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FR 01 / FR 101

Principles & Practices of Silviculture

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

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Unit 1: Introduction to Forest, Forestry and Silviculture

Unit Structure

1.0 Learning Objectives

After completing this unit you shall be able to:

- Define forest, forestry and silviculture
- Know the classification of forests and forestry
- Appreciate Forests in India and
- Describe the history of development of forestry in India

1.2 Introduction

Forests are the resources which render many services to the humans throughout the globe. They not only help in regulating the streams, winds but also provide wood (the most widely used material) and food in the form of wild edibles. Forests are essential for the well-being of humankind. The object of forestry is mainly to get the best services from the forests not only for the present generation but also to the future generations. Thus, forestry means the uses as well as preservation of the forest. Thus, basically forestry is the growing of trees as a crop which can be cut and used. The true concept of forestry is that of devoting land permanently to forest production. Successive crops of trees are grown upon the same land and these crops are either cut clean and replanted or are made to reproduce themselves naturally by seeds or sprouts.

In this unit we will be acquainted with various terms related with forestry and with the practice of forestry. We will also learn about importance and uses of forests, historical developments in forestry, our national forest policies, and forests of India and world. At last we will also understand the definition and concepts of silviculture.

1.3 Forest and Forestry

1.3.1 Definition of Forest

The word forest is derived from the Latin word **'foris'** which means '**outside'**. Originally, forest meant simply wild or uncultivated land regardless of cover. The Indian word 'jungle' has been adopted in the English language to describe a collection of trees, shrubs, etc., which are not grown in a regular manner, as contrast with 'forest', which is any vegetation under a systematic management [1]. Forest has been defined by various scientists and organizations differently. These definitions are as follows:

According to American Society of Foresters, a forest is *"A plant association predominantly of trees or other woody vegetation occupying an extensive area of land"* [2].

According to another definition, *"An area set aside for the production of timber and other forest produce, or maintained under woody vegetation for certain indirect benefits which it provides, e.g., climatic or protective"* [1].

In simple words, it is *"A plant community predominantly of trees and other woody vegetation, usually with a closed canopy".* Or *"An area of land proclaimed to be a forest under a forest law"* [1].

There are great variations in the definitions of "Forest" which varies from place to place, region to region and one country to another country. It mainly depends upon the objectives of management, land use, vegetation type, composition and altitude, etc.

The definition of the word "forest" is not reflected in major conservation Acts of India, i.e Indian Forest Act, 1927, and Forest Conservation Act, 1980. However, the word 'Forest' and "Forest land" were defined by Hon'ble Supreme Court of India. According to the court the word "forest" must be understood according to its dictionary meaning. This description covers all kinds of forests which are recognized in the law i.e., reserve, protected or other categories as mentioned in Section 2(i) of the Forest Conservation Act 1980. Further, the term "forest land" has its mention in Section 2 of the Forest Conservation Act (1980) and includes "forest" as understood in the dictionary meaning as well as any other area recorded as forest in the Governmental records irrespective of its ownership [3]. As mentioned in the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Right Act 2006), "Forest land" means land of any description falling within any area and includes unclassified forests, un-demarcated forests, existing or deemed forests, protected forests, reserved forests, Sanctuaries and National parks.

Our country has redefined forests after Kyoto Protocol as, **"A forest is a land area of at least 0.05 ha, with a minimum tree crown cover of 15%, and tree height of at least 2 m".** Whereas as per the India State of Forest Report 2011, Forest Area means the area recorded as "Forest" in government records and the term "Forest Cover" includes **"all lands with more than 1 ha area with more than 10% tree canopy density irrespective of their legal status and species composition** [4]**.**

Food and Agriculture Organization (FAO) defines the term **"Forest"** as **the** Land having trees of more than 5 meters spread in over 0.5 hectares and with more than 10 per cent canopy cover, or trees able to reach these thresholds *in situ* [5]. It does not include land falling mainly under agricultural or urban land use. International Union of Forest Research Organizations (IUFRO) defines 'forest' as a land area with a minimum of 10% tree crown coverage (or equivalent

stocking level), or formerly having such tree cover and that is being naturally or artificially regenerated or that is being afforested. As per European **Commission**, a forestland is defined as having at least 20% canopy closure (10% in the Mediterranean forests) and a minimum area of 0.5 ha.

1.3.2 Definition of Forestry

The term "Forestry" is defined as, "the science, art and practice of understanding, managing and using wisely the natural resources associated with, and derived from forest lands [6]http://www.forestry.ubc.ca/general-information/what-is-forestry/).

According to University of Maryland Extension [7], Forestry is the science of tending woodlands.

Canadian Forest Service **(**Glossary of Forestry Terms) defines **Forestry as, "**The science, art and practice of managing trees and forests and their associated resources for human benefit.

Forestry may thus be defined as, "Forestry is the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources to provide for the continuous production

*As per Food and Agriculture Organization (FAO) 2015, the term "Forest" has been defined as "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 per cent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use***".**

Changes in SAF Definition of Forestry

[12]

The science and art of managing forests in continuity for forest purposes, i.e., for wood supplies and forest influences (1916)

The scientific management of forests for the continuous production of goods and services (1944, 1958).

The science, the art, and the practice of managing and using for human benefit the natural resources that occur on and in association with forest lands (1967)

The science, art and business of creating, managing, and conserving

forests and associated resources in a sustainable manner to meet desired goals, needs, and values — note the broad field of forestry consists of those biological, quantitative, managerial, and social sciences that are applied to forest management and conservation; it includes specialized fields such as agroforestry, urban forestry, industrial forestry and international forestry (Adopted by IUFRO

of the required goods and services [1].

1.3.3 Branches of forestry and their interrelationship

Forestry has five different branches:

1. **Silviculture**: If refers to certain aspects of theory and practices of raising forests crops, methods of raising tree crops, their growth and after care up to the time of final harvesting.
2. **Forest Mensuration:** It refers to the determination of dimensions, form, volume, age and increments of the logs, single trees, stands or whole woods.
3. **Silviculture system:** Process by which the crops constituting a forest are tended, removal and replaced by new crops
4. **Management:** Practical application of sequence technique and economics to forest estate for the production of certain desired results
5. **Utilization:** Branch of forestry which deals with harvesting, marketing conservation and applying the forest produce to a variety of uses eg. Timber, fuel, charcoal, pulp wood, ply wood.

Another way of classifying forestry is on the **basis of aims or objectives** and may be of the following type:

1. **Protection of Environmental Forestry:** Protection of land, regulation of water cycle, Wild life conservation Modernization of climate conditions, combination of above.
2. **Commercial or Production Forestry:** Timber and other raw materials.
3. **Social Forestry:** Raising forests outside the traditional forest with the involvement of society. Various forms of Social Forestry are:

    i) Community Forestry: The practice of forestry on lands outside the conventional forest area for the benefit of local population has been called Community forestry. Community forestry seeks the involvement of community in the creation and management of such forests. Thus it is raising of forests of public or community land

ii) Farm Forestry: Farm Forestry is defined as the practice of forestry in all its aspect on farms of village lands generally integrated with other farm operations. It is raising forest trees on farms lands. It is further classified as:

a) **Non commercial farm forestry:** raising of trees by individuals for domestic needs (usually by the farmers)

b) **Commercial farms forestry:** Farmers grow trees on commercial basis on farmlands.

iii) Extension Forestry: Extension forestry which includes the activity of raising trees on farm lands, villages wastelands and community forest areas and on lands along the sides of roads, canal banks and railway lines (Anon., 1976). More recently, there has been emphasis on dynamic land use planning and efforts are made to maximise production on farmlands under agroforestry.

iv) Agro-Forestry: Agro-forestry has been defined as a sustainable land management system which increases the yield of the land, combines the production of crops and forest plants and/or animals simultaneously or sequentially on the same unit of land and applies management practices that are compatible with the cultural practices of the local population.

v) Recreational Forestry: More recently, there has been considerable demand for recreational forestry, which is defined as the practice of forestry with the object of developing and maintaining forests of high scenic value. Recreational forests are being developed near towns and cities. The areas are being planted with flowering trees, shrubs and creepers to provide forest atmosphere near towns and cities.

1.3.4 Classification of Forest

Forests are classified in different ways.

A) Classification according to origin of forest

The forests may have their origin either from seeds or from sprouts arising from coppice cut. Accordingly forests are classified as:

i) High forest: forest originated from seeds

ii) Coppice forests: forest originated vegetative from suckers or sprouts from stump

B) Based on species composition- pure vs mixed crop

Pure forest is defined as, "a forest composed of almost entirely of one species, usually to the extent of not less than 80%." It is also called pure crop or pure stand.

Mixed forest is defined as, "a forest composed of trees of two or more species nitermingled in the same canopy; in practice, and by convention, at least 20% of the canopy must consists of species other than the principal ones".

Another terms used are **'virgin forests'** and '**second growth'**. The former term refers to express the original state of natural forest where cutting has never taken place, whereas later is used to express the crop that has come up in an area after harvesting or logging of older crop.

According to National Forest Policy of 1952, four (04) categories of forests were identified based on their functions. These are as follows:

1. **Protection Forests:** Those forests which must be preserved or created for physical and climatic considerations.
2. **National Forests:** Those forests which have to be maintained and managed to meet the needs of defense, communications, industry, and other general purposes of public importance;
3. **Village Forests:** Those forests which have to be -maintained to provide firewood to re-lease cow-dung for manure, and to yield small timber for agricultural implements and other forest produce for local requirements, and to provide grazing for cattle;
4. **Tree Lands**: Those areas which though outside the scope of the ordinary forest management are essential for the amelioration of the physical conditions of the country.

According to National Commission on Agriculture (NCA) (1976), the forests were classified into three major categories. These are as follows:

1. **Protection Forests:** The practices of managing the forests for their protection function are called Protection forestry. The objectives of protection forestry are to protect the site due to instability of terrain, nature of soil, geological formations, etc. Such areas where manipulation of the forest cover is not desirable may be classed as protection

forests. The forests located on higher hill slopes, national parks and sanctuaries, preservation plots, biosphere or nature reserves and wilderness areas may be included under protection forests. The practice of forestry with a view to conserving flora, fauna, soil and water, increasing water yields, reducing floods and droughts, amelioration of climatic conditions, etc. is called Protection Forestry.

2. **Production Forests:** The practice of forestry with object of producing maximum quantity of timber, fuel wood and other forest produce is called Production Forestry. The production forestry can be further classified into:

   (i) Commercial Forestry: Commercial forestry aims to get maximum production of timber, fuel wood and other forest products as a business enterprise.

   (ii) Industrial Forestry: Industrial forestry aims at producing raw material required for industry. In Production forestry, there is a greater concern for the production and economic returns.

   (iii) Mixed Quality Forests

   (iv) Valuable Forests

   (v) Inaccessible Forests

3. **Social Forests:** Social Forestry is the practice of forestry which aims at meeting the requirement of rural and urban population. The object of social forestry is to meet the basic needs of community aiming at bettering the conditions of living through:

   - Meeting the fuel wood, fodder and small timber requirements
   - Protection of agricultural fields against wind
   - Meeting recreational needs and
   - Maximizing production and increasing farm returns

Check Your Progress

Q1. Define forestry and silviculture.
Q2. Discuss the various branches of forestry and their interrelationships.
Q3. What are the various ways of classifying forest? Discuss in brief.
Q4. Differentiate between high forest and coppice forest?

1.4 Importance of Forests

Forests and trees play a vital role in the life of humans as they provide many goods and services directly or indirectly to humans and society. Some of the direct benefits include tree products, wild edibles, medicines, fodder, fuels and timber for construction, fencing and furniture. The importance of the forests may be understood by the **direct and indirect** roles they play for humans or ecosystems or environment as a whole as discussed below.

1.4.1 Direct roles of forests

i) Timber uses: Trees are used as timber since the evolution of human civilization. The timber from trees is used commercial use as well as non-commercially. The timber uses include uses of poles in construction houses, manufacture of windows, doors and furniture etc. Wood-based panel and paper/paperboard production show steadily rising demand which is partially offset by reductions in the demand for sawn wood.

ii) Uses as fuelwood and charcoal: A large amount of wood is needed to get energy for cooking and keeping our houses warm particularly in cold winters or regions of cold climate particularly in rural areas. As per the estimates of FAO (2000) about 1.86 billion m^3 of wood is extracted from forests for fuel wood and conversion to charcoal. Of this total, roughly one-half comes from Asia, 28% from Africa, 10% from South America, 8% from North and Central America and 4% from Europe. According to an estimate, 11% of world energy consumption comes from biomass, mainly fuelwood [8]. IEA (1998) also estimated that 42% of India's primary energy consumption comes from biomass. It is observed that poor people in developing countries derive their household energy requirement from fuelwood and charcoal.

iii) Non-timber forest products (NTFP): Non-timber forest products (NTFPs) include all those products or services other than timber which are produced in forests. It includes tree products such as wild edibles, latex, wild cocoa, honey, gums, nuts, fruits and flowers / seeds, spices, condiments, medicinal plants, rattan, fodder, fungi, berries and also includes animals and their products. These products have a variety of uses to human society.

1.4.2 Indirect roles of forests

Apart from direct benefits, forests also provide many indirect benefits. Forests can significantly alter the environmental conditions in favour of human society and thus bring about the well-being of human and ecosystem as a whole. Some of these indirect benefits are as follows:

- Conservation of Biological Diversity
- Watershed protection
- Arresting landslides and erosion
- Control of floods
- Recharging of natural springs
- Carbon storage and sequestration
- Tourism and recreation values
- Amenity values
- Option and existence values

Check Your Progress

Q1. How forest are useful to humans? Discuss

Q2. What do you understand by indirect benefits? Discuss in context of indirect benefits derived from forests.

1.5 History of Forestry Development in India

Scientific forestry in India is attributed to a German Botanist named as Sir Dietrich Brandis. He was appointed as the first Inspector General of Forests of India in 1864. Thus, scientific forestry is almost over 150 years old in India. It was Brandis who formulated Indian Forest Act of 1865. He evolved the policy of tree cover measurement, demarcation of forests, survey and mapping of areas suitable to be designated as reserved or protected forests under the Indian Forest Act 1865. A revision in Indian Forest Act (1865) was passed in 1878 and it is in this act that provisions were made for the constitution of reserved and protected forests [1]. Dr. Voelcker, another German Forestry Expert was invited by Government of India in 1893 in order to examine the condition of Indian agriculture and to get expert opinion as how to improve upon it. Dr. Voelcker, in his report which he submitted in 1893, mentioned

the role of forests vis-a-vis agriculture and he also emphasized on the need of having a national forest policy for the betterment of agriculture. Following his recommendations, the Government of India formulated its first National Policy in 1894.

1.5.1 National Forest Policy -1894

The purpose of this policy was to lay down general principles for forest management in India. Forest Policy of India triggered the development of forest policies in various other countries under the British Empire of that time. The basic principles of this policy were:

(i) The main objective of management of State forests is public benefit. In general, the constitution and preservation of a forest involve the regulation of rights and the restriction of privileges of the user of the forest by the neighbouring population

(ii) Forests situated in hill slopes should be maintained as protection forests to preserve the climatic and physical conditions of the country, and to protect the cultivated plains that lie below them from the devastating action of hill torrents

(iii) Forests which are the store-house of valuable timbers should be managed on commercial lines as a source of revenue to the State

(iv) Ordinarily, if a demand for agricultural land arises and can be met from a forest alone, it should be conceded without hesitation, subject to the following conditions:

- honeycombing of a valuable forest by patches of cultivation should not be allowed;
- cultivation must be permanent and must not be allowed so to extend as to encroach upon the minimum area of forest that is needed to meet the reasonable forest requirements, present and prospective;
- forests that yield only inferior timber, fuel wood or fodder, or are used for grazing, should be managed mainly in the interest of the local population, care should be taken to see that the user does not defeat its subject and the people are protected against their own carelessness.

1.5.2 National Forest Policy-1952

Substantial increase in population of humans as well as livestock by the first half of 20th Century, resulted into heavy pressure on forests as more and more land needed for agricultural production and pasture lands. Such land came from diversion of forest land.

Apart from this, developmental projects such as river-valley projects, industries, communications and defense needs, etc. all leaned very heavily on the forest produce. These all caused heavy loss in forest cover. Consequently evolution of Forest Policy of 1952 took place. This national policy stressed on the following points:

(i) persuading the primitive people to give up the harmful shifting cultivation;

(ii) increase of the efficiency of forest administration by having adequate forest laws;

(iii) giving requisite training to the staff of all ranks;

(iv) providing adequate facilities for the management of forests and for conducting research in forestry and forest products utilization;

(v) controlling grazing in the forest; and

(vi) promoting welfare of the people.

1.5.3 National Forest Policy-1988

Even after enunciation of NFP 1952, degradation of forests by overuse didn't stop. Thus, forests suffered serious depletion due to relentless cutting for meeting ever-increasing demand for fuel-wood, fodder and timber; inadequacy of protection measures; diversion of forest lands to non-forest uses without ensuring compensatory afforestation and essential environmental safeguards; and the tendency to look upon forests as revenue earning resource. Therefore, the need of having new forest conservation strategy was being felt in the decade of seventy. Accordingly the NFP was revised in 1988. Basic objectives of the policy were:

- Maintenance of environmental stability through preservation and, where necessary, restoration of the ecological balance that has been adversely disturbed by serious depletion of the forests of the country
- Conserving the natural heritage of the country by preserving the remaining natural forests with the vast diversity of flora and fauna, which represent the remarkable biological diversity and genetic resources of the country
- Checking soil erosion and denudation in the catchment areas of rivers, lakes, reservoirs in the interest of soil and water conservation, for mitigating floods and droughts and for the retardation of siltation of reservoirs.

- Checking the extension of sand-dunes in the desert areas of Rajasthan and along the coastal tracts
- Increasing substantially the forest/tree cover in the country through massive afforestation and social forestry programmes, especially on all denuded, degraded and unproductive lands.
- Meeting the requirements of fuelwood, fodder, minor forest produce and small timber of the rural and tribal populations.
- Increasing the productivity of forests to meet essential national needs.
- Encouraging efficient utilization of forest produce and maximizing substitution of wood.
- Creating a massive people's movement with the involvement of women, for achieving these objectives and to minimize pressure on existing forests

The principal aims of this Forest Policy, thus, were to ensure environmental stability and maintenance of ecological balance including atmospheric equilibrium which were vital for sustenance of all life-forms, human, animal and plant. The deriving of direct economic benefit are next to the principal aim.

1.5.4 Van Mahotsawa

Van Mahotsav is an annual afforestation programme in India in which afforestation activity is carried out in the first week of July i.e., 01 to 07 July every year. It was in 1950 when this movement was first initiated in the leadership of then Union Minister for Food and Agriculture, Shri K.M. Munshi. Literally Van Mahotsava means “a Festival of Van or Jungle”. The concept behind this plantation programme is to strengthen our green cover and thus, to derive benefits for Country’s growth and development. Selection of July first week is probably because it is the time of rains and any afforestation programme done during this period usually meets with success.

Check Your Progress

Q1. What are various forest policies of India? Discuss.
Q2. Scientific forestry in India is attributed to _____.
Q3. The latest National Forest Policy of India is of year _____.

Q4. Van Mahotsava was started by _____.

Q5. Write a brief note on Van Mahotsava.

1.6 Forests of World and India

In 1990, the world had 4,128 million hectare of forests; by 2015 this area had decreased to 3,999 million hectare. This is a change from 31.6 per cent global land area in 1990 to 30.6 per cent in 2015. We can describe forest area change as a process of gain (forest expansion) and loss (deforestation). There was recorded a net loss of some 129 million ha of forest from 1990 to 2015 (an annual net loss at the rate of 0.13 per cent). It is as large as about the size of South Africa. The largest forest area loss occurred in the tropics, particularly in South America and Africa, although the rate of loss in those areas has decreased substantially in the past five years. Average per capita forest area declined from 0.8 ha to 0.6 ha per person from 1990 to 2015.

The bulk of world's forests are natural forests with reported natural forest area amounting to 93 per cent of global forest area, or 3.7 million ha in 2015. From 2010 to 2015, reported natural forest area decreased by a net 6.5 million ha per year. This is a reduction in net annual natural forest loss from 10.6 million ha per year from the period 1990 to 2000.

Total forest area in India in 1970-71 was 748 thousand sq km (23%) of the total geographical area as against 718 thousand sq km (22%) of total geographical area in 1950-51.

Region	Forest area, 2005 (mill. ha)
Africa	63,5412
Asia	571,577
Europe + all Russian Federation	1001,394
North and Central America	705,849
Oceania	206,254
South America	831,540
World	3,952,026

Source: FAO, 2006a

The increase in forest area from 1950 to 1971 was mainly attributed to transfer of forest area from private to public ownership and their inclusion in forest area statistics. This resulted into increase in State managed forest area from 83% to 93% during 1950-51 to 1970-71. Forests owned (or managed) by corporate bodies and private individuals constituted 4 per cent and 2 per cent respectively in 1970-71 as compared to 0.3 per cent and 16.7 per cent respectively during 1950-51.

In the latest report 2019 [4], the total forest and tree cover of the country is 8,07,276 sq kms (which is 24.56 per cent of the geographical area of the country) compared to 8,02,088 sq

kims (24.39 per cent) as reported in 2017 (ISFR 2017). The report marked an increase of 5,188 sq kms of forest and tree cover combined, at the national level as compared to the previous assessment [4].

