruning, climber cutting and girdling of unwanted growth, but does not include regeneration fellings and ground operations like, soil working, drainage, irrigation and controlled-burning'.

Difference between tending and cultural operations

(1) 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.

(2) 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.

(3) 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.

(4) 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 fellings done in the area.

(5) 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.

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

8.2.1. Definition

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 number 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 lm 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.

8.2.2: 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 can not be increased by silvicultural operations, it can be distributed amongst an optimum number of trees selected on the basis of their form, quality and potentialies of growth in future by removing or felling other inferior trees. Thus, thinning results in the pro-duction 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. Thinnings achieve this object by (a) utilizing the thinned material and (b) shortening the rotation as **shown below:**

(a) Utilization of thinned material—As thinnings are started from the time the crop passes into pole stage, all the trees that would have perished in natural selection are removed in thinnings and utilized. The following table prepared from the yield tables gives the percentage of yield of thinnings to the total yield of standard as well as small wood:

Species	Age in years	Grade of thinning	Site quality	Total yield	Accumulated yield of thinnings	Percentage
Teak (Plantaion)	80	C	I	9,230	4,300	46.6
			II	7,020	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

The 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 thinnings, increases the diameter of the remaining trees, a given exploitable diameter can be reached in shorter period by heavier grades of thinnings. For example, in I quality area. according to multiple yield table, deodar reachcs 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 thinnings.

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

(5) To maintain hygienic conditions in the stand—The thinnings 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: Thinnings improve the quality of wood produced from a stand by removing trees of poor quality in favour of best trees. Quality of the wood is also improved by control-ling the rate of growth and keeping it uniform by judicious thinnings.

(7) To ensure decomposition of raw humus in temperate forests--As thinnings open 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 foresler 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 charac 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 bight 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. 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.

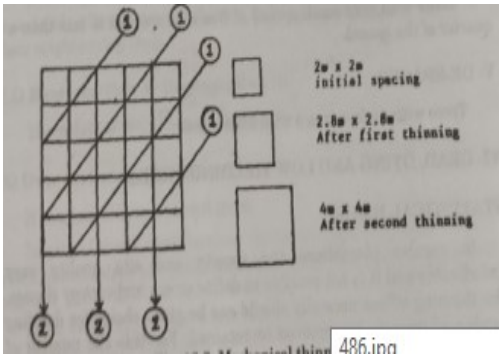


Fig 1. Mechanical thinning

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 formula 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 sissoo 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, 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 —

(a) It is useful in areas where the demand of small timber is more and have market for selling.

(b) It is most suited for light demander species eg. Teak, sal, Chirpine sissoo, semal etc.

(c) It is simple to apply and even a less trained staff can mark the trees for felling.

(d) This thinning practice improves the hygeinic condition because several diseased and insect infected trees are removed.

(e) This thinning is preferred where climber infestation is a problem but should not be carried out where there is danger of soil erosion.

(f) 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.

(g) Removal of lower crown classes help in the natural regene-ration of the species

The demerits of ordinary thinning are as below –

(h) In several areas where the thorny bushes, undesirable trees and climber infestation is 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.

(i) (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.

(j) (iii) In a situation*where the predominants and dominants are not able to utilise 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.

(k) (iv) In absence of the demand or market of small thinning poles, the thinning material can not be utilized economically. If allowed to remain in the jungle depot it would increase the fire hazards.

(l) (v) There is always danger of exposure of the soil. The soil ero-sion may be increased, particularly in slopy areas by removal of lower crown classes. Many of these trees may therefore, be retained as soil cover and as an insurance against causalities among the larger trees.

GRADES OF ORDINARY TINNNING

There are various grades of thinning. The grade of thinning to be adopted depends on experience. The "heavy thinning" implies C- grade 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 codominants 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.

3. Crown Thinning

This is also known as "thi 'lig from above". This is a kind of selective thinning in which thi ing 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 dom.]. nated and suppressed stems are retained unless they are dead, dying or diseased. The crown thinning favours 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 codominants are removed which are interfering with the growth of predominant (dominant) trees. In cafe of choice between relatively poor predomin ants and promising codominants, the codominants are favoured 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, chirpine, 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.

The advantages of crown thinning are —

(a) This method checks soil erosion and damage due to frost, snow, wind etc. is reduced. Shade bearing trees are also protected.

b) The side branches are pruned in a better way due to the presence of trees of lower crown classes.

(c) The lower crown classes help in controlling weeds and shrub growth.

(d) 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.

The disadvantages of crown thinning are :

(a) The dominants are adversely affected when growth factxyrs are limited and there is tough root, competition for moisture end nutrients.

(b) The lower tree classes make difficult various operations e.g. marking, felling, logging nod extraction of the thinned

(c) It requires experience nod skill. The method being flexible requires greater check on the trees to he marked and removed

(d) The diseased end inflect 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:

(1) 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 HI and II are removed. This is like D grade ordinary thinning, but retains all III, II and is not quite so heavy on I.

(ii) 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.

4. 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 selec-tion 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 promi-sing neighbours. 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 consi-dered 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). Codominants or even dominated trees of perfect stem form, and standing in the necessary position relative to neighbouring elite stems, may be preferred to quite fair but less acceptable dominants. The variation in intensity of felling which have not been standarised 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 quadrant of 10m x 10m makes it often obligatory toto select bad elites.

(iv) 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.

(v) The amount of work done varies with the availability of fund.

(vi) It is cumbersome and time consuming.

5. 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 chirpine 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 neighbours) 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.

(6) Maximurn/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 ir 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.

(1) N/D Relationship

The NM curve for indian species has not been found independent) of the site quality. But it ispossible 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 oftrees correspon-ding to a given standard average diameter. A standard logarithmic equation for the given grade of thinning can be formed — Log n = – a log d + K

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

(2) N/112 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 i liken). The relationship is

$$N \alpha \frac{1}{H2} \text{ (Czninowaski,1969)}$$

Tree-Area Ratio

If Y = area occupied by a single tree and d = diameter then for that tree

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

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

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

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

(3) 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.

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) (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 thinnings 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 thinnings 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.

THINNING IN IRREGULAR CROPS

AN It is difficult to classify tree in an irregular crop. The general classi-fication 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 neighbours on all sides and should not be more valuable than their neighbours. 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 removal 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.

8.4. 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 chirpine the no. 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 stagn-ates 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 unsaleable, chirpine 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 he 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 thinn-ing 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.

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 keep 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.

8.5: Summary

UNIT 9: Energy and Industrial plantation:

Unit Structure

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 country. India has huge human population of 125 crore. Most of the population (75%) residing in rural area which totally depends upon forest to meet out their energy requirement. The demand for fuelwood in India is increasing day by day. India‟s current firewood consumption is more than 133

million tonnes; most of it isbeing 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 tonnes of cattle dung equivalent to about 60 million tonnes of fuelwood are burnt annually in our country. If this much quantity of cattle dung is incorporated into the soil then it could increasesoil productivity. Similarly fuelwood 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 fuelwood 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 thanfor fibre content.

9.2: Definition of Energy plantation

A energy plantation is one that grown purely for plant material for their fuel value than for fibre 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 resultsinto 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 weightand 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 green house 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 require 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 Agroforestry one of the most important considerations is to identify species which are compatible with each other also compliment 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 maurtiana 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 firewoods on burning give 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 valueof 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 firewoodas 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 trees species for energy plantation: (charcoal making)

Charcoal making: *Acacia nilotica, Adina cordifolia, Anogeissus latifolia, Casuarina equisetifolia, Pinus roxburghi, 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 viscose, Jatropha glandulifera, Jatropha curcas, Tecoma gracilis and*Ipomoea camea* etc.

Besides 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:

i) Latex
ii) Vegetable oil and waxes

iii) Resins
iv) Essential oils
v) 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, Pedilanthes 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.
- Important species are

9.5.3. 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 chinesis, Strychnos nux-vomica and *Vateria indica* etc.

9.5.4. 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 forautomobiles.