The forests in our country have been grouped into 5 major categories and 16 types as per the classification of Champion and Seth (1968). The distribution of these groups indicates 38.20% subtropical dry deciduous, 30.30% tropical moist deciduous, 6.7% subtropical thorn and 5.8% tropical wet evergreen forests. Other categories include subtropical pine (5%), tropical semi-evergreen forests (2.5%) and other smaller categories. Temperate and alpine areas cover about 10% of the forest areas in the Himalayan region.

1.7 Silviculture

Silviculture literally means the culture of tree species to develop them into forest. In other words, it includes all those measures which have relation with the formation, preservation and treatment of forests. Thus, Silviculture is concerned with the regeneration, growth and development, and harvesting procedure of mature individuals so as to achieve the objects of management of forest crop. It also explains the various operations conducted during the aforementioned processes and application of the various Silviculture systems adopted to get the desired regeneration of forest crop and the conditions essential for the success of crop.

1.7.1 Definition

Silviculture may be defined as the art and science of producing and tending a forest. According to Spurr [9], Silviculture may be defined as, “the theory and practice of controlling establishment, composition and growth of the forest”. In other words, Silviculture is that branch of forestry which deals with the establishment, development, care, and reproduction of stands of timber or forests. In general, Silviculture may be defined as art and science of growing and reproducing timber stands on permanent or regular basis.

Thus, Silviculture includes two distinct parts i.e., regeneration of forests and tending of forests.

1.7.2 Relationship of Silviculture and other branches of forestry

Silviculture has a central place in forestry and is closely related to almost all the branches of forestry. It is the silviculture which helps in achieving the objective of plantation or results

into optimum economic returns (Forest Management). Similarly optimum use of money and resources in silviculture is through the adequate knowledge of Forest Management, thus both silviculture and forest management are complementary to each other. Similarly, Forest utilization, Forest protection and Forest mensuration are closely related to silviculture. For example, Forest utilization means utilization of various forest products and it appears that it has no or least relation with silviculture. However, when you closely observe these, you will find that the tree growth, development and regeneration are greatly affected by the methods of harvesting. In addition to this, means of transportation and disposal of logging debris from the forest floor will also have impacts on existing crop as well as future forest reproduction, establishment and growth of the forest i.e., new forest stand. According to Pack (1930), "Better utilization makes possible better silviculture and is a greater incentive to silviculture. It is utilization that makes silviculture purposeful". Forest Protection is also closely related with silviculture. Forest protection deals with those biotic or abiotic factors of the environment which negatively affect the growth and development of the forest crop i.e., climate, diseases, insects, fire etc. One cannot think of success in silviculture without the adequate knowledge for forest protection. Another important branch of forestry in forest mensuration and it certainly has direct or indirect relation with other branches of forestry. It is through mensuration that we can calculate the existing volume in forests, or expression of data in numerical forms is through mensuration only. Therefore, silviculture in forestry cannot be practiced without taking into consideration knowhow from other branches of forestry. If it is practiced without proper knowhow of other branches, the forest produced would be similar to natural forest.

1.7.4 Aims and objectives of silvicultural practices

The commonest objective of silviculture is the production of wood crops to secure the highest returns in quantitative and economic terms. In addition to production, protection of watersheds and lands adjacent to the forest, conservation of wild life and natural resources may be of primary importance in certain cases. Broadly speaking, objectives of the silviculture are to produce maximum volume and highest quantity of timber and thus, to maximize the economic returns and also to ensure protection of the site and preserve the forest. However, the objective for which a particular forest is maintained, depends on needs

of the owner so far as his freedom of action is not limited by rights of third persons, or by legal enactments. The objectives of silviculture may be one or more of the following:

1. To yield produce of a definite description, for instance trees and shrubs of special beauty, or trees giving a certain kind of timber, or other produce fit for particular purposes, such as grass, turpentine, etc.
2. To produce greatest quantity of wood or other produce per acre and per year.
3. To produce the highest possible money return on the invested capital.
4. To produce certain indirect effects, for instance, influence on climate, to regulate the 'drainage of the country, to prevent landslips or avalanches, to arrest shifting sands.

Thus, the main objective of silvicultural practices is to create and maintain the condition of a forest in such a way that it will maximize the returns in a given area in given time favouring the objectives of the owner, although it is not a universal statement as objects of the owner may vary from place to place and time to time. In other words, silviculture is mainly concerned with maximization of the returns under existing ecological, economic and financial limitations.

The purpose of silviculture can be summed up as the creation and maintenance of such a forest as will yield the highest returns in a given time, however, more precisely the definitions should be as “silviculture is the production and maintenance of such a forest as will best fulfill the objects of the owner”.

1.7.5 Source of silvicultural knowhow and scope of silviculture

In order to arrive at the objectives of silviculture, there are five principal sources of knowledge as follows:

1) Knowhow of fundamental plant physiology, which helps in understanding the basic relations of plants to the factors that influence their growth and development
2) Forest ecology which helps in understanding the relationship of forest crop with surrounding biotic and abiotic factors
3) Silvicultural systems which helps which system will be appropriate under given set of conditions to achieve the objectives
4) Forest itself gives much information to the observer

5) Existing literature on the silviculture of object crop species

As far as the scope of silviculture is concerned, it is not only to produce individual forest crops but also to build a permanent forest which can continue indefinitely to satisfy the objective of management. The main tool of a silviculturist is cutting by which s/he manipulates plantation of forest. Cuttings are carried out throughout the life of a forest crop i.e., in initial period as well as later period of growth and development of forest crop so that suitable form of crop be achieved.

Check Your Progress

Q1. How silviculture is related to all branches of forestry? Discuss.
Q2. Discuss the aims and objectives of silviculture.

Summary

Forests are the resources which render many services to the humans throughout the globe and are essential for the well-being of humankind. As far as importance of Forests is concerned, Forests and trees play a vital role in the life of humans as they provide many goods and services directly or indirectly to humans and society. Some of the direct benefits include tree products, wild edibles, medicines, fodder, fuels and timber for construction, fencing and furniture whereas indirect benefits include Conservation of Biological Diversity, Watershed protection, Arresting landslides and erosion, Control of floods, Recharging of natural springs, Carbon storage and sequestration, Tourism and recreation values, Amenity values and Option and existence values.

The science of managing forests is known as Forestry. It means the uses as well as preservation of the forest. It may be defined as, “the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources to provide for the continuous production of the required goods and services”. Scientific forestry in India is attributed to a German Botanist named as Sir Dietrich Brandis. Dr. Voelcker, another German expert, emphasized on the need of having a national forest policy for the betterment of agriculture. Following his recommendations, the Government of India formulated its first National Policy in 1894. Second Forest policy of India came into existence in 1952. At present we have National Forest Policy of 1988. Forests are the

resources which render many services to the humans throughout the globe. Forests are essential for the well-being of humankind. Forestry means the uses as well as preservation of the forest. Forestry has five different branches i.e., Silviculture, Mensuration, Silviculture system, Management and Utilization. Whereas based on the objectives forestry has three branches - Protection forestry, Commercial or Production forestry; Social Forestry.

Silviculture is defined as, “the theory and practice of controlling establishment, composition and growth of the forest”. The objective of silviculture is the production of wood crops to secure the highest returns in quantitative and economic terms. Silviculture is concerned with the regeneration, growth and development, and harvesting procedure of mature individuals so as to achieve the objects of management of forest crop.

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Unit 2: Factors of Locality I - Atmosphere and Climate

Unit Structure

2.0 Introduction

In the previous unit, you get acquainted with the definitions and other terms of forestry and silviculture. Silviculture in its simplest sense is art and science of growing forest crop. But when growing of forest crops is concerned then it is a complex process and mainly governed by many factors operating in the area. In other words, the immediate environment plays an important role in growth and development this process. Environment includes abiotic as well as biotic components and these components affect directly or indirectly the various life process of plants as the basic requirements for the germination, growth and development of plants is met up by its immediate surroundings. The germinating plant sends its roots into the soil for stability, support and nourishments whereas stem comes above the soil surface into atmosphere from where it receives certain other requirements like heat, light and moisture. Therefore, it is the soil and the atmosphere which act upon forest vegetation and affect its growth and development processes directly or indirectly. These are known as locality and locality factors in silviculture.

In this unit, we will discuss various factors of locality with detailed emphasis on climatic factors and their effects on forests.

2.1 Learning Objectives

After completing this unit you would be able to:

- Define factors of locality
- Explain the types of factors of locality
- Explain atmosphere and climate as a factor of locality
- Describe the importance and role of various climatic factors
- Explain bio-climate and microclimate

2.2 Factors of Locality

2.2.1 Definition

Factors of locality may be defined as **"Effective climatic, topographic, edaphic and biotic conditions operating in an area or site, which have influences on the biotic components of the area**". These are also referred to as '**site factors or habitat factors**'.

In other words, anything around the living organisms or vegetation or crop which affects them directly or indirectly includes what is known as **factors of locality**. It is our environment (living organisms and non-living components) that affects us or other living organisms. For example temperature conditions, moisture conditions, pressure conditions, soil conditions, biodiversity or a combination of these conditions affects the living organisms. Rate of photosynthesis in plants is affected by amount of light which in turn is affected by topography i.e., altitude, latitude or aspect of the area. Similarly, metabolic activities of the organisms are influenced by temperature and moisture conditions which also vary from place to place. The variations in these conditions from one place to another place results in variation on type of organisms or diversity of species. Thus, all these physical, chemical or biological agencies constitutes that is known as factors of locality. In reality, environment is a complex of many factors and these factors remain in a state of continuous interaction with other environmental factors. Therefore, they act in conjugation and their combined result is reflected in the form, types and diversity of vegetation or organisms.

2.2.2 Types of locality factors

Factors of locality are classified into four (04) main categories:

A) **Climatic factors (**Atmosphere and Climate): It includes Solar radiations (Light, Heat and temperature), Moisture, Wind, Pressure,

B) **Topographic factors:** It includes Configuration of land surface, altitude, latitude, slope, aspect and exposure

C) **Edaphic factors:** It includes physical properties of soil, chemical properties of soil.

D) **Biotic factors:** It includes plants, wild animals, insects-pests, man and his domesticated animals.

Check Your Progress 1

1. What do you understand by factors of locality? Define and explain.
2. Discuss the different types of Factors of Locality.

2.3 Climatic factors (Atmosphere and Climate)

Climate is defined as, "an average weather conditions prevailing in an area whereas weather is characterized by temperature, humidity and pressure conditions of an area at a particular time". Thus, climate is characterized by temperature, moisture, humidity and pressure conditions of an area, and it is these conditions that greatly influence directly the growth and development of all organisms. Thus, all those components which make up climate or which define the climate of an area come within the periphery of **climatic factors**. The climatic factors include conditions (temperature, wind, moisture, pressure, solar radiations) of atmosphere and include all factors associated with the atmosphere which influence life of organisms. It also includes atmospheric gaseous components i.e., Oxygen, Nitrogen, Carbon dioxide, Moisture, Solid bodies, Ammonia and Nitric Acid, which directly and indirectly have effects on various biological, physical and chemical processes and are of thus, special significance in Silviculture. The climate of a locality has comparatively greater influence upon germination, growth and development of plants, therefore, it demands special attention particularly in silviculture. This is because of this variation in climatic conditions which causes difference in plants species from one climate to another. Species found in cold climates of high altitudes regions of Himalaya are different from those found in lower altitudes or topical regions. The high pressure conditions in high altitudes results into stunted growth whereas the same species if found

in lower altitudes may grow to higher heights. The various climatic factors are discussed in the following paragraphs in detail.

2.3.1. Atmospheric gases

Among the important atmospheric gases are included oxygen, nitrogen, carbon di oxide etc. It also include

Oxygen: Earth's atmosphere contains 21 per cent of oxygen. Oxygen is needed for energy generation in almost all the living organisms except chemosynthetic bacteria. In case of plants, they also take up oxygen during day and night but during the days (in the presence of sunlight) another process operates which is called photosynthesis or a process food production. In this process more of oxygen is produced than utilized by plants and this more of oxygen is released into the atmosphere for use of other organisms. It is only the green plants that reduce CO_2 concentration in the atmosphere and purify atmosphere through production of oxygen. Anything that impairs with photosynthesis will have impacts of oxygen and thereby affect the life processes.

Nitrogen: About 79 % of nitrogen is present in the atmosphere. It is also an essential element which is needed in amino acids, nucleic acids and various other enzymes. Nitrogen is absorbed by plants from the soil as nitrates and then nitrogen compounds are transferred from plants to other organisms through food chain. Nitrogen is released back to atmosphere as a result of death and decay of organisms. Availability of nitrogen in the soil effects growth and development processes.

Carbon dioxide: About 0.04 % of the volume of the atmosphere consist of carbon dioxide which is received from a variety of sources, as combustion or decomposition of plants, the breathing of animals, volcanoes, spring water issuing from the interior of the earth, combustion of coal and lignite, from various minerals as for instance calcium carbonate. Plants, except certain parasites and saprophytes, take the carbon dioxide which they require through their leaves from the atmosphere. Subsequently, when they die and are decomposed, their carbon is converted back into carbon dioxide, and returned to the atmosphere; hence, plants form an important link in the movement of carbon dioxide. Being a greenhouse gas, Carbon di oxide has impacts on global as well as local climates and weather changes.

Solid bodies: The atmosphere always contains a certain quantity of organic and inorganic solid bodies, which remain in suspension due to their light weights and minute size. These bodies are carried about by air currents and may be deposited in certain localities. Further, certain quantity of these solid bodies are also distributed along with rain, snow, or hail. Amongst the substances which are brought to the ground in this way, are calcium carbonate, magnesium carbonate, sodium chloride, calcium sulphate, ferric oxide, alumina, silica, organic nitrogenous matter, etc. Further, these tiny particles also help in the condensation process and also enriches the soil, where they get deposited.

Ammonia and Nitric Acid: Ammonia and nitric acids are in limited quantities and they supply nitrogen to forest plants in adequate quantities sufficient for the formation of seeds. A certain quantity of ammonia and nitric acid is brought into the soil by the annual rainfall and helps in meeting the requirements of forest for its growth and development. Species belonging to Leguminosae family are capable of absorbing nitrogen directly from atmosphere and assimilating them into amino acids.

2.3.2 Light or Solar radiations

As we all know that light is very important for survival of organisms as it is an important factor required for food production i.e., photosynthesis by green plants and its subsequent transfer to other organisms of the ecosystem through food chain. The intensity and amount of solar radiations affects photosynthesis process and this is why it is one of the important climatic factors. It is important to know that the amount and intensity of solar radiation not only varies from one place to other but also from one season to another season of the year.

The importance of solar radiations can be understood by the fact that it provides us light as well as heat energy. Both of these are very important for the functioning of various ecosystems. The importance of light and heat can be explained as under:

- Sunlight is needed for the formation of chlorophyll in green plants. The amount of chlorophyll in turn affects the quality and quantity of photosynthesis by leave tissues.
- Sunlight influences daily opening and closing of stomata which in turn influences the vital processes such as transpiration, absorption and release of CO_2 and O_2, thereby, controls rate of respiration and photosynthesis (Weaver and Clements, 1929).

- Sunlight is required in the process of photosynthesis by green plants which in turn influences growth and development of whole plant. Therefore, light has been recognized as one of the important factors that influence growth, development and reproduction. Strong sunlight causes many of the chloroplasts to lie in line with the light rays, thus, screening each other from the full effect of the radiant energy. In shade leaves they are arranged at right angles to the light rays increasing the surface available for absorption (Weaver and Clements, 1929).
- The position of leave in many plants changes during the day in order to affect the angle of incoming light. Such leaves often have pulvini which enable plant to change the position of their leaves [1].
- Leaves are the plant part which is most susceptible and undergo the greatest change in response to light. The continuous exposure of leaves to sunlight results in the formation of palisade cells which are placed at right angles to the leaf surface. The amount of palisade tissue developed in the leaves of the same plant may vary from one position to another position. The leaves located in the upper part of a tree crown are fully exposed to the sunlight have rich amount of palisade tissue in comparison to the interior of the crown which remain in the shade of upper leaves.
- The Form and structure of plants is affected by Light and also influences certain physiological functions considerably. The elongation of stem and branches is a response to light in forest. Lack of light is the main stressor for vegetation on the forest floor. Therefore, at the edge of the forest, the plants at the forest floor bend outward so as to absorb maximum light. For example, low intensity of light and infra-red radiations causes elongation of axes of trees thus, height growth. The plants growing in shade are taller than the plants grown in light under other similar conditions. In presence of sunlight, the crown takes a larger shape which in turn results into faster growth and development. This effect of light is used in creating clear bole in trees through proper spacing between the individuals so that shading affect do not allow lower branches to grow. This way light is an important tool in developing proper form and structure of forest trees.
- Light intensity and light quality has a relation with phototropic effects. Most of the chlorophyll-bearing plants and their branches have a tendency to bend towards the

light. Therefore, a tree that is growing below a tree with large crown or spreading branches bends away from the axis of the larger tree (Strasburger 1930). However, if a tree is equally illuminated on all sides, it will not bend even if the intensity of light is very low. It is only the infra-red region that stimulates elongation process (Arthur, 1936).

- Intensity of light determines the growth of trees by affecting rate of photosynthesis. Growth is total photosynthesis minus the portion used up in respiration. Further, the quality of light greatly affects the height and diameter growth of the plants. The plants grown under blue light are short in height whereas UV light causes dwarfness e.g. stunted growth of plants in alpine regions in response to greater exposure to UV radiations. Contrary to this red light and infrared light helps in height increment. Very high intensity of light is, however, fatal for the protoplasm.
- Good light conditions have a positive role in improvement of resistance to cold and drought as well as to disease, insect attack, and other unfavorable influences. Light is known to have considerable influence on the hardening of plants against cold (Dexter, 1933). Further, the plants raised in the shade conditions are less resistant to drought than those grown in full sunlight.
- The amount of light is greatly influenced by latitude, altitude and season which in turn affect many processes directly which require light such as flowering, fruiting, and dormancy. It is now well understood that the length of day is an important factor in determining the time of beginning and ending of the dormant period. Plants have varying degree of sensitivity towards flowering. Some species flower more quickly in long days whereas others in short days.
- Photoperiodism is the phenomenon of physiological changes that occur in plants in response to relative length of day (i.e. photoperiod). The photoperiodism was first discovered by Garner and Allard (1920). Thus, the length of the growing season influences the degree to which a tree will stand shade. Thus, the kind of species or plants in a locality greatly depends upon length of photoperiod. Based on this, the plants are classified into three main categories:

Short day plants (SDP) or long-night plants: These plants require a relatively short day light period (usually 8-10 hours) and a continuous dark period of about 14-16 hours for subsequent flowering e.g., Rice, coffee, soybean, tobacco and chrysanthemum.

The dark period has critical importance and must be continuous. If it is interrupted with a brief exposure of red light (660-665 nm wavelength), it will not flower whereas prolonging of the continuous dark period initiates early flowering.

Differences between short day and long day plants

Short day plant	Long day plant
Plants flower when photoperiod is less than the critical day length	**Plants flower when photoperiod is morethan the critical day length**
Interruption during light period with darkness does not inhibit flowering	**Interruption during light period with darkness inhibit flowering**
Flowering is inhibited if the long dark period is interrupted by a flash of light	**Flowering occurs if the long dark period is interrupted by a flash of light**
Long continuous and uninterrupted dark period is critical for flowering	**Dark period is not critical for flowering**
Flowering does not occur under alternating cycles of short day and short light period.	Flowering occurs under alternating cycles of short day followed by still shorter dark periods Phytochrome

Long day plants (LDP): These plants require longer day light period (usually 14-16 hours) in a 24 hours cycle for subsequent flowering. These plants are also called as short night plants e.g. Wheat, radish, cabbage, sugar beet and spinach. In long day plants, light period is critical. A brief exposure of red light in the dark period or the prolongation of light period stimulates flowering in long day plants.

Day neutral plants (DNP): These plants flower in all photoperiod ranging from 5 hours to 24 hours continuous exposure e.g. tomato, cotton, sunflower, cucumber, peas and certain varieties of tobacco. During recent years, intermediate categories of plants such as **long short day plants** and **short long day plants** have also been recognized. **Long short day plants** are short day plants but must be exposed to long days during early periods of growth for subsequent flowering e.g. Bryophyllum. **Short**

–long day plants are long day plants but must be exposed to short day during early periods of growth for subsequent flowering e.g., certain varieties of wheat and rye.

Light and shade in relation to tree growth are of the greatest importance in practical silviculture, especially in the regeneration, tending of woods, the composition of mixed woods, etc. The most important period in this respect is early youth, because at that time several species require some shelter, either against heat or frost. If that shelter, on the other hand, is excessive the young trees may be permanently injured, or even die. Some species, which are shade bearing, require a certain amount of shelter, or protection, during early youth, therefore, are called "**shade demanding**".

2.3.3 Heat and Temperature

Heat and temperature are the two important climatic factors which play important role in the growth and development of organisms. Heat (unit of heat is joules) **represents to the energy transfer between two systems** whereas temperature represents to the total kinetic energy of a system (Unit of temperature is Kelvin or Celsius). The biggest source of heat in our planet is sun's energy or solar energy. The transfer of heat energy through electromagnetic radiations from sun to our earth maintains its temperature. It is heat or energy transfer that results into increase of temperature in earth. This is also applicable in case of various organisms in our ecosystem. However, temperature of an area is not constant but keeps changing depending on time and season or other changing conditions. Some of the important factors which determine the temperature of an area are:

- **Effect of elevation:** The temperature decreases with rise in elevation above the sea.
- **Effect of Aspect and gradient:** It is the aspect of an area which decides the angle of strike of sun's rays in the soil. This is why in the northern hemisphere, aspects between south-east and south-west are the warmest, and those between north-east and north-west the coldest. The degree of the gradient further modifies this effect, which also depends on the latitude. The aspect also affects the temperature in exposing a locality to air currents, or protecting it against them. This effect may be favourable or the reverse according to the nature of the air currents.
- **Presence or Absence of Forest Vegetation:** Localities which are bare of vegetation are struck by the full sun's rays, thereby cause the temperature at soil surface to rise.

Whereas presence of vegetation creates obstruction for sun's rays and lowers the soil surface temperature.

- **Water exchange between sea and land mass:** Exchange of air between dry land and sea makes the climate of the dry land more equable i.e., low temperature during the day and higher during night.

Temperature has a diversity of effects on vegetation and other living beings. The effects may be summarized in the following point:

- It affects the organisms through its effect on various metabolic processes.
- It increases rate of transpiration, respiration and photosynthesis which in turn results in growth and development of species or organisms.
- It enhances microbial activities in the soil which results in faster recycling of organic wastes and releases nutrients into soil which are subsequently taken up by plants for their growth and development. Thus, temperature results into diversity of species in an area. The more the temperature the more diversity of species will be there. For example, tropical region have very high species diversity in comparison to the colder temperate or alpine regions of the world.

NOTE:

I) Neither very high nor very low temperatures are useful for the organisms' growth and development as it causes many processes to cease.

II) Vegetation having half (root) portion below the soil and half portion (shoot) above the soil, therefore, the air temperature and soil temperature differently affect the growth and development and other processes of vegetation.

Effects of very high temperature on plants

i) The solar radiation directly as well as through its influence on air temperature provides heat to the plant body and helps in satisfactory initiation and continuation of various physiological activities, e.g., transpiration, photosynthesis and respiration. High temperature increases transpiration while low temperature decreases it. Though photosynthesis takes place under a wide range of temperature varying with species and locality, increase of temperature upto 25° C increases photosynthesis, after that it decreases sharply, the rate of respiration

increases as temperature rises from 0°C to 40°C but it decreases when temperature is below 0°C or higher than 40°C. Thus, temperature exerts a great influence on the vital physiological activities of trees, it causes heat injury to the plants which either decreases the activity of the enzymes responsible for photosynthesis or degenerates the enzymes, thereby affects photosynthesis. Even if heat stress injury does not occur, the rate of photosynthesis is expected to decline because of increase in photorespiration than photosynthesis, net result is less photosynthesis.

ii) Seed germination and seedling vigor are important traits for obtaining a sound forest stand and subsequent high crop yields. Seed germination is highly dependent on temperature. However, seeds performance regarding germination varies from species to species.

iii) Soil temperature is one of the major environmental factors that influence not only the proportion of germinated seeds, but also the rate of emergence and the subsequent establishment, even under optimum soil and irrigation conditions (Prasad & Allen 2006).

iv) It has been shown by Robert (1988) and Prasad (2008) that temperature affects the seed germination through three distinct physiological processes during seed germination. These are:

- temperature together with moisture content, determines the rate of deterioration in all seeds
- temperature affects the rate of dormancy loss in dry seeds and the pattern of dormancy change in moist seeds; and
- in non-dormant seeds, temperature determines the rate of germination

v) **High temperature,** although enhance seed germination but results into death of the plants in early stages due to damage to embryo or young seedling tissues. The optimal temperature for structural integrity and activity of most enzymes is within the range of 30–45°C. Beyond 45°C the enzymes are denatured and deactivated, however, it may vary depending upon species.

vi) Very high temperature results into loss of humidity and thus, adversely affects the plants.

vii) Seedlings are highly sensitive and affected due to wilting. Severe wilting results into seedling mortality.

viii) Excessively high temperature results into cracking of stems particularly those having thin bark.

Effects of very low temperature on plants

Excessively low temperature below 5^0C results into **frost and snowfall**. Both of these phenomenon are harmful for plants. Frost is simply the chilling of air below freezing point. It is of three types i.e., radiation frost, pool frost and advective frost based on mode of occurrence. **Radiation frost** is the kind of frost that occurs on the nights with clear sky due to radiation cooling and **Pool frost** results from accumulation of heavy cold air to a considerable depth into natural depressions from adjoining areas. This has more deleterious effect on vegetation than the radiation frost. This kind of frost is characteristics of hilly regions and the valleys whereas the **Advective frost** is the kind of frost resulting from the cold air brought from elsewhere.

Snowfall results in winter season in higher altitude or latitude areas as a result of atmospheric moisture condensation at low temperature when water precipitates in solid form. It takes place upto 1200 m asl in Himalayas, however, the snowfall occurring below 2000m altitude remains as snow for very short period of time whereas above 2000 m it remains as such in ground ranging from few days to months.

Harmful effects of frost are as follows:

i) During frost nights, the water below the soil freezes. In the morning when sun rises, the solar radiations causes leaf surfaces to heat up and accelerate the rate of transpiration. Whereas the water below the soil is still frozen resulting into partial or permanent death of plants.

ii) Frost lifting is a phenomenon which results into uprooting of young seedlings as a consequence of volume increment inside the earth due to freezing of water. This causes unearthing of soil.

iii) Frost also causes damage to cells due to freezing of water which in turn results into damage to protoplasm and cell wall.

iv) Frost causes damage to the wood due to freezing of water and increase in volume, thus resulting into cracking of wood tissues. This breaking of woody tissues dues to frost is

called as **frost crack.** Whenever frost damages a part of the plant, the plant tries to cure the damaged portion by callus formation, however, continued damage this site by frost results into failure of the function of callus and develops a site which is easily affected by fungi. This is called **frost canker.**

Snow has both injurious as well as beneficial effects to plants. The beneficial effects include:

i) Heavy winter snowfall and thus, low temperature is essential for the germination of temperate species such as deodar

ii) Snow recharges streams and reservoirs

iii) Snow acts as blanket and prevents further drop in temperature and thereby safeguards seedlings and vegetation from the damaging effect of excessive cold and frost.

Injurious effects of snow include:

i) It causes mechanical bending of tree bole and branches

ii) Breaking of tree crown and branches results from heavy accumulation of snow

iii) Soil erosion and uprooting of trees results from sliding snow

Effect of air temperature

- The air temperature provides heat to the plant bodies and helps in completion of various physiological activities such as respiration, photosynthesis and transpiration. High temperature enhances transpiration whereas low temperature reduces it. Rate of photosynthesis is increased by temperature upto 25°C and decreases after that. Similarly respiration rate is increased as temperature increases from 0°C to 40°C however the same is decreased below 0°C and above 40°C.
- Air temperature increases microbial activities and thereby enhances decomposition or degradation processes in the ecosystem. It also helps in release of nutrients in the soil and thus makes them available to plants for absorption.
- Enzyme activities are influences by air temperature. Very high temperature (above 50°C) and very low temperature (below 0°C) causes ceasing of enzyme activities.
- Air temperature enhances metabolic and divisional activities in cambium cells in shoot.

- As air temperature affects various physiological activities through its effect on enzymes and other activities, thus, it affects growth and development of plants.
- Temperature is essential for seed germination.

Effect of soil temperature

- Soil temperature affects absorption of moisture and nutrients. However, temperature rise above 35°C causes adverse action on absorption as at this rise in temperature affects the permeability of plasma membrane.
- Soil temperature affects cambial activities particularly in temperate climate. The activity gets increased during warmer soils whereas decreased in colder soils.

2.3.4 Moisture

Moisture remains present in atmosphere and in soil. The source of moisture in the atmosphere is transpiration from plants and evapouration from various land surfaces, sea, lakes, rivers and moist bodies which in turn is the source of water to various parts of the globe and it occurs in the form of rain, snow, hail and dew. Vapour from various surfaces rises in the atmosphere until it again gets condensed into water. It either settles as dew on cool objects, or falls as rain, snow and hail from the cloud to the ground. Plants receive water from the soil through the roots and participate in the evaporation through their leaves. Heat action results into vapour from water which in turn causes evaporating bodies to become drier and cooler, and also reduce the temperature of the surroundings. Rate of evaporation is governed by the temperature i.e., the higher the temperature the higher will be rate of evaporation and accordingly the air at high temperature can hold more of moisture than air at low temperature. Hence, evaporation is more rapid in summer than in winter and it is generally also greater during the day than at night.

Water is fundamental to the vital processes of plants, animals and other organisms. The significance of water to organisms can be understood by the following facts:

- It supplies the soil with water, where it is taken up by the roots of the trees.
- It governs the degree of transpiration from the leaves of the trees.
- Water is present in all protoplasm, all cell walls and vacuoles. The water in vacuoles causes turgidity and growth of cells and thus, of organisms.

- Water is an important constituent of carbon / food assimilation process during photosynthesis and is, thus, directly assimilated. Carbon assimilation gets retarded in non-turgid plants and ceases in wilted plants.
- Ascent of sap in stems results in absorption of nutrients and its transfer to various organs.
- Respiration also requires water and the process is ceased when the water content drops below a certain minimum.
- Water causes cooling of plant and animal body through sweating in animals and transpiration in plants.
- Water is necessary for all movements due to swelling and irritability.
- Structure of plants is influenced to a great extent by the water in the atmosphere and soil. Water is available for the trees through air or through soil. Water is mainly absorbed from soil by the roots of the plants.

Snow and ice have a considerable effect upon trees. During early youth snow may protect forest plants against excessive cold. Later on, a heavy snow fall, or the formation of ice or rime, may break the branches and tops of trees, or even fell them to the ground, especially if snow and wind act together. The danger is generally greatest in densely grown young woods, more particularly those consisting of conifers or of broad-leaved trees with the dry leaves still adhering to the branches. Shallow rooted trees are more easily thrown than deep rooted species. Forest trees are also liable to be damaged by hail, which may injure, not only the soft shoots, but also the bark of species with a smooth surface.

2.4.5 Air currents or wind

The atmosphere is, practically, in constant motion. The principal cause of this is the uneven heating of the earth by the sun. The heat, which becomes free on or near the surface of the earth, warms the adjoining air and causes it to rise, its place being taken by colder air from other parts of the earth.

The ascending air, after cooling, sinks again in its turn. In this manner a circular motion exists between the equator and the poles as well as between dry land and large sheets of water.

Owing to a combination of these currents with the motion of the earth, modified wind directions are produced. The prevailing wind directions on the northern hemisphere are, therefore, from the south-west and the north-east, according as to whether the original current started from the tropics or the polar region.

A second cause of wind currents, especially of storms, is the sudden condensation of considerable quantities of aqueous vapour, which forces air to rush from all sides into the space of reduced pressure. Air currents are of paramount importance to all organic life on the earth, because they produce a thorough mixture of the constituents of the atmosphere. Without them, the land would soon lose all moisture. The motion of the atmosphere ensures a proper distribution of moisture, carbon dioxide, oxygen and nitrogen over the earth. Air currents may affect forest trees injuriously principally in two ways:

- By unfavourably modifying the temperature and moisture of a locality
- By injuring, breaking, bending, or overturning them

Dry winds frequently reduce the moisture of a locality to a dangerous degree; moist and cold winds may reduce the temperature, and thus, interfere with the healthy growth of the trees. Strong winds may break the leading shoots or side branches, cause trees to assume a curved shape, or even throw single trees and whole woods to the ground.

The damage done to trees by strong winds differs very considerably according to species. Shallow rooted trees, like the spruce, suffer most, while deep rooted trees, like oak are much less affected.

Check Your Progress 2

1. “Climate is regarded as a factor of locality” Justify your answer.
2. How moisture effects the life of organisms? Discuss.
3. Write an extended note on Light as a factor of locality.
4. Write a short note on photoperiodism.
5. Discuss heat and temperature with reference to their effect on life.

Summary

Factors of locality may be defined as “Effective climatic, topographic, edaphic and biotic conditions operating in an area or site, which have influences on the biotic components of the area”. These are also referred to as ‘site factors or habitat factors’. Broadly four (04)

kinds of Factors of locality have been identified namely Climatic factors (Atmosphere and Climate), Topographic factors (Configuration of land surface, altitude, latitude, slope, aspect and exposure), Edaphic factors (physical properties of soil, chemical properties of soil), Biotic factors (plants, wild animals, insects-pests, man and his domesticated animals).

Climate is defined as, "an average weather conditions prevailing in an area whereas weather is characterized by temperature, humidity and pressure conditions of an area at a particular time". The climate of a locality has comparatively greater influence upon germination, growth and development of plants, therefore, it demands special attention particularly in silviculture.

Among the important atmospheric gases are included oxygen, nitrogen, carbon di oxide etc. Earth has about 21 per cent of oxygen. Oxygen is needed for energy generation in almost all the living organisms except chemosynthetic bacteria and thus effect the life of organisms. Nitrogen is present in atmosphere and is about 79 per cent. It is important because it is an essential element of amino acids, nucleic acids and various other enzymes. Carbon dioxide is present in low amount i.e., about 0.04 per cent yet has important role as is used up by plants in preparation of food through photosynthesis and also acts as greenhouse gas maintaining the temperature of the globe. Among other important bodies are solid bodies which remain suspended in atmosphere along with gases.

One of the most important climatic factors is Light or Solar radiations which is very important for survival of organisms as it is an important factor required for food production i.e., photosynthesis by green plants and its subsequent transfer to other organisms of the ecosystem through food chain. The importance of solar radiations can be understood by the fact that it provides us light as well as heat energy which are very important for the point view of ecosystem functioning. Further, sunlight affects formation of chlorophyll in green plants, daily opening and closing of stomata, photosynthesis, Form and structure of plants. Its intensity determines the growth of trees by affecting rate of photosynthesis. It has role in resistance to cold and drought as well as to disease, insect attack, and other unfavorable influences.

The amount of light is greatly influenced by latitude, altitude and season which in turn affect many processes directly which require light such as flowering, fruiting, and

dormancy. Photoperiodism is the phenomenon of physiological changes that occur in plants in response to relative length of day (i.e. photoperiod). The photoperiodism was first discovered by Garner and Allard (1920). Based on photoperiodism, the plants are classified into three main categories: Short day plants (SDP) or long-night plants, Long day plants (LDP) and Day neutral plants (DNP).

Heat and temperature are the two important climatic factors which play important role in the growth and development of organisms. The temperature decreases with rise in elevation above the sea. It is also affected by aspect and gradient, presence or absence of Forest Vegetation, water exchange between sea and land mass. The effects of temperature on the organisms are through its effect on various metabolic processes. It increases rate of transpiration, respiration and photosynthesis which in turn results in growth and development of species or organisms. Very high temperature when temperature exceeds the normal growing range i.e.,45°C, it causes heat injury. Seed germination is highly dependent on temperature. Temperature together with moisture content, determines the rate of deterioration in all seeds, it also affects the rate of dormancy.

Excessively low temperature below 5^0C results into **frost and snowfall and b**oth of these phenomenon are harmful for plants. Harmful effects of snow includes into partial or permanent death of plants, frost lifting of young seedlings, damage to cells and wood due to freezing of water, breaking of woody tissues due to frost **crack.** However, s**now** has both injurious as well as beneficial effects to plants. Low temperature is essential for the germination of temperate species. Snow helps in recharging of streams and reservoirs, it also acts as blanket and prevents further drop in temperature and thereby safeguards seedlings and vegetation from the damaging effect of excessive cold and frost. The injurious effects of now include mechanical bending of tree bole and branches, breaking of tree crown and branches, soil erosion and uprooting of trees.

Moisture remains present in atmosphere and in soil. Water is needed by all organisms as it is universal solvent and is present in all protoplasm, all cell walls and vacuoles. The water in vacuoles causes turgidity and growth of cells and thus, of organisms. It is an important constituent of carbon / food assimilation process during photosynthesis and is, thus, directly assimilated. Ascent of sap in stems results in absorption of nutrients and its transfer to various organs. Respiration also requires water and the process is ceased

when the water content drops below a certain minimum. Water causes cooling of plant and animal body through sweating in animals and transpiration in plants. Water is necessary for all movements due to swelling and irritability. Structure of plants is influenced to a great extent by the water in the atmosphere and soil. Water is available for the trees through air or through soil. Water is mainly absorbed from soil by the roots of the plants.

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Unit 3: Factors of Locality II: Topographic, Edaphic and Biotic Factors

Unit Structure

3.0 Introduction

In the previous unit, we discussed about the factors of locality relating to climate i.e., solar radiations, rainfall, wind and pressure, and their effects on growth, development and reproduction of organisms.

In the current unit, we will discuss those factors of locality on which the climatic conditions of an area depends. The topographic or physiographic factors are those factors which

influence climatic conditions of an area, affect the organisms or vegetation. Such factors include earth configuration, altitude, latitude, slope, aspect and exposure. These factors have important indirect effects upon forest environments through their influences on climatic and soil factors. The conditions of climate and soil are affected in a diverse manner by the physiographic factors such as earth's configuration, altitude, slope, exposure, aspects and surface conditions. We will also discuss edaphic and biological factors.

3.1 Learning Objectives

After completing this unit you would be able to:

- Define topographic factors, edaphic factors and biotic factors
- Know the various components of topographic, edaphic and biotic factors
- Appreciate the roles of these factors in the life of organisms

3.2 Topographic Factors

Topographic factors are those factors which are related to land configuration such as altitude, slope, aspect, exposure, latitude and longitude. These factors by effecting climate and soil features bring about effects in vegetation of the area. These are again subdivided into following types:

a) Configuration of earth's surface

b) Altitude, Latitude and exposure

c) Slope and aspect

d) Surface conditions

e) Non-living and Living components on soil surface

3.2.1 Configuration of earth's surface

The configuration of the earth surface, the direction of mountain chains and distance from the sea has great climatic significance (Rubner, 1934). It is on these features in which the direction of wind, atmospheric humidity, rainfall and other type of precipitations are dependent. Rock types effect on the soil water supply and the location of springs and thus on the type of vegetation. Similarly, effects of air are more on the hill tops in comparison to

valleys. The topography of an area affects the forest vegetation through its influences on rainfall distribution. Rainfall on the other hand tends to be higher on the windward side in comparison to leeward side whereas wind-borne snow is likely to be carried away from windward side and deposited on the leeward side for a longer period of time. According to Braun-Blanquet (1932), the earth configuration has an increasing trend from south to north in northern hemisphere and with increasing elevation in mountainous regions. The soil of lower lands of the slopes has more fertile soil in comparison to soil in the higher ridges as soil is deposited in the base along with water. Further, those areas which are close to large bodies generally have moist air and more favorable temperature than those areas located away from these bodies.

3.2.2 Altitude and Latitude

Altitude and latitudes greatly affects the climate of an area. Areas located at higher elevations receive more intensity of solar radiations particularly during clear weather and winds are also very strong at regions of high elevations than regions of low elevations. With regard to temperature of soil, it has been observed that it decreases with increasing altitude. These all factors in combination modifies the climate of these areas and this is reflected in the kind of vegetation and the difference can be observed very vividly. Further, the low density of atmosphere at higher elevations results into absorption of more heat. Studies around the world have shown that altitude has indirect effects on the increment and shape of forest trees. According to Honda (1892), increase in elevation has indirect effects upon individual trees in the following manner:

- Growth in height diminishes regularly and noticeably whereas growth in basal area at breast height does not diminish so rapidly. Similarly, total increment also decreases gradually.
- The period of development particularly maturity is prolonged.
- Shape of tree bole shape deviates from cylinder to conical or neiloid.
- The form factor at breast height becomes smaller.
- The height of crown development gradually decreases and reaches nearer to ground at higher altitudes. Similarly proportion of branches and branch-wood also increases.

Similarly latitude of a place also has influence upon the climate. It affects temperature, rainfall and wind patterns, thus, have effects on the vegetation. The kind of precipitation and its amount also changes with latitude. In higher latitudes snowfall is more whereas in lower latitudes rainfall. This can be reflected on the kind and diversity of vegetation found in lower latitudes than in the higher latitudes.

3.3.3 Slope, aspect and exposure

Slope (or gradient) may be defined as the angle the surface with horizon. It is this slope which controls the surface runoff, soil erosion, and amount of water that percolates vertically downward. The higher the slope more will be surface runoff, higher chances of soil erosion, and low percolation. Slope also controls intensity of solar radiation by shifting its angle of incidence. In case of forest vegetation, better growth is observed on land with moderate slope due to better drainage than areas with flat angle. Grebe's (1886) has given forest classification based on its gradient as:

- Gentle - 5 to 10°
- Medium - 11 to 20°
- Steep - 21 to 30°
- Very steep - 31 to 45°
- Precipitous - over 45°.