9.5.5. Calorific value:

The amount of heat produced when 1 g of fuel is completely burnt in excess of air or 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 isregarded as good fuel. CV of hydrogen is 150 KJ/g. However, it is not commonly used fuel because of highlycombustible 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 andspecific gravity

Sr. No.	Species	Sp. gravity	Calorific value K cal/kg
1.	*Acacia auriculiformis*	0.60-0.78	4800-4900
2.	*Acacia catechu*	1.00	5142-5244
3.	*Acacia dealbata*	0.70-0.85	3500-4000
4.	*Acacia leucophloea*	0.78	4899-4886
5.	*Acacia mearnsii*	0.70-0.85	3500-4000
6.	*Acacia nilotica*	0.67-0.68	4800-4950
7.	*Acacia senegal*	-	3200
8.	*Acacia tortilis*	-	4400
9.	*Adina cordifolia*	-	3855
10.	*Aegle marmelos*	0.91	4495
11.	*Albizia lebbek*	0.55-0.64	5163-5166
12.	*Albizia odoratissima*	0.73	5131-5266
13.	*Albizia procera*	0.68	4870-4865
14.	*Alnus nepalensis*	0.32-0.37	4600
15.	*Anogeissus latifolia*	0.94	4948
16.	*Anogeissus pendula*	0.94	4900
17.	*Anthocephalus cadamba*	0.94-0.53	4800
18.	*Artocarpus heterophyllus*	0.51	5318
19.	*Azadirachta indica*	0.75	-
20.	*Baringtonia acutangula*	0.58	5078
21.	*Bauhinia retusa*	0.72	5027
22.	*Bauhinia variegata*	-	4800
23.	*Butea monosperma*	0.54	4909
24.	*Bischofia javanica*	0.74	5162

25.	*Cajanus cajan*	-	4594
26.	*Cassia siamea*	0.60-0.80	-
27.	*Casuarina equisetifolia*	0.80-1.2	4950
28.	*Cedrela toona*	0.57	5113-5168
29.	*Chloroxylon swietenia*	-	4759
30.	*Dalbergia sissoo*	0.75-0.80	4908-5181
31.	*Diospyros melanoxylon*	0.79-0.87	4957-5030
32.	*Diospyros montana*	0.70-0.80	5125
33.	*Dodonaea viscosa*	1.20-1.28	5035-4939
34.	*Emblica offcinalis*	0.70-0.80	5200
35.	*Eucalyptus camaldulensis*	0.6	4800
36.	*Eucalyptus globulus*	0.80-1.00	4800
37.	*Eucalyptus grandis*	0.40-0.70	4900
38.	*Eucalyptus tereticornis*	0.70	4800
39.	*Gmelina arborea*	0.42-0.64	4763-4800
40.	*Grevillea robusta*	0.57	4904-4914
41.	*Grewia spp.*	0.67	5292
42.	*Hardwickia binata*	1.08	4891-4952
43.	*Holoptelia integrifolia*	0.63	5228
44.	*Lannea coromandelica*	0.55	4933
45.	*Leucaena leucocephala*	0.55-0.70	4200-4600
46.	*Madhuca longifolia*	0.56	5043-5156
47.	*Mangifera indica*	0.58	4610
48.	*Melia azedarach*	0.56	5043-5176
49.	*Morus alba*	0.63	4371-4773
50.	*Michelia champaca*	0.45	5068
51.	*Ougeinia oojeinensis*	0.85	5178
52.	*Pithecellobium dulce*	0.64	5177-5600
53.	*Pongamia pinnata*	0.75	4600
54.	*Populus euphratica*	0.48	5008-5019
55.	*Prosopis chilensis*	0.80-0.92	5000-5500
56.	*Prosopis cineraria*	0.77-0.94	5000
57.	*Prosopis juliflora*	0.70	4800
58.	*Pterocarpus marsupium*	0.79	4904-5141
59.	*Pterygota alata*	0.25-0.62	5160
60.	*Quercus leucotrichophora*	0.74	4633
61.	*Schleichera oleosa*	0.91-1.08	4928-4950
62.	*Sesbania grandiflora*	0.55	4407
63.	*Shorea robusta*	0.68-0.82	5095-5433

64.	*Syzygium cuminii*	0.67-0.78	4834
65.	*Tamarindus indica*	0.91-1.28	4909-4969
66.	*Tamarix aphylla*	0.60-0.75	4835
67.	*Tectona grandis*	0.55-0.70	4989-5535
68.	*Terminalia alata*	0.71-0.94	5047-5373
69.	*Terminalia arjuna*	0.74-0.82	5030-5128
70.	*Terminalia chebula*	0.77	3967
71.	*Trema orientalis*	0.48	3095
72.	*Xylia xylocarpa*	0.92	4975-5044
73.	*Zizyphus mauritiana*	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 gobar 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.

9.7. Summary

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.

References