It has been observed that slope gradients between 5 and 30° are best suited for forest growth whereas a gradient of above 45° is very negative for forest growth and it usually have little or no forest growth. On **low slope grounds**, deep soil is found and tree roots have scope for free development, however, usually the drainage is poor which results into swamps like situations. Highest yield (per acre) is noticed on **gentle slopes** provided that other climatic conditions are favorable. **Medium slopes** have moderately deep soil and usually supply of soil moisture is also adequate, therefore, supports dense forests and results in high yields of timber under favorable conditions. **Steep slopes** have shallow soil and only certain species thrive on them particularly shallow rooted ones. In **Very steep slopes** have a thin soil along with many rocks and boulders scattered on the surface. It is observed that tree species with short and stunted growth thrive on them. **Precipitous slopes** do not sustain a continuous forest but scattered individuals or groups of trees are found where soil has accumulated to sustain tree life. In mountains particularly in

Himalayas, the vegetation on steep slopes is washed out as a result of heavy surface run-off, landslides and floods during rains.

The direction of the slope is called **aspect.** Aspect of the land or slope determines the amount of exposure to solar radiations which, in turn, modifies the moisture content, temperature of soil and air, and kind of vegetation and its density. For example a slope towards north or poleward is considerable high in moisture and thus, cooler in comparison to southward or equator-ward slopes in mountains. Aspect of a site has direct relation with solar radiations and thus, with temperature and soil moisture. This in turn affects the kind and diversity of vegetation. The amount of heat absorbed by the soil and consequently the temperature of the soil on a given site mainly depends on how vertically or near to vertical the sun's rays strike at it. Generally, the sun's rays strike the soil surface much more obliquely on north aspects (or north-facing slopes) than on south aspects (or south facing slopes). Therefore, former receives much less heat than that of the latter. This also increased more vaporization in south facing slopes consequently are also drier. In mountains, the trees are observed to grow at altitudes lower than their normal range on the cooler (north aspect slopes) and above their normal altitudinal range on the more sunny and warmer southerly slopes. The warmer and drier southern slope in dry regions are not favorable to forest vegetation. The effect of exposure to a considerable extent gets modified towards the higher latitude. Exposure decreases with distance from the equator and also slope gradient modifies it in response to action of air currents. The effect is greatest when the sun's rays strike the soil vertically.

3.3.4 Non-living and living components on soil surface

Non-living components and living components have direct as well as indirect effects on the soil and thereby on vegetation on it. All those non-living components which tend to help in absorption of water, retardation in water evaporation and reduces extremes of temperature, will promote the growth of vegetation. Among non-living components, there are two major kinds i.e., snow and forest leaf-litter (fallen leaves, twigs, and dead herbage). Snow protects vegetation during the winter by shielding the surface soil and root contained in it from excessive cold. The distribution of snow cover determines the vegetation boundary. The areas in alpine regions which are covered with snow in most part of the year remains devoid of trees and only grasses and small shrubs are found

there. The snow acts as a blanket to forest growth and is important for seed germination and its success. In general, regions having a heavy snowfall coupled with adequate summer warmth usually sustain heavy forest cover. In mountainous regions, snowfall directs water to percolate in the deeper layers of water and thus, recharging the natural springs and our river systems. On sites of heavy snow accumulations, the snow acts as a water reservoir which results in luxuriance of vegetation in the following growing season. Snow influences plant form by its weight and often causing trees to assume prostrate forms. In regions of extreme cold, the parts of the tree exposed above the snow gets regular freezing resulting trees appearance as shrub-like or to develop low, umbrella-like crowns. Deep snow acts as a defense against loss of moisture by transpiration. Thus, many tender shrubs and trees in their juvenile stage are able to survive in the winter because of protection offered by snow.

Another important non-living component which affects the vegetation is leaf-litter content over soil. Litter means the undecomposed organic matter lying on top of the humus layer. It is composed of fallen dead leaves, branches, twigs, dried herbage, and other debris lying in a forest floor. It is continually being replenished from vegetation and is continually being consumed by decomposition in the formation of humus. It has almost the same mechanical effect as snow in keeping the soil moist, and more uniform in temperature. As the layer of litter is present in the growing season as well as in the winter, it has a well-marked influence on the kind and character of living ground cover such as moss, herbs, and tree seedlings, which it tends to suppress.

Living Soil Cover includes every kind of covering over the soil formed by living vegetation. Both the physical and chemical relations of soil are affected by the living ground cover. This green cover modifies local environment in variety of ways as follows:

- It regulates soil and air temperature.
- It acts as a screen against the sun's rays.
- It helps percolation of water inside the soil.
- It decreases the action of the wind.
- It helps in maintaining cooler air and moist conditions underneath the vegetation .

Check Your Progress 1

1. What do you understand by topographic factors?
2. How topographic factors affect the climate? Discuss.
3. Differentiate between altitude and latitude.
4. What is the affect of altitude on temperature? Discuss.
5. Discuss the slope, aspect and exposure.

3.3 Edaphic factors

All those factors which are related to soil and which affect directly or indirectly to the various components of an ecosystem are known as **edaphic factors.** In other words, all those factors which relate to structure and composition of soil and its physical and chemical characteristics are known as **edaphic factors**. Soil is a very important component of ecosystem and all living organisms directly or indirectly derive various nutrients from soil and these are very essential for their growth and development. Apart from this, soil substratum is essential for plants in which their roots penetrate for getting nourishment as well as support or anchoring. The various factors affecting growth and development processes of organisms particularly vegetation relating to soil may be categorized in three categories:

- Edaphic factors relating to physical properties of soil
  - soil structure
  - soil composition
  - soil profile
  - depth of soil
  - soil temperature
  - soil moisture
- Edaphic factors relating to chemical properties of soil
  - pH
  - mineral matter
  - soil air
  - soil water

- inorganic soil matter
- organic matter or humus
- soil acidity

- Edaphic factors relating to biological properties of soil
  - soil biotic components (Soil organisms, microorganisms, mycorrhizae)

The vegetation of an area is greatly affected by the physical and chemical properties of soil and also by soil biotic components present in the soil. Therefore, the important factors determining the physical properties and chemical properties of soil are described as follows:

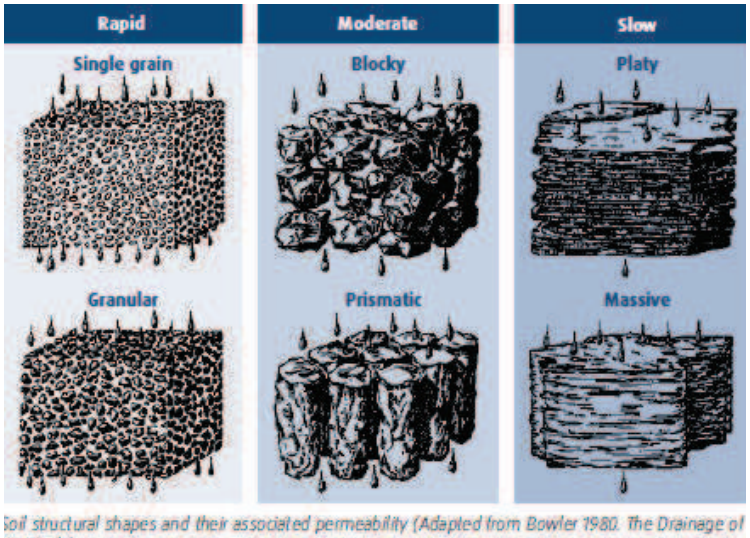
3.3.1 Soil structure

Soil structure refers to the arrangement of soil particles such as sand, silt and clay into aggregates. In other words soil structure is the size, shape and arrangement of solids which affect the pores size and thus, to the capacity of retaining and transmitting air, water and other dissolved substances. The ability to support vigorous root growth and development also depends on the soil structure. The various shapes and soil structure types that may exists include - Crumb, Granular, angular blocky, sub-angular blocky, prismatic, columnar, single grain, massive Crumb and granular structures.

A crumb structure is highly porous relative to a granular aggregate.

A platy structure occurs in some soils just below the surface horizon and creates obstructions in drainage.

Blocky and sub-angular blocky types are common in sub-soils but may also occur in surface soils.



Soil structural shapes and their associated permeability (Adapted from Bowler 1980. The Drainage of Wet Soils).

Prismatic and columnar structures are common in sub-soils of arid and semi-arid regions.

Single grain is characteristic of sands with very little organic matter content.

Massive soils have their particles adhering without any regular cleavage like many hardpans, puddled soils or soils repeatedly cultivated at the very wet moisture contents. Soils which are single grained or massive are also referred to as "structure less."

An ideal soil contains about 50 percent solids, 25 percent water, and 25 percent air by volume.

Importance of soil structure

- It is the soil structure on which various soil characteristics such as soil capacity to hold water, air and other dissolved substances, depends.
- It is important for vigorous root growth and development.
- It is important as it affects soil productivity and is often regarded as a key to soil productivity.
- It affects plant growth through its influence on infiltration, percolation, water retention and runoff, aeration, and mechanical impedance to root growth.
- Large pores helps in good aeration and infiltration of water that results into reduced runoff and thus, reduced erosion. Further, good aggregation of soil holds particles together and thus, reduces the impact of surface runoff and raindrop in detaching particles.

3.3.2 Composition of soil

Soil generally includes mineral matter (sources are decomposed rock or carried to the area by water or air currents), organic matter (sources are remnants of plants and animals), water (partly liquid, partly in the shape of vapour) and gases (such as air, carbon dioxide and ammonia).

The mineral substances form the greater part of the soil in the form of ores, salts, acids and metals. Ores include silica, alumina, lime and magnesia which occur most frequently in soils. Silica is represented chiefly in sand which combines with alumina to form clay. Clay and sand together form loam. Lime appears mainly as calcium carbonate in

calcareous soils, also as calcium sulphate in gypsum. Magnesia is the most frequent in dolomite, though smaller quantities are found in most other soils.

Among salts the most important ones are Potassium carbonate (potash), sodium carbonate (soda), sodium chloride (common salt), carbonates, sulphates and phosphates of iron and manganese. The quantity of salts in the soil does not, as a rule, exceed 0.5 per cent and rarely 1.0 per cent. Larger quantities are found only in certain soils such as salt plains in the vicinity of the sea coast or salt springs or in some peaty and swampy soils. Potassium carbonate is of importance since a fair amount of it is required by forest trees for their growth and development. Sodium chloride acts favourably only if present in small quantities whereas higher quantities are harmful. Salts of iron often are injurious for growth of vegetation.

Among Acids are two free acids such as carbonic and humic acids which generally appear in soils.

Among metals, only iron is of importance in silviculture. It appears as ferrous oxide and as ferric oxide. The former is believed to be injurious to plant life whereas Ferric oxide may be mixed with soils and is not injurious below 10 per cent.

Soils may also be classified according to the rapidity with which the humus is decomposed, as very active soils, active soils, moderately active soils and inactive soils.

Soil classification

Soil Types	Clay	Sand	$CaCO_3$	OM
i) Loams or free soil	20-30%	50-70%	5-10%	2-5%
ii) Clays	> 40%	<50%	<5%	2-5%
iii) Clay-sands	>30%	<50%	<5%	2-5%
iv) Marls	>30%	<50%	5-10%	2-5%
v) Peat clay	>30%	<50%	<5%	>5%
vi) Sand	<10%	>80%	<5%	2-5%
vii) Calcarious sand	<10%	>70%	5-10%	2-5%
viii) Peaty sand	<10%	>70%	<5%	>5%
ix) Calcareous	<10%	50-70%	>10%	2-5%
x) Peats	<10%	<50%	<5%	>35%
Other kind of soil				
xi) Dolomite	a chalky loam with much Magnecium Carbonate			
xii) Gypsum	a soil which is rich in Calcium Sulphate			
xiii) Salt soil	excessive percentage of salts especially NaCl			
xiv) Ferruginous soil	excessive proportion of Ferric Oxide			

Very active soils are those soils in which the decomposition of humus is excessively quick such as dry porous sand and calcareous soils.

Active soils are those in which the decomposition of humus proceeds at a rate favourable for growth and development without actually exhausting the supply of organic matter. E.g., moderately moist loamy sand, sandy loam and loamy marl.

Moderately active soils are those where decomposition is too slow for a healthy development of most plants. E.g., stiff clay, wet soil, heather soil.

Inactive soils are those soils which has either excess of moisture or absence of humus thus, little or no decomposition takes place. E.g. peat soil, shifting sand, etc.

3.3.3 Soil profile

The soil profile is defined as the vertical section of the earth inside the earth more or less 6 feet. The profile composition varies while moving inside and also it varies from one place to another place. It mainly depends on climate, vegetation type and parent rock. Normally the top soil is thicker inside the forest, however, it also varies from one forest type to another forest type.

The vertical section of the soil normally contains **five layers** which are called as horizons which are as follows:

i) O - horizon (organic horizon or litter zone)

ii) A - horizon (top soil)

iii) B - horizon (sub soil)

iv) C - horizon (weathering rock)

v) R - horizon (bed rock)

i) **O- horizon:** It is the topmost soil layer which is also known as litter zone. It is characterized by the presence of fresh or partially decomposed organic matter. This horizon is usually absent in desert, grassland and cultivated lands.

ii) A- horizon: It is the second layer after O-horizon in forest soils whereas topmost soil in in other kinds of soils. It is further subdivided into three sub types - A1, A2 and A3 horizons. **A1-horizon**, the topmost part of the A-horizon contains high humus and organic matter therefore also rich in bacteria and other microbes. **A2-horizon** is the zone of maximum leaching and has comparatively less organic matter. **A3-horizon,** the lowermost layer of A- horizon, acts as transition layer between B-horizon and A-horizon.

iii) B- horizon: It is also known as **zone of illuviation** where material from A-horizon are received. It also consists of B1, B2, B3 sub-divisions. It is deep coloured with aluminum, iron and organic colloids. This is the zone up to which roots of shrub and trees reach.

iv) C - horizon: It is comparatively thick layer and consists of large masses of withered mineral deposits.

v) R- Horizon: It is a bed rock and water is reserved over it.

3.3.4 Soil texture or physical nature of soil

The physical properties of soils are of great importance to vegetation growth and development as it affect supply of water and nutrients. The soil is composed of material varying in size from boulders to minute particles of colloidal size. It is on the percentages of the various size classes of particles that the various physical soil properties (i.e., water holding capacity, water percolation etc.) depends. There are usually two extremes of soil particles i.e.,, some particles are very fine whereas others are very coarse, and between these two extremes, other soil particles of different sizes also remain present in the soil. Based on the particle's size, soils are of mainly three types- **clay, silt and sand**.

Name of Particle	Size (mm)
Clay	<0.002
Silt	0.002-0.02
Fine sand	0.02-0.2
Coarse sand	0.2-2.0
Fine gravel	2.0-5.0
Gravel	>5.0

Clay is the soil having particles with diameter 0.002 mm or less.

Silt is the soil with particle size ranging between >0.002 mm and less that 0.05 mm.

Sand is the soil with particle size ranging from >0.02 and <2.0 mm.

Apart from these three categories, **fine gravels** with particle size 2.0 to 5.0 and **gravels** with particle size >5.0 mm are also identified.

Texture is the relative proportion of clay, silt and sand present in soil. The proportion of above mentioned particles i.e., clay, silt and sand, in the soil influences the physical properties of soil such as aeration, water holding capacity, drainage etc. The principal physical properties of importance in silviculture are the following:

- **Consistency or binding power or the cohesion** between the different particles of the soil depends on the chemical composition of the different parts, the degree

of division and the quantity of moisture in the soil. Generally, it is greatest in clay and smallest in sand. Presence of humus moderates both extremes.

- **Shrinking or the reduction of the volume of the soil** under the process of drying causes cracks in the soil, followed by the exposure of the roots. Heavy soils crack more than light soils.
- **Capacity to hold water** is generally proportional to the percentage of fine earth and humus in the soil.
- **Hygroscopicity (the capacity of the soil to attract and condense aqueous vapour from the atmosphere)** depends on the degree of division of the particles, and on the temperature. The finer the division, the greater the hygroscopicity and more vapour is condensed at a low temperature than at high temperature. Soils rich in humus show the greatest hygroscopicity followed by loam and lime soils, and it is smallest for sandy soils.
- **Permeability** (the capacity to let water pass through) is greatest in sand with coarse grains and is smallest in clay soil. Clay soils are usually close to impermeable therefore waterlogging takes place. In many cases, the clay particles of a mixed soil are gradually carried into the subsoil where it forms an impermeable layer by binding with iron oxide.
- The Capacity to become heated is greatest in sand (hot soil) and smallest in clay (cold soil). Calcareous soils are close to sand and loam to clay in this property.

The physical properties are of special importance through their action upon moisture. In this respect, the chemical composition of the soil is of less important than the admixture of humus and the degree of division of the particles; hence, sand and clay represent the extremes. Thus, texture of soil is regarded as one of the important edaphic factors and affects the plants in the following ways:

- The status of nutrients in the soil depends on the texture e.g., clay soil has higher nutrient concentration whereas sand has low nutrient content. Thus, the nutrient supply is affected due to this.
- Soil aeration is good in sandy and coarse textured soil in comparison to silt and clay.

- Water holding capacity of coarse textured soil and sandy soil is very poor and water is drained out quickly whereas fine textured soils have good water holding capacity and poor drainage. At times very fine textured soils lock the water and result in water logging.

3.3.5 Depth of soil

Depth of the entire soil mass as well as thickness of its various horizons are important in the growth of a forest because of their bearing on the total amount of water stored in the soil and that available for plant growth. In addition the depth and physical character of the various horizons determine to a large extent the growth of tree roots.

3.3.6 Soil temperature

According to Vesque (1878), high soil temperature gives rise to an abundance of sap and to short and thick roots, stems, and leaves. Low soil temperature, on the other hand, causes a diminution in amount of water and nutrients absorbed. This causes dwarfing, so characteristic of trees growing in cold soils. Willows and some other woody plants often assume prostrate forms in such soils. A naturally warm soil is favorable to early germination of seed, early start of vegetation, rapid decomposition of humus and, as a consequence, a larger production of timber. A cold soil tends to an excessive accumulation of organic matter. Warm soils are more variable in temperature than cold soils owing to their greater loss of heat through radiation on cold nights. Vegetation growing in warm soils is more subject to injury from spring frosts. The lowering of soil temperature under closed, natural forest canopies affects:

- Length of time that seeds remain viable in the litter.
- Germination.
- Survival of young seedlings.
- Development of seedlings.

One of the most important requisites for seed storage in the forest floor without deterioration is low temperature (Hofmann, 1917). Under natural conditions, seeds in the litter remain viable longer under a high forest of full density, owing to its effect in lowering surface temperature. Germination fails even when moisture and aeration conditions are at

their optimum, if the temperature is too low (Hawley, 1922). A heavy thinning increases the temperature of the surface soil and hastens germination.

Heat and temperature of the soil depends on following conditions:

- Duration of direct sunlight and angle of incidence of the sun's rays. The nearer the sun strikes the soil at right angles the greater the heat it produces in soil.
- Latitude, slope, and exposure, all affect soil temperature. Soil temperature decreases with increase of altitude.
- The specific heat of soils depends on soil composition. Quartz sand heats quickly whereas peat heats very slowly.
- The amount of water in soils is of great significance as it influences temperature due high specific heat of water than soil.
- Dry soils heat quickly but soils containing much water retain heat longer. Thus desert soils are very warm in the day and cold at night, because they rapidly lose their heat by radiation.
- Clay soils are cold because they retain large quantities of water.
- The darker soils have greater absorptive capacity than lighter soils. Consequently darker soils get heated quickly when exposed to sunlight. Dark soils cool more rapidly than light soils, owing to their greater loss of heat through radiation.
- A porous, gravelly soil absorbs the sun's heat very rapidly and becomes highly heated on the surface however, the heat gets quickly lost.
- The conductivity of heat is greatest in rocky soil, particularly that containing limestone. Loose soil conducts heat slowly because of the larger air spaces.
- Vegetation that covers the soil affects soil temperature because it shields the soil from direct insolation and evaporation and intervenes in preventing loss of heat by radiation.

3.3.7 Soil moisture

Water is the most important component of the soil, as plant life is impossible without a certain quantity of moisture. It affects vegetation principally in the following manner:

- It assists in the decomposition of the rocks

- It assists in the formation of humus, and regulates both the admission of air into the soil and its temperature
- It is an important agent in the process of nourishing and shaping the plant. More especially, it carries through the roots the mineral substances from the soil into the plant.

However, a certain degree of moisture in the soil may act favourably whereas an excess of water especially if stagnant, is always injurious. Excess of water reduces the activity of the soil (by driving out air), lowers the temperature, and increases danger from frost. It also renders increase in soil acidity.

The soil receives water from one or more of the following sources:

- From the atmosphere, as dew, rain, snow, hail or as vapour condensed by the hygroscopic action of the soil
- From ground water resting in the subsoil
- From inundations, whether natural or artificial

Water derived from the atmosphere acts most favourably, provided the supply is suitably distributed over the different seasons of the year, and the soil is capable of retaining moisture sufficiently long during dry weather. Where these conditions are wanting, ground water is likely to act more favourably, because it produces a more even degree of moisture in the upper layers of the soil. Natural inundation water is in many cases objectionable, because it renders the soil too wet at one time, and too dry at others. Artificial inundation, or irrigation, produces very favourable results, but it is generally expensive.

3.3.10 Soil air or gases

It is only necessary to add that the amount of air in the soil varies within wide limits, and that the amount of carbon dioxide depends on the quantity of organic matter in the soil, and the rate at which it is decomposed.

3.3.11 Inorganic soil matter

The chemical analyses of rocks indicate that they contain all of the elements necessary for plant growth. However, during the processes of soil development many of the important elements such as calcium, magnesium, potassium, and phosphorus are leached from the surface soil, or ‘A’ horizon but usually a part of the total leached material is precipitated in

the 'B' horizons or at lower depths and may again be brought to the surface in the periodic litter fall in a forest. The most important classes of soil-forming minerals are:

- silicates,
- oxides and hydroxides,
- carbonates, and
- phosphates

Of these silicates are by far the most important as they weather to form the finer fractions (silt, clay, and colloidal). The silicates are source of calcium, magnesium, sodium, potassium, fluorine, iron, aluminum, and silica to the soil. The oxides and hydroxides give quartz (SiO_2), manganese, iron and aluminum. The carbonates supply calcium, magnesium, lead and copper. The phosphates contribute calcium, flourine and phosphorus. Most rocks contain many other minerals of different composition, so that in general, the parent rock from which soils are developed contains all the inorganic elements necessary for plant growth.

3.3.12 Organic matter or humus

Humus includes all organic matter which is gradually decomposed, and forms in mixture with the upper layer of mineral substances the black earth of the forest. The sources of humus are the annual leaf fall and fallen twigs and dead plants. The humus decomposition releases many important element which are required for growth and development of the plants. Humus are of different kinds. **Mild humus or forest humus** is formed when air and water act in adequate proportion upon fallen leaves or moss, etc. **Dry mould** is formed when in the absence of moisture, excessive air acts upon certain plants. **Acid humus** is the result of decomposition when excess of moisture is available but air remains deficient in the soil. The best humus for forest vegetation is **mild forest humus**.

3.3.13 Soil acidity or pH

Acidity of soil solution is due to an excess of hydrogen ions (H^+) over hydroxyl ions (OH^-); but if the hydroxyl ions are in excess as compared to hydrogen ions, the solution becomes alkaline. pH value which is defined as, "the negative logarithm of the reciprocal of H+ ions concentrations. pH of 7 indicates neutrality, higher value indicate alkalinity and lower values to acidity".

Soil acidity influences vegetation growth by its effects on nitrogen-fixing bacteria, effects on earthworms and by decreasing the solubility and, thereby affects the availability of salts. On the other hand certain species belonging to family Ericaceae grow well on acid soils. The degree of acidity depends largely on the kind of vegetation and the nature of the humus layers in any environment. However, forest vegetation may tolerate wide pH ranges.

3.3.14 Effects of soil on plant growth and development

All soils have their origin from rocks. In course of time certain other substances are added from different sources. In some cases, the soil covers the rock from which it has been derived whereas in others, it gets carried away in distant places by violent convulsions, or by water and air currents. The first kind of soil is called as "**indigenous soil**" whereas the second kind is known as "**exotic soil**". All soils found in near the sea coast, river deltas, inland by water courses and lakes is exotic soil also referred to as alluvial soil.

Effect of the Soil upon Forest Vegetation: Soil has importance because it provide forest vegetation with stability, suitable space for spreading of the root system, moisture in adequate quantities and continuously, and nutrients in sufficient quantities and in a condition suitable for absorption by the roots. Any soil which provides these requirements is well to be called as fertile soil. It has been observed that a fertile forest soil must possess the following properties:

- A sufficient depth
- A suitable degree of porosity
- A suitable degree of moisture
- A suitable chemical composition

The depth is measured by the thickness of the soil layers and by the portion of the subsoil which can be penetrated by the roots. The root system varies considerably from species to species. Some have tap roots such as oak, chestnut, pine, silver fir, maple whereas others have strong side roots which send down deep going rootlets, such as alder. Some other kind of species go to a moderate depth e.g. beech and birch. There are some other species which spread mainly near the surface e.g. spruce. The nature, composition, and degree of moisture of the soil modify the root system to some extent, which in young trees

frequently differs from that in a more advanced age. This because of this variation in root system that certain species thrive well only in deep soil while others can subsist in shallow soil though they prefer the former. The best indicator of the depth of soil is reflected in the height growth of trees. The more is soil depth the more is height growth of trees where in contrary to this, the deficiency of soil depth results in fall off in tree height growth. Thus, trees may be classified based on their demands for depth of soil:

i) **Shallow soil demanding species such as** Spruce, pine, birch etc.

ii) **Moderate depth demanding species such as** willows, alder, horse chestnut

iii) **Greater depth demanding species such as w**hite poplar

iv) **Greatest depth demanding species such as** Silver fir, sweet chestnut and oaks

A suitable degree of porosity is needed for appropriate tree growth. Neither too firm nor too loose soils are favourable for tree growth. It is difficult for tree roots to penetrate the soil layers if soil is too firm and it also prevent the admission of the necessary air, interfere with the movement of water and have a tendency of waterlogging and thus swampiness accompanied by enhanced danger from frost, strong shrinking and cracking in summer. Whereas very loose soils endanger the stability of the trees and are liable to be uprooted by water or wind. Such soils also suffer from rapid drying and rapid decomposition of the humus. The plants growing in such soils also suffer from frost lifting. The best soils are loam and calcareous soils with a good layer of humus.

A suitable Degree of Moisture is needed for proper development of vegetation although it varies from species to species. By suitable degree of moisture is meant that it should correspond to the natural requirement of any particular species. The more continuous supply of such water is maintained during the growing season, the more favourable will be the growth and development of the species. Apart from these conditions, the soil porosity, the nature and proportion of its component parts affect the degree of moisture.

A suitable Chemical Composition mineral and organic substances is essential for proper growth of species as it affects the development of the trees party by providing nutrients and partly by determining the physical properties of the soil. Woody plants take the greater portion of their nourishment from the air, more specifically carbon, but a certain portion, including the mineral substances is derived from the soil. Hence, it is of importance to

ascertain the actual quantities of such substances in the plant. It is found that the amount of substances required by forest trees are more or less same as by field crops.

Check Your Progress 2

1. Define edaphic factors. Discuss its various categories.
2. Write a note on soil structure and its impact on various physical properties of soil.
3. Discuss various kinds of soil structure types.
4. Explain the importance of soil structure in plant growth
5. Write a detailed note on structure and composition of soil.
6. Write a brief note on soil profile.
7. Differentiate between soil structure and soil texture.

3.4 Biotic Factors

Living organisms in an area have direct or indirect influence on desired species and constitute what are known as **Biotic factors.** Biotic factors include associate tree species, microorganisms, parasites, or other life in the area which interact with one another or with desired species and modify the soil, moisture, climate or other conditions of the area. Such interactions among the living components is called as **Biological (Biotic) interactions.** In nature, none of the organism exists in absolute isolation, but remain connected with other organisms or living components directly or indirectly and such interactions or connections are fundamental to the survival of organism and the functioning of the ecosystem as a whole.

Biotic interactions can involve individuals of the same species (**intraspecific interactions**) or individuals of different species (**interspecific interactions**). Pollination, symbiosis, predation, herbivory, or cannibalism, mutualism are some important kinds of interactions operating among individuals of same or different species. In interactions, individuals may affected directly or indirectly depending upon whether there exists a direct relation or some intermediaries is involved in such interactions. Such interactions or inter-relationships among organisms profoundly affect growth and development of desired forestry species. Various kinds of interactions among the biotic factors can be categorized into following heads for the ease of study point view.

- Competition – struggle for growing space, light and nutrients

- Interrelationships between plants
- Interrelationships between plants and animals, particularly the effect of animals
- Interference by man.

3.4.1. Competition – struggle for growing space, light and nutrients

Whenever trees grow close enough together to form stands, competition sets in i.e., there starts a struggle between individuals of the same species or among individuals of different species for the available space, nutrients or water or in brief for their existence. In both fully stocked and overstocked stands which have developed naturally, there occurs a intense competition for light and space aboveground and for soil moisture, nutrients as well as space below the ground (Korstian and Coile, 1938). The intensity of competition among the individuals of different species depends upon the ecological similarities of the species, i.e., the higher the same ecological demands the more intense will be the competition among them. In the process of competition results into the elimination of the weaker individuals by vigorous and healthier individuals in other words, it happens according to Darwin's theory of **"survival of the fittest"**. It has been observed that in different parts of the earth, many species got eliminated due the intense struggle for growing space, light, water and nutrients.

Competition is an interaction between individuals of same species or different species in which one species is positively affected (beneficial) whereas other is negatively affected (harmful). This can be because of limitation of food, water or space or at least one of these three. According to the competitive exclusion principle, individuals of species less suited to compete for essential resources should either adapt or die out although principle of competitive exclusion is rarely operates in natural ecosystems [1].

Competitions may be categorized into two types based on whether it operates among individuals of the same species or individuals of different species. Thus, competition if is two types:

- **intraspecific competition** (among members of the same species)
- **interspecific competition** (among individuals of different species)

A) **Intraspecific competition:** Intraspecific competition occurs when members of the same species compete for the same resources in an ecosystem. The organism that obtains less resources, will usually perform less well than if it lives alone.

B) **Interspecific competition:** Interspecific competition may occur when individuals of two different species struggle for obtaining similar but limited resources such as nutrients, or light or space. In case, the resources are in limited quantity then at least individuals of one species are negatively affected in terms of lowered production, growth, or survival. Interspecific competition are very powerful in altering populations or communities and thus, in evolution.

3.4.2. Interrelationships among plants

There are many interrelationships exists among the plant species. Some are beneficial whereas in some one species is benefitted whereas other get negatively affected or even sometimes other remains unaffected. Thus, interrelationships between or among forest species are many and with varying degrees of dependence. As emphasized by Warming (1909) interrelationship is shown in all degrees of bondage from parasitism to the interdependence of plant communities. There are mainly following kinds of interrelations exists in nature:

- Parasitism
- Commensalism
- Mutualism
- Symbiosis
- Predation
- Saprophytic association

a) Parasitism is the kind of interrelationship in which one species derives water or nutrient or both from other organism and also responsible for some kind of negative impact on it. Former individual is called parasite whereas later is called host and such relationship are always hostile or unfriendly in nature. Pure Forests are highly affected by parasitism because in such forests, parasites spread very rapidly in the host individuals as there are no barriers.

Plant Parasites and their impacts of forests: There are present a number of parasites in the forest which cause damage to trees in various stages of its life. Soon after arise of young plants above the ground, various fungi of the soil such as species of *Pythium, Rhizoctonia*, *Fusarium, Corticium,* and possibly *Phytophthora,* attack the root or the hypocotyl.

Damping-off is another kind of attack which occurs by root infection even after the stems have started to become erect and woody. Damping-off can be recognized by the signs of the young plants losing their erect position after coming out of soil surface. Soon after getting infected, the plants die within few days. One of the important thing to note here is that the seedlings of some tree species are much more susceptible to infection than others, therefore, it is one of the factors which indirectly help in shaping the composition of mixed stands.

There are many plant parasites which cause spotting in leaves or even defoliate the trees which results into reduced photosynthetic activity by reducing the area of functioning leaf surface and thus, yield is severely reduced.

Parasitic fungi infecting the living tissues of the bark and wood, especially the cambium, are much more destructive than parasites which are confined to the leaves. They may gain entry inside the plant body through the stomata, young branches before the cork tissue is developed, however, in the later stages they get access only through openings in the bark which may be caused by insects, fire, frost and other external agents. The main difficulty with such kind of diseases or infections is that it is very difficult to locate them.

In cases of bark and wood infection by parasites, it has been observed that disease usually progresses with passage of time and eventually tree gets killed.

There are examples of parasitic infections in which the parasite remains inactive for months or even years and even no signs of presence of parasite are visible, example blister rust on white pine. However, when the parasite gets suitable conditions, it starts developing fruiting bodies on the surface of the plant and these reveals the presence of a parasite in the plant. Many of such parasites have capability of destroying both young and old timber, therefore, have far-reaching importance in determining the character of forest communities and the composition of stands. Normally bark of a tree is a protective layer

from infections but when due to some or other reasons it gets injured and exposes sapwood or heartwood then infection may take place. Such infection gradually destroys the wood and the tree becomes hollow. Such wood becomes worthless.

The parasitic species which attack sapwood, spread their mycelia in all directions soon after infection and cause large areas of dead tissue to appear on the surface of a tree. In such cases, the presence of wood-rotting fungi is revealed only after the damage has been taken place and infection is recognized by presence of fruiting bodies on the surface of stump or along the bole of a standing tree.

b) Commensalism is a relationship in which one organism is benefitted by the association whereas other is remains unaffected (neither benefitted nor harmed). It occurs when one organism takes benefits by interacting with another organism by which the host organism is not affected. Example of commensalism are 'nurse plants' which are large plants that offer protection to seedlings from the weather and herbivores, thus, giving them opportunity to grow.

c) Mutualism is an interaction between two or more species, where both the species in relation derive some or other benefit from one another but the condition is that the species are not closely associated. An example of this is **Mycorrhizae in which** the roots of trees are intimately associated with fungal hyphae. It has been observed that there is an interchange of nutritive materials between the root and the fungus and fungus also helps in better absorption of water and nutrients from the soil. Association of fungus with roots may superficial which form a sheet around the roots and root tips. This kind is called as **ectotrophic mycorrhizae.** Whereas in another kind of association fungus lives in the root cortex and known as **endotrophic mycorrhizae.** Mycorrhizae aid trees in obtaining nitrogen from humus which contains little or no nitrates.

d) Symbiosis is also similar to mutualism in that both the species derive benefits from each other but the difference is that both are closely associated with each other and both species involved in the interaction may be obligate which means that they cannot survive in the short or long term without the other species. Example is the relationship which exists between the bacteria in the nitrogen tubercles on leguminous plants. Another example are **Epiphytes** that remain attached to areal parts such as stem or branches. Here the epiphytes get mechanical support from the trees and thus to get access to light in turn they

are capable of absorbing atmospheric humidity and provide the same to plants and thus help in overcoming injury from drought.

Lianas (climbing woody vines) are associated with other plants in that they depend upon them for mechanical support. Their presence in a forest gives it characteristic physiognomy. They exhibit diverse adaptations to facilitate mechanical support on other species. Certain species root climbers whereas others are twiners. A large variety of other lianas climb by means tendrils.

e) Predation

Predation is a biological interaction in which one organism feeds on other organisms, the former is called predator and later as prey (the organism that is attacked upon). The act of predation often results in the death of prey. Predator often consume whole tissues of prey after its death. An example of this is carnivory which involves large animals such as a lion or a tiger, hunting smaller animals like rabbits or deer, etc.

f) Saprophytes obtain their carbon nutrients from the dead parts of other organisms. Some saprophytes appear to live on the dead tissues of particular species, hence are associated with those species. Most saprophytes, however, are associated with a great variety of species, often of widely different genera, for example, most of the fleshy fungi so characteristic of forest communities.

3.4.3 Effects of Wild Animals

The interrelationships between forest plants and animals are many and variable. All degrees of bondage or interdependence exist which may be either beneficial or even mutual need of both. They usually remain interdependent which is evident from the fact that certain kinds of animals are only found in defined forests. One can observe that the localities rich in insect life sustain the kind of vegetation which have attractive flowers.

Although there are many advantages of wildlife in forestry operations, yet many animals are disadvantageous also particularly when population of such animals is high. Such wildlife also affect the character of forest communities as some has positive and others have negative impacts on plant communities. Many rodents which are beneficial in distribution of seed, yet have also harmful impacts as they also eat seed or they cause injury or even destroy young plants. Whereas there are some mammals or many insects

which are usually destructive. They feed upon foliage or fruit. Some of the wild animals and their impacts on forest vegetation are described in detail in the following paragraphs.

Deer and Elk cause the same injuries to forest vegetation as caused by domestic animals. They cause damage to seedlings and sapling through browsing and thus influence the forest composition.

Beaver (Rodent) engaged in various developmental activities in and around the forest stand can often change the physiographic characteristics of the site. Soil moisture conditions can get changed by erecting dams at the outlets of lakes and along streams. Composition of stands is changed as they do selective felling of trees for the purpose of fuel or fodder or timber. Beaver may fell or girdle all trees of the preferred species adjacent to their ponds.

Rabbits cause damage to seedlings and small trees by cutting off or chewing of buds, small branches or stems which frequently results in the death of trees. They usually prefer the growing shoots of seedlings. Rabbit damage to trees is more serious in regions where heavy snowfalls cover up other readily available sources of food (Baker, Korstian, and Fetherolf, 1921).

Squirrels eat the seeds and fruits and cut off young twigs and buds of many tree species (Hosley, 1928; Hatt, 1929). They may destroy almost all the seed produced by a species. However, sometimes squirrels and other small rodents bury, in the litter and soil, tree seed which later germinates and contributes additional reproduction (Korstian and Baker, 1922). Squirrels are also known to distribute the seed of oak, hickory, chestnut and also of some confers.

Porcupines cause the most serious damage by gnawing of bark of live trees. They often partially or completely girdle the main stems which results into weakening of trees, bushy topped shape or spike topped (Gabrielson and Horn, 1930; Taylor, 1935). Injury can be seen on any part of the bole as porcupine can climb a tree. Porcupines if present in abundance may completely consume the seedlings or may ruin the larger trees by causing serious injury enough to lead to their death.

Mice feeds on the seeds of many forest species. Mice even gnaw the bark of seedling and young trees during the winter when there is scarcity of food. Sometimes population of mice

may increase to such extent that it may cause serious damage to most of the trees on an area (Hatt, 1930). Preferential eating and thus, girding for certain tree species by mice results into change of the forest composition particularly of mixed stands. The damage by mice can be minimized by maintaining the proper balance of predator animals inside the forest such as hawks, owls, snakes and carnivorous mammals. However, sometimes mice are also beneficial to a forest as they feed on pupae of harmful fly and thus, prevent epidemic (Graham, 1928).

Birds are beneficial as well as harmful to forest stand, however, they have more beneficial influences. They are important agents in the natural dissemination of seeds having fleshy fruits. Birds also feed on insects and pests and thus reduce the damage caused by them (Adams, 1923; McAtee, 1926). Some birds also eat the seeds of species. In general. birds because of their recreational and aesthetic values and generally beneficial influence, should be protected and encouraged to increase in forests.

Insects help in pollination of many tree species. However, many species of insects are very much harmful to forest stands as they feed on seed, buds, foliage and some even on sap from the leaves. Their relation with trees results in the formation of abnormalities such as galls and other deformities, whereas others bore into bark, wood or pith of the shoots or roots and thus, may cause the death of trees or render the wood of little economic value. Accumulation of dead logs or trees inside the forest constitute the flaming material and hence increase the fire hazards. Further, fungi infestation is easy inside the tree which have already worded upon by insects as they gain easy access through openings made by the insects.

3.4.5 Domestic Grazing Animals

The grazing of domestic animals on forested areas is of common occurrence everywhere in the world. Overgrazing results in its impact on natural reproduction and growth seedlings and saplings. Overgrazing causes more damage to broadleaved forests than coniferous ones as they like broadleaved species thus, results in favorable growth and development of coniferous species particularly in mixed stands. In general, overgrazing has effects on soil, moisture and reproduction. The soil is rendered compact and more or less impermeable to air and water, thus, making it more difficult for reproduction to initiate and get established. The destruction of herbaceous vegetation on the forest floor through

grazing, particularly on slopes, increases erosion. Grazing results in killing of many seedlings whereas other get trampled or otherwise injured. Seeds are eaten and young plants rooted up and destroyed by hogs or swine. The grazing of hogs in longleaf pine forests almost completely eliminates natural reproduction of that species in parts of the South (Chapman, 1926; Wahlenberg, 1946). Grazing animals even cause damage to young plants (when their crown gets elevated enough beyond their reach) by gnawing or peeling of bark, thus, killing or severely injuring it. However, in most cases, when the trees once elevate their crowns above the reach of domestic animals, they are free from further direct injury. The fire hazards are considerably reduced in overgrazed areas thus, greatly reduces the fire hazard.

3.4.6 Interference by humans

Humans are the most powerful and harmful agent leading to deforestation or tending to disturb natural conditions in forests. Many of the human needs are fulfilled from forests and this is why they cause damage to forests. They derive from forests timber, wild-edibles, fuel, fodder, medicinal plants and many more products, and these are the reasons which have profoundly resulted into modification of forest vegetation. Man has been engaged in clearing of forested land for agriculture, unregulated cutting of timber in lumbering operations, grazing of livestock on forest areas, burning of forest and range lands, depletion of game and predatory animals allowing an unnatural increase in the rodent population, drainage, elimination of native plants, and introduction of plants and animals. Thus, man has altered the condition of natural forests and has significantly affected the forests by conversion for agriculture expansion, cutting for lumbering industry, introduction of exotic plants and animals species, introduction of insect-pests and human-made forest fires and losses to vegetation and wild animals.

Check Your Progress 3

1. Define biotic factors.
2. Differentiate between intraspecific and interspecific interactions.
3. What is competition? Discuss in brief.
4. Write a note on interrelationship among plants.
5. Differentiate between commensalism and symbiosis.
6. Discuss the impacts of domestic and wild animals on growth and development of plants.

Summary

- In this unit, a detailed account of topographic or physiographic factors, edaphic factors and biotic factors gave been given.
- **Topographic factors** are those factors which are related to land configuration such Configuration of earth's surface, Altitude, Latitude and exposure, Slope and aspect, Surface conditions, Non-living and Living components on soil surface. These factors by effecting climate and soil features bring about effects in vegetation of the area.
- **Edaphic factors** are all those factors which are related to soil and which affect directly or indirectly the various components of an ecosystem. Soil is a very important component of ecosystem and all living organisms directly or indirectly derive various nutrients from soil and these are very essential for their growth and development. Apart from this, soil substratum is essential for plants in which their roots penetrate for getting nourishment as well as support or anchoring. The various factors affecting growth and development processes of organisms particularly vegetation relating to soil are - edaphic factors relating to physical properties of soil (soil structure, soil composition, soil profile, depth of soil, soil temperature, soil moisture), edaphic factors relating to chemical properties of soil (soil acidity or pH, mineral matter, soil air, soil water, inorganic soil matter, organic matter or humus), edaphic factors relating to biological properties of soil or soil biotic components (Soil organisms, microorganisms, myccorrhizae).
- Among **biotic factors** are included various kinds of organism in the surounding which includes vegetation, animals, microbes, insects and human. It affects through competition, interrelationship and association (negative and positive). Wild animals and domestic animals directly affect the vegetation as they may eat or trample the grwoing vegetation/ seedling.

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Unit 4: The Tree and the Forests: Germination, Growth and Development

Unit Structure

4.0 Introduction

Recall your knowledge from previous units in which got the understanding of basics of forest and forestry, and various kinds of factors of locality which directly or indirectly influence the kind of vegetation through their influences on growth and development processes. We also discussed silviculture that can be distinguished in two distinct parts - growth and reproduction, and harvesting. The objective of silviculture is to get maximum return in shortest time particularly of merchantable part of tree (i.e., bole). Therefore, in order to attain this objective, it is important to have understanding of the growth and development processes of the forest and how to bring about change in the forest structure, shape and composition. This is possible only when a forester or silviculturist has sound and clear understanding of processes relating to tree growth and development i.e., height growth and diameter growth as well as reproductions.

In this unit we will discuss the germination, growth and development of forests and trees, and the various processes involved therein. We will also discuss reproduction and kinds of reproduction or regeneration in forest in brief.

4.1 Learning Objectives

After completing this unit, you will be able to:

- define and differentiate tree and forest
- explain germination and germination processes
- illustrate growth and development processes
- define forest regeneration and
- differentiate between various kinds of regeneration methods

4.2 The Trees and the Forests

4.2.1 The Trees

Recall the lessons you learnt in the earlier classes regarding five kingdom classification given by Whittaker (1969). According to this system, the whole living world has been divided into five major categories, viz. **Monera, Protista, Fungi, Animalia and Plantae**. Of these, Plantae is the category which includes Algae, Bryophytes, Peridophytes, Gymnosperms and Angiosperms.

When one observes plants and their structure, they can easily divided into three types- herbs, shrubs and trees although sometimes another category of plants is also identified i.e., climbers (which may be herbaceous as well as wood kind).

Generally, the **herbs** are those plants which have delicate stems and their shoot portion usually die at the end of season or year although the underground portion may remain live for two years or more. The **Shrubs** are those plants that may grow up to six (6) meters in height but have many branches arising from the base. Futher, they also have woody elements in them. The **Trees** are the large perineal plants with a well-defined wood stem and a well-defined crown.

In silviculture, we are generally concerned with the germination, growth, development, harvesting and reproduction of tree species which belong to Gymnosperms and Angiosperms only. Therefore, a general account of these two major sub-categories is discussed herewith.

A) **Gymnosperms:** The word Gymnosperms has its name derived from two latin words- 'gymnos' means naked and 'sperma' means seed. The seeds of Gymnosperms remain exposed before as well as after fertilization as the ovary wall around the ovule is lacking. This is the reason gymnosperms as also known as 'naked seeded plants'. The species belonging to Gymnosperms vary in size ranging from creeping one to the tallest trees of the world. The various examples of gymnosperms are Deodar (*Cedrus deodara*), Chirpine (*Pinus roxburghii*), Thuner (*Taxus buccata*) and the giant redwood tree species (*Sequoia* gigantean).

The roots of Gymnosperms are mainly tap roots. Roots of some of the plants have association with fungal species and forms what is known as mycorrhiza for example in *Pinus* sp. Whereas in some other cases specialized roots are found which are known as coralloid roots which also harbor to N2 fixing Cyanobacteria for example *Cycas* sp,. The stems in Gymnsoperms are mostly branched, however, in some cases it remains unbranched example *Cycas* sp. The leaves may be simple or compound which are well-adapted to withstand extreme climatic conditions such as temperature, humidity and wind. The needle shaped leaves are specifically adapted for reducing moisture loss from the leaf surface. Additionally, presence of thick cuticle layer and sunken stomata also help in minimizing water loss.

As far as reproduction is concerned, the gymnosperms are heterosporous i.e., two kinds of haploid spores are produced. These are known as microspores and megaspores. The organs which produce these spores are known as sporangia. Sporangia are located on sporophylls and sporophylls are arranged spirally along an axis to form a compact strobili or cones. Those strobili which bear microsporophylls and microsporangia are called microsporangiate or male strobili whereas the strobili or cones which bear megasporophylls and megasporangia are known as macrosporangiate or female strobili. The production microspores and its further development into male gametophyte (pollen grain) takes place in microsporangia. The male or female cones or strobili may be borne on the same tree (*Pinus sp.*) or in different individuals (*Cycas sp.*). On the other hand a female gametophyte is produced in megasporangia as a result of meiotic division of megaspore mother cell which is differentiated from one of the cells of nucellous. The nucellus remains protected inside envelope and the composite structure what is known as ovule. One of the four

daughter cells produced after meiotic division, develops into female gametophyte. The multicellular female gametophyte is also retained within megasporangium. Unlike bryophytes and pteridophytes, in gymnosperms the male and the female gametophytes do not have an independent free-living existence. They remain within the sporangia retained on the sporophylls. The pollen grain is released from the microsporangium and carried through wind before coming in contact with the opening of the ovules borne on megasporophylls. The pollen tube carrying the male gametes grows towards archegonia in the ovules and discharge their contents near the mouth of the archegonia. Following fertilization, zygote develops into an embryo and the ovules into seeds which are always naked.

B) Angiosperms: Angiosperms are also known as flowering plants. The flowers are reproductive structures in which ovules are present inside the ovary which after fertilization develops into fruits. Thus, seed are always remain protected in contrast to gymnosperms where seeds are naked. Angiosperms are divided into two main categories- Dicotyledons and monocotyledons based on the number of cotyledons present in the seed.

Difference between dicots and monocots

Dicots	Monocots
The leaves are net veined	Leaves are parallel veined
Vascular bundles are arranged systematically	Vascular bundle scattered
cambium tissue is present so secondary growth occurs	Cambium absent therefore, secondary growth is absent
Floral parts are present in four, five or multiples of these	Floral parts are multiples of three of three
seed contains two cotyledons	Seed contains single cotyledon
Life forms are herbs, shrubs and trees	Mainly herbs and grasses
Examples *Ranunculaceae, Leguminosae, Asteraceae, Apiaceae*	Examples: *Graminaceae, Liliaceae, , Palmaceae, Orchidaceae*

The Dicotyledons are highly diverse category and there are about 200000 species so far recorded. All the broadleaved trees belong to Dicotyledons. There are mainly three life forms found in nature- trees, shrubs and herbs.

4.2.2 Morphological characteristics of trees

A typical tree has some parts below the ground and some parts above the ground. The below ground part is root whereas above ground parts include stem and crown. These parts are discussed in the following para in brief:

A) **The Crown and branches:** The tree crown refers to the top most aboveground part of a tree which includes stem and its branches along with leaves and reproductive structures. The shape and size of the crown vary greatly with species and growth conditions. Dicotyledonous trees and conifers develop a branch system carrying the foliage, however, the crown form is much influenced by environment. The typical outline of crown is an elongated cone becoming broader and more rounded with increasing size or age. The final shape may range from cylindrical or conical in conifers to more or less oblong (in majority of the trees) and spherical forms to umbrella shaped in *Acacia planifrons.*

Branching pattern and habit is a species specific character and there are found a great variation in branching. In the majority of the trees, it appears completely unsystematic on account of the development only few buds out of many. In trees with opposite leaves such as teak and adina, the branches also tend to develop in opposite pairs, but one of the pair usually gets ahead so that the feature is only noticeable in the ultimate twigs (Champion, 1948).

The angle of branches with main stem or axis also has variations from species to species. In most trees, the angles fall between 60° to 70°, however, in some species much steeper angle of 20° or 30° has also been found. Examples are *Populus nigra*, *Cupressus sp.* and *Acacia arabica*. At the same time, there are species having branches at right angle to the main axis or placed parallel to the ground whereas in some others the angle becomes narrower and braches grown in downward direction. This is characteristic feature of conifers growing in higher elevations where snowfall is a frequent phenomenon and as a result develop drooping habit.

As far as degree of branching from the main branch is concerned, again a lot variation is found from species to species. Trees exposed to severe wind generally have a dense twiggy crown and the internodes are shorter than usual.

The most important variation in tree foliage is its deciduous or evergreen habit. The deciduous tree is leafless every year for a period which varies from a week or ten days in the case of *Shorea robusta* to over six months in Hymenodictyon. The period also varies considerably for any given species according to the climate and conditions in which it grows. Thus teak and toon are practically evergreen in favourable moist and warm localities. The old foliage do not fall until new buds unfold. A very exceptional example is of sandal wood (*Santalum album*). It is an obligatory root parasite. It can be evergreen as well as deciduous depending upon the deciduous or evergreen habit of host tree.

The old leaves of evergreens remain persistent till new foliage become well developed. In general, the life of evergreen leaves is considerably longer, commonly 2 or 3 years, and even up to 7 years or more for conifers at high elevations. Evergreen leaves are usually thicker and stronger than deciduous leaves and cast a heavier shade however, this is not always true. In dry evergreen forest many deciduous trees cast a very heavy shade during the period they are in leaf.

Shedding of smaller twigs is also regular phenomenon in some species like Cryptomeria, oaks, Emblica, and all pine species whereas there are other species in which it happens only occasionally e.g. *Bombax*.

Leaf texture is also of diverse type. By leaf texture is meant the shape and size of leaves. The leaves which are large, thick and coriaceous do not decompose easily and form a thick layer on the forest floor. Sometimes such thick leave cover is hazardous particularly for being fire prone. Further regeneration is also negatively affected. Sal leaves and pine needles are examples of this kind. There are other kind of leaves also which are thin and fragile, and decompose easily. Such leaves are beneficial from silvicultural view point as increase fertility of the soil. Further, large leaves like those of teak and Dipterocarpus or even of sal retain largere amount of water during rain and cause large drops to fall on the ground floor, and thus, is liable to be harmful to regeneration as it splashes mud over the seedlings. This drip action often results in the death of the seedling.

B) The Stem

The morphology of stem is influenced by the type of crown it carries. The lower branchless portion of the stem is known as bole.

Some trees have an inherent tendency to form a tall erect straight bole with relatively more or less free of branches, e.g. most conifers, *Dipterocarpus* sp, *Eucalyptus*, *Bombax* and *Michelia champaca*. Teak seedlings are branchless till three years. Many other trees species also show this tendency but for shorter time period.

Many species develop forked stems in response to external repeated injuries caused by lightening, hail storms or defoliation by humans etc. particularly during initial stages of growth. It is most commonly a response to external agencies or factors and can be found in individuals of many species, like deodar, chirpine, oaks etc.

Development of a clean bole is of great advantages in forestry as it is on this that quality of timber depends. In most species, however, side branches are formed and persist for varying periods, but their growth tends to cease as they are shaded by the rest of the crown above them. In some other species, it has been observed that during the period of bole formation no side branches of any size are developed and the small ones formed soon die and drop usually by or other external forces. Another important thing regarding clean bole is **Epicormic branches.** Epicormic branches are those branches which have their origin from dormant buds on shoots that have elongated in a previous period of growth. Development of such branches can reduce the quality of timber and thereby market value of the tree particularly when they develop on boles of potentially high-value trees.

Buttressed stems and fluted stem are another morphological feature which profoundly influences the quality of wood. Buttress is simply the excessive swelling at the stem bases. This is particularly found in many trees of the wet tropical forest and also in some of dry tropical regions. The buttress may sometimes extend as long as 15 feet or more up in some species. Fluted stem is irregular involutions and swellings above the stem base. It is also regarded as a serious defect in timber that affect the quality for timber.

Diameter, height and volume of trees varies from species to species. Even for a single species it varies from initial growth phases to later phases of growth. Initially

there is found mainly height growth and it is when the height growth ceases, then diameter and volume increment takes place. The maximum diameter, heights and volume has been recorded from different species are as follows:

Maximum recorded girth of trees from various localities

	CBH	Locality
Terminalia myriocarpa	46'	Assam (Lakhimpur)
Platanus orientalis	41'	Kashmir (Srinagar)
Cedrus deodara	38'9"	Jammu (Muhu Mangat)
Dipterocarpus turbinaius	28'	Burma (Thaungyin)
Tectona grandis	26'7"	Burma (Pahok)
Shorea robusta	25'8"	Uttarakhand (Ramnagar)
Picea morinda	24'8"	Jammu (Ramban)
Quercus semecarpifolia	22'8"	Jammu (Ramban)
		Source: HG Champion 1948

C) Root system

The Root: The roots is that portion of the plant which develops inside the soil and grows away from the light. Unlike stem it does not produce the leaves, flowers and fruits. The roots of trees support them firmly to the ground, absorb soil moisture containing mineral salts and send it to stem for onward transmission to the leaves and maintaining their supply to above ground portion of tree which includes stems and crown. Roots are comprised of two kinds, viz., tap root and adventitious roots.

Ci) Tap roots: The tap root is primarily descending roots formed by direct prolongation of the radicle arising from embryo. It is conical in shape, develops towards permanent moisture in the soil and sometimes, attains considerable length. According to Champion (1948), it sometimes penetrates to great depths up to 100 ft in *Prosopis spicigera* and *Acacia arabica,* and as deep as 30-47 ft. in 10 years. In *Dalbergia sissoo* (Shisham) (HG Champion 1948). The tap-root of have been reported to extend downward As the tap root grows, it develops horizontal branches and sub-branches forming rootlets, are known as lateral roots. The end of the rootlets are covered with fine hairs, called as root hairs. These root hairs spread in the soil particles, and absorb soil moisture to translocate it to stem and leaves where the food is manufactured.

The horizontal roots on the other in *Dalbergia sissoo* (Shisham) are known to spread in a radius of 8 to 12 ft. However, in some trees, they are generally confined to the area covered by the crown, but for others they extend much further and so extensively overlap the roots of the surrounding trees. Trees growing along the edges spread their roots a long way out into it, 100 ft. or more especially in worked soil. This is one reason why trees in isolation for long time are much more wind hardy in comparison to those which are recently isolated due to felling of tree around them. On the basis of depth of

the root system, the trees are classified into shallow rooted and deep rooted trees. Shallow rooted trees are those whose root system does not extend far enough into the soil to save them from relatively easy wind-throw. The deep rooted trees, on the other hand, are those whose roots go very deep in the soil.

Cii) Adventitious roots: Adventitious roots are the roots produced from parts of the plants other than the radicle or its subdivisions. Following kinds of adventitious roots are commonly found in trees:

i) Prop roots: Those adventitious roots which remain suspended in the air till they reach the ground. On reaching the ground, they enter into it and get fixed in the soil and support the thick branches of the tree, e.g. *Ficus benghalensis* (L).

ii) Stilt roots: The adventitious roots which emerge from the butt of a tree above ground level, so that the tree appears as if supported on flying buttresses, e.g. *Pandnus* (Kewra)

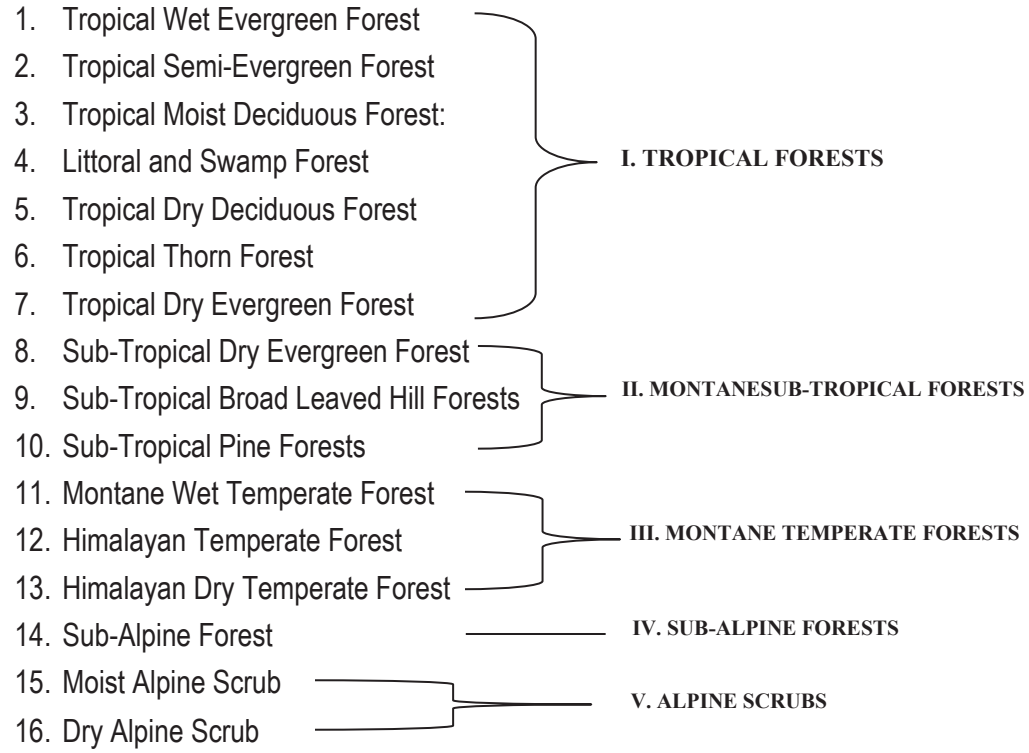
iii) Pneumatophores: This kind of adventitious roots are knee shaped and spike like projection of the roots of swamp tree, enabling the submerged roots to obtain oxygen, e.g. *Rhizophora sp. Heretiera*, *Bruguiera*.

iv) Parasitic roots: These are the specialized adventitious roots meant for absorbing nutrition and water from the host plant e.g. *Santalum album* (Chandan).

4.2.2 The Forests and Forest types

In simplest meaning, Forest is an assemblage of trees maintained mainly for production of timber and other forest produce, or sometimes maintained for deriving certain other indirect benefits such as climatic regulation or land/ soil protection. However, forests and their composition is not static but it varies from place to place depending upon climatic and edaphic condition prevailing there. Therefore, forests are differentiated into various sub categories based on its composition. Such categories are known as forest types which may be defined based on their composition, geographical location, climatic conditions and edaphic features. The forests are classified because they vary from place to place and one single set of management practices can or cannot be applied in other kinds. The classification of Indian Forest types was given by Champion and Seth in 1968. In this classification, the forests of India have been divided into five major groups and are further

subdivided into sixteen (16) type groups (Forest Types) based on climatic and vegetation. These are presented in the following figure:



1. Tropical Wet Evergreen Forest: Mainly found in Western Ghats along with its western face and south west (SW) of upper Assam through Cachar, and in Andamans. These are very lofty, multi-strata, very dense and mesophytic evergreen forests. The height of trees is usually more than 45 metres. Such forests are very diverse with numerous epiphytic species but with few climbers. The important species of these forests are Mesua, white Cedar, Calophyllum, Toon, Dhup, Palaquium, Hopea, Jamun, Canes, Gurjan, Chaplash, Jamun, Mesua, Agar, Bamboo, etc.

2. Tropical Semi-Evergreen Forest: These forests are found in the Western Coast, Assam, lower slopes of the Eastern Himalayas, Orissa and in Andamans. These are also the forests with high density and closed canopy but less than the Tropical Wet Evergreen Forests. They may have species which are evergreen also includes deciduous. These forests are also rich in diversity with heavy climbers, bamboos less prevalent and epiphytes are also in abundance. Important species include Aini, Semul, Gutel, Mundani, Hopea, Denteak, Kadam, Trul, Laurel, Rosewood, Mesua, Haldu,

Kanju, Bijasal, Kusum, Thorny Bamboo, Bonsul, white Cedar, Indian Chestnut, Lilsea, Holloch, Champa, Mango etc.

3. **Tropical Moist Deciduous Forest**: These forests are distributed throughout Andamans, moist parts of U.P., M.P., Gujarat, Maharashtra: Karnataka and Kerala. These are the forests with Irregular top storey and predominantly composed of deciduous species. Trees can attain a height of 40 m. or more. Trees are heavily buttressed. Trees in the lower canopy or second storey with some evergreens. Undergrowth include shrubs, bamboos and heavy climbers. The important species include Padauk, White Chikrasi, Kokko, Kadam, Dhup, Teak, Laurel, Haldu, Rosewood, Mahua, Bijasal, Lendi, Semul, Dhaman, Garari, Amla, Kusum, Common bamboo, Sal, Lendi, Haldu, Pula, Litsea, Jamun, Mahul, etc.

4. **Littoral and Swamp Forest:** Mainly evergreen species of varying density and height, always associated with wetness. Littoral forests are found along the coast and swamp forests in the deltas of bigger rivers. For example Sundarbans in West Bengal. Important species to this type are Sundri, Bruguiera, Sonneratia, Agar, Bhendi, Keora, Nipa, etc.

5. **Tropical Dry Deciduous Forest**: The species belonging to this category are mainly deciduous. The upper canopy remains more or less closed. Species reaches to a height of 20 m. Shrubs and herbs are present in the ground as enough light reaches the forest floor. Bamboos, climbers and epiphytes are also present. The forests are found from the foot of the Himalayas to Cape Comorin except in Rajasthan, Western Ghats and Bengal (Sangreia 1967). Some of the important species include Teak, Axlewood, Tendu, Bijasal, Khair Rosewood, Amaltas , Palas, Haldu , Kasi, Bel, Lendi, Common bamboo, Red Sanders, Anjan etc.

6. **Tropical Thorn Forest:** These are the forest found in xerophytic conditions. Such forests are mainly dominated by thorny leguminous species. Trees are of short boles and low branches, low storey has smaller trees and shrubs with spiny and xerophytic characteristics. Climbers are very few. These are found in a large strip in South Punjab, Rajasthan, Upper Gangetic Plains, the Deccan plateau and the lower peninsular India.

Important species include Khair, Axlewood, Neem, Sandalwood, Dhaman, Acacia senegal, Kanju, Palas, Aak, etc.

7. **Tropical Dry Evergreen Forest:** Forests attain a canopy of upto 12 m. high with complete canopy, mostly of coriaceous leaved evergreen trees of short boles, no canopy layer differentiation, bamboos rare or absent, grass not conspicuous. Restricted to a small area of Karnataka Coast which receives some summer rain also. Important species found in these forest types are Khirni, Iamun, Kokko, Ritha, Tamarind, Neem, Machkund, Toddy Palm, Gamari, Canes etc.

8. **Sub-Tropical Broad-Leaved Hill Forest:** These forests are distributed in the lower slopes of Himalayas in Bengal and Assam and other hill ranges such as Khasi, Nilgiri and Mahableshwar. It includes luxuriant forest evergreen species such as Jamun, Machilus, Meliosma, Elaeocarpus, Celtis etc. .

9. **Sub-Tropical Pine Forest:** These are pure forests of Chirpine. Usually fire frequencies are higher and few shrubs. Distributed throughout the whole length of North-west Himalayas between 1000-1800 m in Uttarakhand and Himanchal Pradesh. Not found in Kashmir probably due to weak SW monsoon. Important species are Chir, Jamun, Oak, Rhododendron.

10. **Sub-tropical Dry Evergreen Forest:** These are the forest which include small stunted evergreen trees along with thorny shrubs. Herbs and grasses also appear seasonally particularly during monsoon. These are found in the Bhabar, the Siwaliks and the western Himalayas upto about 1000 m. important species include Olive, Acacia, Pisfacia, etc.

11. **Montane Wet Temperate Forest:** This forest type is found in the higher hills of Madras and Kerala from 150 m upward and in Eastern Himalayas on the higher hills of Bengal, Assam and NEFA from 1800 to 3000 m. Trees are mostly evergreen types, mostly short-boled and branchy attaining large girth, height rarely 6 m., crowns dense and rounded leaves. Important species include Machilus, Cinnamomum, Litsea, Magnolia, Indian Chestnut, Birch, Plum etc.

12. Himalayan Moist Temperate Forest: This includes pure coniferous forest. Trees attain a height from 30 to 50 m. Underwood mostly evergreen. Mosses and fern grow freely on trees. Extends along the entire length of the Himalayas between the pine and the sub-alpine forests in Kashmir, Himachal Pradesh, Punjab, U.P., Darjeeling and Sikkim between 1,500 and 3,300 m. Important species include Oak, Fir, Spruce, Deodar, Celtis, Chestnut, Maple, Kail, Yew, Maple, Birch, etc

13. Himalayan Dry Temperate Forest: Predominantly coniferous forest with xerophytic shrubs, hardly any epiphytes and climbers. Found in the inner ranges of the Himalayas where SW monsoon is very feeble, precipitation below 100 mm. mostly snowfall occurs. These are distributed in Ladakh, Lahoul, Spiti, Chamba, Bashahr, Garhwal and Sikkim. Important species are Chilgoza pine, Deodar, Oak, Maple, Celtis, Parrotia, Olive, etc.

14. Sub-Alpine Forest: Dense growth of small crooked trees or large shrubs with coniferous over wood, mostly fir and birch. Conifers 30 m. high, broad-leaved trees 10 m. high. Occurs at the upper limit of tree forest in the Himalayas adjoining alpine scrub and grasslands. Himachal Pradesh. Important species are Fir, Kail, Spruce, Rhododendron, Plum, Yew, etc,

15. Moist Alpine Scrub: Low evergreen dense growth of Rhododendron and Birch. Mosses and ferns on the ground with.alpine shrubs and flowering herbs. Occurs along the entire length of the Himalayas above 3000m. Distributed in Kumaun (Uttarakhand) upto 3,800 m. Importnat species include Birch, Rhododendron, Berberis, Gardchuk, Uttis, Abies, Juniperous etc.

16. Dry Alpine Scrub: The uppermost limit of scrub·xerophytic, dwarf shrubs, over about 3,500 metres. Found in High Himalayas over 4,000 m where rainfall is low. Important species are Juniper, Honeysuckle, Artemesia, Potentilla, Rhododendron etc

The most abundant types are Tropical Dry Deciduous (29.15%) and Tropical Moist Decoduous forests (23.3%), occupying over 70% of the country's forest area, followed by the Tropical Thorn forest (6.9%), Tropical Wet Evergreen (6%) and Sub-tropical Pine forest (5%) (Sangria 1967).

Check Your Progress 1

1. Differentiate the tree, shrub and herbs.

2. Differentiate between Gymnosperms and angiosperms.
3. Differentiate monocots and dicots.
4. Write an extended note on forest types of India.

4.3 Seed Germination

Seed germination is the beginning of the next generation and is the principal means of reproduction in most of the tree or woody species. It is through this process that transfer of information (i.e, genetic materials) from one generation to the next generation takes place. The seed germination may be defined as, "the emergence and development from the seed embryo of those essential structures which indicate its ability to produce a normal plant under favourable conditions of temperature, moisture and nutrients".

As explained earlier in 5.2, the seed-producing organisms of the plant kingdom belong to the division Spermatophyta which are further subdivided into two sub-divisions- Gymnospermae (gymnosperms) and Angiospermae (angiosperms). The reproductive structures in these categories of plants begin with initiation of reproductive buds which develop into flower or strobili and finally after fertilization results into **the seeds**. When the favourable conditions come, the seed starts germinating and thus, develops into new seedlings.

4.3.1 Phase of seed germination

A seed is a ripened ovule which consists of an embryo, food storage tissue and a protective covering (Seed coat). There are three conditions which are needed in order to bring about seed germination. These are as follows:

- **viability of seeds** i.e., embryo should be alive and capable of germination
- **appropriate environmental conditions** i.e., availability of water, adequate temperature range, ample oxygen, and sometimes light also
- **Breaking of dormancy** i.e, in some of the seeds embryo remains dormant and in such cases breaking of dormancy occurs only when interaction of the seed with favourable environment happens, whereas in case of adverse environmental conditions, a secondary dormancy may develop which may cause further delay in germination of the seed.

There are normally three phases of seed germination which are explained in the following paragraphs:

Phase I - Initial phase of Germination: Most of the seeds are usually dry and contain less than 10 per cent of moisture and usually covered with a dry and hard seed coat. Therefore, in the initial phase of germination, first of all seed absorbs water for breaking of seed coat and this is followed by a tri-phasic (three-stage) increase in seed fresh weight due to water uptake. Seed germination initiates with **Imbibition** of water (characterized by an initial rapid increase in water uptake).

Phase II - Lag Phase: After imbibition of water starts a period of active metabolic activity and very low water intake. It is a period when seed remains highly active physiologically and metabolically which prepares seed for germination. Following are the cellular activities during the lag phase:

- **Maturation of mitochondria:** Dry seed contains inactive mitochondria which need to be rehydrated in order to make them active enzymatically.
- **Initiation of protein synthesis:** mRNA present in the dry seed can only become active after polysomes are formed as a result of seed hydration which further initiates protein synthesis. This process starts as soon as imbibition completes. Proteins are necessary for cell growth and development during germination.
- **Metabolism of storage reserve: The reserve food available in the seed is broken down** to produce substrates for energy production and to produce amino acids for new protein synthesis. This is the as enzymatic process.
- **Specific enzymes:** Some specific enzymes are produced which include those responsible for cell wall loosening in the embryo or tissues surrounding the embryo.

Phase III - Radicle Protrusion: Initially cell enlargement causes redicle to protrude and soon after this, cell division takes place in the radical tips. Radicle protrusion occurs when:

- the water potential of the cells in the radicle becomes more negative due to metabolism of storage reserves;
- cell walls in the hypocotyl and radicle become more flexible to allow cell expansion; or
- cells in the seed tissues surrounding the radicle weaken to allow cell expansion in the radicle

4.3.2 Seedling Emergence

Seedling emerges out of the soil as a result of division and elongation of root and shoot meristems. The embryo of higher plants consists of a shoot axis bearing one or more cotyledons and a root axis (radicle). At the seedling stage, the stem has three parts - hypocotyl, cotyledonary node and the epicotyl. **The hypocotyl** is the stem between the cotyledons and the radicle whereas in some seedlings, there is a marked swelling at the hypocotyl-radicle junction which is known as **collet or collar**. **The epicotyl** is the section between the cotyledons and the first true leaves. With the initiation of growth, the fresh and dry weight of new seedlings increases with the utilization of storage tissues and also increases the **oxygen uptake**. In the course of time, metabolic activities of seed storage decreases however, in some plants where persistent cotyledons participate in photosynthesis process. Roots also increase in size and their surface area also increases which in turn result into higher absorption of water and mineral nutrients. There are mainly two patterns of germination based on whether or not hypocotyl is raised above the ground. The one in which hypocotyl elongates forming a hypocotyl hook and raises the cotyledons above the ground is known as **epigeous germination** whereas in other pattern hypocotyl does not expand, thus, along with cotyledons also remain buried inside the soil. This kind of germination is called **hypogeous germination**. It is the epicotyl which expanses in this case.

4.3.4 Storage Reserve Utilization

Initially, new embryo remains dependent upon the storage reserves in endosperm, perisperm or cotyledons. The major storage reserves are proteins, carbohydrates (starch) and lipids (oils) which are converted to amino acids and sugars readily utilizable by early embryo for its growth and development. The embryo is dependent on the energy and structural materials from stored reserves until the seedling emerges into the light and can begin photosynthesis. Enzymes (proteinases) are required to catabolize storage proteins into amino acids that, in turn, can be used by the developing embryo for new protein synthesis. These enzymes can be present in stored forms in the dry seed, but the majority of proteinases are synthesized as new enzymes following imbibition.

Starch is a major storage material in seeds mainly stored in the endosperm but can also be found in the embryo and cotyledons. The non-living starchy substances in the

endosperms are surrounded by a layer of secretary cells called as **aleurone layer**. Gibberellin initiates the synthesis of numerous enzymes in the aleurone that are secreted into the endosperm including **amylases** that hydrolyses starch to sugar (simple sugar and maltos) that are eventually synthesized into sucrose for transport to the embryo axis. Some enzymes break down the cell walls of the endosperm to allow movement of sucrose to the scutellum for transport to the growing axis.

Lipids are stored in specialized structures called **oil bodies** located in the endosperm and cotyledons of seeds. Glyoxysomes and mitochondria are involved in the catabolism of lipids in the oil bodies. Lipids are mainly stored in the form of triacylglycerides which are catabolized to glycerol and free fatty acids. Free fatty acids are moved to the **glyoxysome** (the specialized structures present in oil-storing seeds only). Free fatty acids is converted to the organic acids, malate, and succinate using enzymes in the glyoxylate in glyoxysomes through glyoxylate cycle. Glyoxysomes and the glyoxylate cycle are unique feature of germinating seeds and are not found in any other part of the plant. The end product this biochemical process is the production of sucrose from storage lipids for use by the developing embryo.

4.3.5 Measures of Germination

Germination is said to have competed when either the radical protrudes through the seed coverings or the seedling emerges from soil or media. In either case, the time needed for individual seed among the seed lot to complete germination usually produces **a sigmoidal germination curve** which is indicative of the way a seed population behaves. There is an initial delay in the start of germination and then a rapid increase in the number of seeds that germinate, followed by a decrease in their appearance over time. It is not necessary that all the seeds of the seed lot germinate, only the viable seeds germinate. There are three different measure through which germination is measured. These are Germination percentage, Germination rate and Germination uniformity.

a) **Germination percentage** is the number of seeds that produce a seedling from a seed population expressed as a percentage. For example, if 75 seeds germinate from a seed lot of 100 seeds, the germination percentage would be 75 percent (75 germinated seeds divided by 100 seeds in the seed lot multiplied by 100 to give a percentage).

b) **Germination speed or rate** is a measure of how rapid a seed lot germinates. It is the time required for a seed lot to reach a predetermined germination percentage. For example, the time required for a seed lot to reach 50 percent germination based on the final germination percentage. This value is the **T50** and can be seen on the sigmoidal and normal distribution curves. Since this value is calculated as 50 percent germination based on the final germination, it is a more meaningful descriptor for high-germinating seed lots.

c) **Germination uniformity** measures how close in time seeds germinate or seedlings emerge. In some seed lots, the time between the first and last seedling emergence is clustered closely around the mean time to 50 percent emergence, while in others this time is spread out. One way to express germination uniformity is as the standard deviation around the mean. This can be reported as the time to 75 per cent germination (T 75) minus the time to 25 per cent germination (T 25).

4.3.6 Environmental Factors Influencing Germination

There are mainly four environmental factors which influence seed germination. These are temperature, water, gases and light. These are explained as follows:

i) **Effects of temperature:** Temperature is a most important environmental factor that regulates the time of germination. Temperature affects both germination percentage and germination speed. There are mainly three temperature points i.e., minimum, optimum, and maximum, are usually designated for seed germination. Optimum temperature is the temperature that produces the largest percentage of seedlings in the shortest period of time. It may vary from 25 and 30°C but can be as low as 15°C. Minimum is the lowest temperature for effective germination, while maximum is the highest temperature at which germination occurs.

Germination speed is usually slower at low temperatures but increases gradually as temperatures rises. However, above an optimum level, a decline in germination rate occurs as with the increase in temperature chances of injury to seed are increased.

Dry, non-imbibed seeds can withstand extremes of temperature. In nature, brush fires are often effective in overcoming dormancy without damaging seeds. Seeds show prolonged storage life when stored at low temperatures, even below freezing for dry seeds.

ii) Moisture: Water is one of the important factors that is essential to bring about germination. It acts as a limiting factor under favourable temperatures for many non-dormant seeds. The rate of water movement into the seed depends on the water relations between the seed and its germination medium. The water potential of the seed is more negative than moist germination substrates, so water moves into the seed. Osmotic potential in the soil solution depends on the presence of solutes (salts). Excess soluble salts (high salinity) may exert strong negative pressure (ex-osmosis) and counterbalance the water potential in seeds. Surface evaporation from sub-irrigated beds can result in the accumulation of salts at the soil surface even under conditions in which salinity would not be expected. Planting seeds several inches below the top edge of a sloping seed bed can minimize this problem. Moisture stress strongly reduces seedling emergence rate from a seed bed.

iii**) Light:** It has been revealed through experiments that light is needed for the germination of certain seeds. Many seeds of temperate region need a minimum period of pre-chilling (cold-treatment). Such seeds remain dormant until favourable conditions. The seeds require light for germination, however they may also germinate in dark if pre-chilled at $2^{O}C$. These observations suggest that light or pre-chilling treatment have similar action which triggers germination of seeds. It has been observed that light has an action in both dormancy induction and dormancy breaking. The effects of light on germination is dependent upon both the wavelength and photoperiod. The seed size of light sensitive seeds is usually very small and a shallow depth of planting is an important factor favoring survival whereas in case of seed being too deep in the soil, the epicotyl may not penetrate the soil. Some important flower crops requiring light for germination include begonia, coleus and primrose. Germination is also seen to be inhibited by light in certain species like *Phacelia*, *Nigelia*, *Allium* and *Amaranthus* etc.

iv) Aeration: Aeration or exchange of gases between the germination substrate and the embryo is essential for speedy and uniform germination. Oxygen (O_2) is needed for the metabolic processes i.e., respiration, in germinating seeds. In general, uptake of oxygen during germination is proportional to the amount of metabolic activity taking place in germinating seed. Oxygen supply gets reduced in the presence of excessive water for example in poorly drained seed beds, particularly after heavy rains or irrigation. Pores in such soils get filled with water which amounts expelling of oxygen

consequently reduction in available oxygen for germinating seed. Further, oxygen has low solubility and slow diffusion in water. These all conditions result in reduced supply of oxygen even though presence of 20% oxygen in atmosphere or at soil surface. However, this response of seeds varies with species to species.

iv) Carbon dioxide (CO_2): High levels of CO_2 has positive effect in overcoming dormancy in some seeds. Carbon Dioxide (CO_2) is produced during respiration and under conditions of poor aeration it can accumulate in the soil.

v) Nutrition: Generally, good seed crop is a result of a favorable nutrient conditions particularly for woody plants. It has been observed that seed production was increased after the fertilizers application especially nitrogen and phosphorus (Owens and Blake 1985). Further, high C/N ratio in shoot tissues has a role in abundant flowering (Kramer and Kozlowski 1979).

Check Your Progress 2

1. What are different phase of seed germination? Discuss in brief.
2. What is Lag phase of seed germination? Discuss.
3. Write a short note on seedling emergence.
4. What are different measures of germination? Discuss.
4. Discuss the impacts of various environmental factors on germination.

4.4 Growth and development in trees

4.4.1 Growth and Development

Growth is simply the change in size and volume of a plant or organism. It is usually an outcome of increase in size and volume of individual cells followed by their division which result into change in form and shape of plants. For example growth of shoots or growth of leaf or root. Growth may take place in whole plant or may be be limited to certain organ depending upon the stage or age of the plant. In the initial stage, whole plant body grows whereas in latter or older stage only certain parts of the plant grows. At cellular level, growth is the result of synthesis of various molecules such as nucleic acids, proteins and lipids which are generally referred to as macromolecules. These macromolecules organize into membranes and organelles such as chloroplast, mitochondria, ribosomes and others.

During the process of growth cells, some cells become specialized to perform some specific task i.e., division of labour sets in. This further results into cell division and formation of tissues. This process of cells becoming specialized is called **'differentiation'.**

Development on the other hand, is the process of growth and differentiation of cells into organs and organisms. For example, in angiosperms (flowering plants), formation of seeds and their germination, results in development of root and shoot. With further growth more branches and leaves are produced till a certain time when vegetative buds get converted to flowering buds. After the formation of flowers, fertilization takes place resulting in the development of fruits and seeds.

4.4.2 Stage of tree growth

(Source: Directorate of Forest, Govt. of WB 2016, L S Khanna 1999 and Sangeiya 1967)

There are broadly four growth stages identified through which a plant passes to attain a mature tree stage. These are as follows:

i) Seedling
ii) Sapling
iii) Pole
iv) Tree

1) **Seedling stage:** It is the first stage after germination till it reached a height of one meter. There are mainly three parts identified at this stage which are:

   - the embryonic root
   - the embryonic shoot, and
   - the cotyledons (seed leaves)

   Once the photosynthesis starts in seedlings, it stops taking energy from stored food reserve in seeds. The apical meristems start growing and give rise to the root and shoot. The first true leaves expand and can often be distinguished from the round cotyledons however, shape may vary from species to species. While the plant is growing and developing additional leaves, the cotyledons eventually grow old and fall off. The seedling grows and begins to develop woody characteristics. The stems harden, change color, and develop a thin protective bark. The stem may bend or develop branches that reach toward light. Seedlings compete for nutrients, water,

sunlight, and space. At this stage the tree is susceptible to many threats that include fire, flood, drought, disease, insect attacks, and animals.

2) **Saplings stage:** Sapling is defined as a young tree from the time when it reaches about one meter (3 feet) in height till the lower branches begin to fall. A sapling is characterized by the absence of dead bark and its vigorous height growth. As the tree starts to get taller, the main trunk thickens and lateral branches arise. A sapling has all the characteristics of a fully grown tree, however, lacks only in size and reproductive abilities. A sapling is characterized by the absence of dead bark and vigorous height growth.

3) **Pole stage:** It is a stage between sapling and tree stage when lower branches start to fall off and crown expansion is conspicuous. Generally, poles are greater than four inches but less than eight inches in diameter. Depending on the species, trees in the pole stage could be as tall as 30 feet.

4) **Tree stage:** It is the final stage of a plant individual when height growth gets slow down but expansion of the **crown** becomes more prominent. Tree is the stage of growth beyond the pole stage. With favourable conditions, a sapling or pole will grow into a mature tree (>8 inches DBH). During this stage, each tree will grow as much as its species and site conditions will permit. In addition, flowers develop, reproduction ensues, fruits form, and seed dispersal can occur. Trees provide the maximum environmental benefits to people during this stage.

   At this stage, the **crown** gets a prominent shape**.** The crown is defined as, “the upper branchy part of a tree above the bole (L S Khanna 1999 Principles and Practice of Silviculture)”. It contains live branches and foliage. Crown shape has importance in silviculture because it indicates the amount of growing space that is needed to maximize timber production. Further, it also controls light to ground surface and accordingly microclimate is defined inside the forest.

4.4.3 Growth and assimilation

During the growth of plant individuals from seedling to tree, the growth occurs in belowground (root portion) and aboveground (shoot portion) of trees. This growth occurs in vertical and horizontal axis in different stages of life and results in height and diameter growth, respectively. Growth from the root and shoot tips that results in increases in height

and length is called **primary growth**. Growth that increases the thickness of stems and branches is called **secondary growth**. Primary growth occurs in small areas called apical meristems which results in increased leaf size, height growth and increase in the length of branches and roots.

Stems and branches of trees and their roots also have growth in horizontal axis i.e., increase in thickness or diameter as a result of what is known as secondary growth. Secondary growth is actually takes place in cambium (The soft layer of cells next to bark) which after cell division and differentiation creates every year new xylem (new wood) and phloem (new inner bark) on the outside. The xylem carries water and nutrients from the roots upward, while the phloem carries sugars from the leaves downward. In the temperate climates, the cambium does not grow during the winter and a dark line can be seen in the wood indicating slowing of cambial growth at year's end. These are the annual growth rings that are visible in many species. In tropical climates, growth may occur round the year, and annual rings may not be visible. In some species, the rings are pronounced, because wood produced in the favourable conditions of spring (early wood) is less dense than wood produced in the summer and fall (latewood). Cork cambium also produces a certain amount of diameter growth. As it grows the cork cambium produces cork, the outer layer of bark. While new cork is produced each year, the outermost layer is shed so that the bark thickness of a mature tree remains nearly the same from year to year. Thus, growth in cork cambium contributes greatly to diameter growth in sapling stage as a sapling develops a thick bark, but diameter growth of a mature tree is mainly due to the production of wood by the vascular cambium.

The growth mainly depends upon **assimilation** which is the result of available food materials, water and energy plus the ability to use them. During the process of growth, part of assimilate (a result of photosynthesis) is used up for in obtaining energy for various metabolic processes (respiration). Whether a tree is vigorous or weak, a certain amount of assimilate (photosynthate) is used up in the maintenance (own energy requirements and replacement of injured parts) of its own body and this kind of use has priority over all other uses. The balance of the assimilate remains available for addition to the body mass (Growth) of the tree.

4.4.4 Flowering, fruiting and seeding

Flowering: As the individual reaches tree stage and further gets matured, the reproductive structures are developed i.e., flowering takes place. Some plant species start flowering as early as in four years such as *Dalbergia sp.* (Shisham) and *Bauhinia sp. etc.* whereas some species flower very late after 10 to 15 years of maturity. Generally, trees growing in open places flower earlier than the trees growing in dense forest. Similarly, the time of flowering has variation. Some species flower during winters whereas other flower during summer. Species like Sal and Shisham flower when new leaves develop, whereas Haldu and *Terminalia* sp. flower when there are ample leaves in them. Among the coniferous species flowering takes place in spring accept in deodar which flowers after rains.

The quantity of flowering also varies from species to species and also from one year to another year. Some years are good seed years whereas in others not. Deodar has a tendancy to have good seed years every fifth year.

A specific type of flowering has been observed in bamboo. It has an irregular flowering. Some species flower after certain interval of years. Sometimes only some of the clumps of bamboo flower (known as **sporadic flowering**) whereas sometimes all the clumps of the bamboo flower (known as **gregarious flowering**).

Fruiting: After the fertilization process, fruits and seeds are developed. These seeds give rise to next generation after their falling to the ground floor and subsequent germination. Fruiting, shape and size of seeds and time of seed germination are species specific character and varies with species to species.

Check Your Progress 3

1. Briefly discuss growth and development.
2. Discuss the various stage of growth.
3. Differentiate primary and secondary growth.

Summary

The summary of this unit is as follows:

- Plants are divided into three types- herbs, shrubs and trees although sometimes another category of plants is also identified i.e., climbers (which may be herbaceous as well as wood kind). Herbs are those plants which have delicate stems and their

shoot portion usually die at the end of season or year although the underground portion may remain live for two years or more. Shrubs are those plants that may grow up to six (6) meters in height but have many branches arising from the base. Futher, they also have woody elements in them. The trees are the large perineal plants with a well-defined wood stem and a well-defined crown.

- In silviculture, we are generally concerned with the germination, growth, development, harvesting and reproduction of tree species which belong to Gymnosperms and Angiosperms only. Therefore, a general account of these two major sub-categories is discussed herewith.
- Trees are only found in Gymnosperms and angiosperms. Gymnosperms are naked seeded plants Some of the examples are Deodar (*Cedrus deodara*), Chirpine (*Pinus roxburghii*), Thuner (*Taxus buccata*) and the giant redwood tree species (*Sequoia* gigantean). Whereas a**ngiosperms** are the other category where trees are found. They are also known as flowering plants. Here the flowers are reproductive structures in which ovules are present inside the ovary which after fertilization develops into fruits. Thus, seed are always remain protected in contrast to gymnosperms where seeds are naked.
- A typical tree has two main parts - underground part (roots) and above ground parts (stem and crown). Roots performs activities like support and anchoring the tree, absorption of water and nutrients from the soil and their transport it to above ground portion of tree i.e., stems. Roots are of mainly two kinds- **Tap root and adventitious roots**
- **Tap roots** have their origin from radicle and has a main conical root in which rootlets and sub-branches arise. The branches and branch-lets have root hairs which are engaged in absorption of water and minerals.
- **Adventitious roots** do not have their origin from radicle but originate from node and internode of stems or branches. Prop roots in *Ficus* sp, stilt roots in Pandnus (Kewra), pneumatophores in *Rhizophora sp. a*nd parasitic roots found in Chandan are examples of adventitious roots.

- Forest is an assemblage of trees maintained mainly for production of timber and other forest produce, or sometimes maintained for deriving certain other indirect benefits such as climatic regulation or land/ soil protection
- The classification of Indian Forest types was given by Champion and Seth in 1968. According to the classification, there are sixteen (16) forest types which are as follows- Tropical Wet Evergreen Forest, Tropical Semi-Evergreen Forest, Tropical Moist Deciduous Forest, Littoral and Swamp Forest, Tropical Dry Deciduous Forest, Tropical Thorn Forest, Tropical Dry Evergreen Forest, Sub-Tropical Dry Evergreen Forest, Sub-Tropical Broad Leaved Hill Forests, Sub-Tropical Pine Forests, Montane Wet Temperate Forest, Himalayan Temperate Forest, Himalayan Dry Temperate Forest, Sub-Alpine Forest, Moist Alpine Scrub and Dry Alpine Scrub.
- Seed germination may be defined as, "the emergence and development from the seed embryo of those essential structures which indicate its ability to produce a normal plant under favourable conditions of temperature, moisture and nutrients".
- There are mainly three phase of seed germination i.e, Initial phase of Germination, Lag Phase and Radicle Protrusion.
- Seedling Emergence takes place as a result of seed germination. Seedling emerges out of the soil as a result of division and elongation of root and shoot meristems. The embryo of higher plants consists of a shoot axis bearing one or more cotyledons and a root axis (radicle). At the seedling stage, the stem three parts - hypocotyl, cotyledonary node and the epicotyl.
- Initially, new embryo remains dependent upon the storage reserves in endosperm, perisperm or cotyledons until the seedling emerges into the light and photosynthesis initiates.
- There are three different germination measures that is Germination percentage, Germination rate and Germination uniformity. **Germination percentage** is the number of seeds that produce a seedling from a seed population expressed as a percentage. **Germination speed or rate** is a measure of how rapid a seed lot germinates. **Germination uniformity** measures how close in time seeds germinate or seedlings emerge.

- There are mainly four environmental factors which influence seed germination. These are temperature, water, gases and light. **Temperature** regulates the time of germination, it affects both germination percentage and germination speed. **Water** is essential for germination. **Light** is needed for the germination of certain seeds. **Aeration or** exchange of gases between the germination substrate and the embryo is essential for speedy and uniform germination as it has role in various metabolic activities. Similarly **Carbon dioxide (CO_2)** has a positive effect in overcoming dormancy in some seeds. Better n**utrition to parent crop** results in good seed crop. Further, high C/N ratio in shoot tissues has a role in abundant flowering.
- Growth is simply the change in size and volume of a plant or organism. In the initial stage, whole plant body grows whereas in latter or older stage only certain parts of the plant grows. During the process of growth, some cells become specialized to perform some specific task i.e., division of labour, sets in. This process of cells becoming specialized is called **'differentiation'. Development** on the other hand, is the process of growth and differentiation of cells into organs and organisms.
- There are broadly four growth stages – Seedling, Sapling, Pole, Tree
- The growth occurs in vertical and horizontal axis in different stages of life and results in height and diameter growth, respectively. Growth from the root and shoot tips that results in increases in height and length is called **primary growth**. Growth that increases the thickness of stems and branches is called **secondary growth**.
- **A specific type of flowering has been observed in bamboo**. It has an irregular flowering. Some species flower after certain interval of years. Sometimes only some of the clumps of bamboo flower (known as **sporadic flowering**) whereas sometimes all the clumps of the bamboo flower (known as **gregarious flowering**).

Unit 5 Forest Regeneration: Natural regeneration

Unit Structure

5.0 Introduction

In the previous unit you learnt about tree growth and development. As soon as a forest crop attains to a certain height and diameter, (which is sufficient to meet the objectives of forest owner) it is necessary to have harvesting of crop so that the owner may derive desired benefit or economic returns from the crop. Whereas if harvesting of such forest crop is not carried out, degeneration starts and results in economic / ecological losses. Therefore, harvesting and renewal (or regeneration) of forest crops are periodic and regular processes

in forestry. **Forest regeneration** is the process of renewal of forest crop by establishing young crop of the same species or any other species in an area where harvesting of old forest crop has been carried out. Regeneration of forest crop is needed as with the passage of time the value of the standing forest crop depreciates and in order to get appropriate returns, harvesting is carried out followed by re-establishment of crop.

In this unit we will discuss the various kinds of forest regeneration methods and a detailed account of natural regeneration. We will discuss natural regeneration from seeds, vegetative parts and coppice. We will also discuss the various factors which affect natural regeneration.

5.1 Learning Objectives

After completing this unit you will be able to:

- define forest regeneration
- define and explain natural regeneration
- explain natural regeneration from seed and various factors affecting it
- explain natural regeneration from vegetative parts
- explain natural regeneration from coppice

5.2 Forest Regeneration- Concept and Definition

Regeneration is basically renewal of a forest crop by natural or artificial means. It is an essential feature in scientific forestry and the sustainability of forest yield depends upon it. A regeneration method may be defined as, “an orderly procedure or process by which a forest is renewed or established either by natural means or by artificial means or by a combination of these both”.

The process of regeneration starts only after the forest crop or stand is harvested. It includes both the **removal of the old stand** and the **establishment of a new crop**. Thus, there are two broad activities involved in the forest reproduction i.e., harvesting of the mature forest crop and thereafter, establishment of new crop. The former process (harvesting) can be controlled completely by humans, however, in regeneration humans have only partial control (limited up to seeding or sowing) whereas majority of it is under the control of nature in both natural regeneration as well as artificial regeneration. A number of factors relating to climate,

soil, water and physiography have direct or indirect effect on establishment of crop after seed germination (natural regeneration) or planting (artificial regeneration) processes.

5.3 Methods of Regeneration

The establishment procedure of new forest crop in a given area forms the basis of distinction between the regeneration methods. Three such methods have been identified. These are as follows:

1. **Natural regeneration:** Natural regeneration is defined as the renewal of a forest crop by self-sown seeds or by coppice or root suckers.
2. **Artificial regeneration:** It is carried out though seeds or plants which are brought to the plantation site by human beings.
3. **Through a combination of natural and artificial means:** Here the natural regeneration is assisted artificially by human beings.

5.4. Natural regeneration

Natural regeneration is defined as the renewal of a forest crop by **self-sown seeds** or by other vegetative parts such as **coppice shoots or root suckers**. Natural regeneration may originate from one of the following sources i.e., seeds, stool shoots, natural layering, suckers or Detached vegetative parts. However, natural regeneration takes place mainly by seeds. There are very few species in which it arises through stool shoots or by other vegetative means. Thus, natural regeneration in an area can be categorized on two main categories:

a) **Natural regeneration by seed:** Such forests are called '**high forest**' or '**seedling crop**'. This is the sexual method of regeneration in which the new plant exhibits the characters of both the parents.

b) **Natural regeneration by vegetative parts:** This is asexual method of regeneration and the new plant exhibits the characters of the parent plant only. When regeneration is obtained from coppice, it is called coppice crop, and the latter develops into a forest called **coppice forest**.

5.4.1 Natural regeneration from seed

Natural regeneration through seeds depends upon following conditions:

- Location of seed trees in nearby the regeneration area. Natural regeneration is impaired if seed trees or seed sources are remotely located.
- No. of seed trees should be sufficient to meet the regeneration needs of the area. Very few seed trees cannot fulfill the seed requirements.
- Edibility of seeds by rodents or other animals causes adverse impacts on natural regeneration even if seed supply is ample.
- Establishment of young plants make the site conditions unfavorable for seed germination, thus, cause hindrance in seed germination.
- Favourable conditions for seed production enhance the chances of natural regeneration
- suitable soil conditions for seed reception, seed germination and survival of seedlings
- Sufficient light and soil space for growth and development of young plants

There are mainly four important requirements of natural regeneration from seed on which depends the success or failure on the method. These are as follows:

- Seed production
- Seed dispersal or dissemination
- Seed germination
- Establishment of seedlings

5.4.1.1 Seed Production

The first essential requirement for a natural regeneration to take place in an area is the availability of **fertile seeds** (or quality seeds) in sufficient quantity. It depends on nature of species, age of the trees, soil conditions, temperature and climate, crown and other external factors.

Seed production is primarily a **species specific character** which is largely a reflection of its genetic makeup. Most of the species seed annually, however, there are some species which do not seed annually. Some species have abundant seed supply every year (examples *Tectona grandis* -Teak, *Dalbergia sissoo*-Sissoo, Shisham and *Acacia sp.*) whereas other either have abundant seed supply after certain period or other do not have seed production

in abundance or have a poor seed production yearly or periodically even. In such species, which do not produce seeds at the end of each year but produce after certain gap of years i.e., periodically, in such cases, the concept of **seed year** prevails. In such cases, **seed year** may be defined as, "**a year in which a given species produces large seed crop over a sizeable area**". However, the amount of seeds for same species in different seed years may not always be uniform. Amount of seeds also varies from species to species and also the interval of years i.e., periods, also vary from species to species. Seed years are categorized as Good, Normal and Poor seed years based on the amount of seed produced.

Species	Seed years
Cedrus deodara (Deodar)	4-5 years
Shorea robusta (Sal)	2 years
Terminalia chebula (Harar)	3 years
Source: Directorate of Forest Deptt., WB, 2016)	

Another factor that influences seed production is the **age of trees**. It has been observed that maximum seed production occurs when the height increment ceases. The main cause of this is the availability of ample amount of growth materials such as carbohydrates for seed production after increment cease otherwise most of it is utilized in height increment. It has also been observed that seeds produced in young trees, if any, are comparatively very less in number and that too with poor seed vigour and poor viability. On the other hand, trees with large crowns produce best quality seeds with large quantity.

Climate is another very important factor on which amount and quality of seeds depends. Generally, hot climatic conditions favour higher number of seeds. This is particularly attributed to metabolic activity which is more in hot climate than cold climate. A warmer **climate** favours early and heavy seed production. Best seeds are produced from middle-aged to medium-sized parent trees.

Soil condition also influence seed production. Soils with sufficient bases, adequate nitrates and higher C/N ratio are favourable for it.

Other external factors include rainfall, fire injury, diseases and other external injuries. Rainfall particularly during the pollen dispersal reduces the seed production considerably as pollens are taken away with water. **Diseases or other external injuries** reduce seed production, whereas fire incidences catalyze seed production. **Pruning of trees** also enhances seed production. Fungus, insect attack and girdling also influence seed production.

5.4.1.2 Seed dispersal or dissemination

Another important factor that influences natural regeneration is dispersal of seeds. Good regeneration depends upon the adequate dissemination of seeds on the regeneration site. Seed dispersal takes place by air, water, insects, birds, animals or humans.

Seed dispersal by wind: Species in which seeds are light weighed, hairy or winged are disseminated by wind. **Winged seeds** are found in species of *Dipterocarpus*, *Termenilias*, Conifers, *Holoptelia*, *Dalbergia*, *Acer*, *Pterocarpus*, *Adina*, *Betula*, *Rhododendron*, and *Oroxylon*. **Hairy seeds** are found in *Bombax*, *Populus*, *Salix*, *Eupetorium, Saccharum* and *Imperata*.

Seed dispersal by water: Examples of water dispersed seeds are most mangrove species, *Shorea* (Teak), *Dalbergia* and *Trewia.*

Seed dispersal by gravity: Seeds are dispersed by gravity in case of the following species, namely, Acorns of Oaks, *Juglans regia*, *Diospyros* and other heavy seeded species on sloping ground.

Animals: Seeds of *Prunus*, Mulberry, Loranthus etc are **dispersed by birds**. Seed *Acacia arabica*, *Prosopis juliflora*, *Ziziphus*, *Anthocephalus* etc. are dispersed by animals.

Explosive mechanism: Some of the species has specific explosive mechanism for seed dispersal. Examples are Oroxylon and species of family acanthaceae.

5.4.1.3 Seed germination

Germination of seeds in natural conditions depend upon certain factors such as:

- Permeability of water through seed coat
- Permeability to Oxygen which is needed in metabolic activities
- embryo should be fully developed at the time of seed fall
- After ripening process- This is the most common cause of delayed germination due to the embryo being chemically unready. Such seeds germinate only when they have undergone a process of after ripening.
- Size of seed – Very minute seeds are washed away in the rain water, whereas very big seeds do not get properly covered by soil or humus, and do not germinate.

- **Viability of seeds** means potential capacity of a seed to germinate. Seeds of some species retain their viability for a long period while those of certain other species lose their viability very soon

- **Germination capacity** is the percentage of seeds in a given sample that actually germinate, irrespective of time. Germination capacity of some species is given below:

Table: Germination capacity Species

10-20	*Abies pindrow, Anthocephalus cadamba*
20-30	*Cassia fistula*
30-50	*Bombax ceiba, Tectona grandis, Cypressus torulosa*
50-70	*Acacia Arabica, Dendrocalamus strictus, Terminalia, tomentosa, Toona ciliate*
70-90	*Acer campbellii, Butea monosperma, Acacia catechu, Albizzia procera, Juglans regia, Shorea robusta*
90-100	*Albizzia lebbek, Artocarpus chaplasha, Cassia siamea, Dalbergia sissoo.*

(Source: L S khanna 1999 Principles and Practice of Silviculture)

- **Plant percent:** All the seedlings that come up after successful germination do not survive owing to adverse environmental factors. An important indicator of how many seedlings will eventually establish themselves is the Plant Percent. Plant Percent is defined as percentage of the number of seeds in a sample that develop into seedlings at the end of the first growing season. Following table gives values of plant percent and germination capacity of some important species:

Species	Germination capacity	Plant percent
Acacia arabica	50	26
Shorea robusta	80	66
Tectona grandis	50	25
Terminalia tomentosa	70	29
Gmelina arborea	85	30
Dalbergia sissoo	90	78
Abies pindrow	13	6

(Source: L S khanna 1999 Principles and Practice of Silviculture)

- **External Factors such as** temperature, moisture, air (oxygen), light and location of seed inside the soil depth influence the seed germination in various ways. Although most of the species are indifferent to Light conditions for germination, however, certain species require light while some others require shade for germination.

  Species requiring light – *Rhododendron sp.*, *Albizzia procera*, *Cassia fistula*

  Species requiring shade – *Swietenia macrophylla*, *Santalum album*

5.4.1.4 Seedling Establishment

Good germination does not necessarily ensure that plantation or regeneration is successful. There are many factors which cause death of a number of seedlings such as frost, drought or other climatic factors or biotic factors such as weeds, grazing, forest fires etc. Therefore, after germination, establishment of seedling is necessary so that it may withstand the external factor. **Establishment** is defined as, "the development of a new crop to a stage when the young regeneration is considered safe from normal adverse influences such as frost, drought or weeds, and does not required any special protection measures or tending operations other than cleaning, thinning and pruning". The establishment of seedling is affected by soil moisture, soil nutrients, soil humus, soil aeration, development of root system, light conditions, grazing, browsing, forest fires and weeds etc.

Seedlings require water and food for their growth and development for which they are dependent on soil. Therefore, presence of soil moisture and availability nutrients in the soil positively affect seedling growth whereas presence of thick humus negatively influences seedling establishment as humus poses obstruction in penetration of roots to deeper layers of soil and it is particularly more harmful in dry or drought conditions. Presence of thick layer of humus is also indicative of deficiency of nutrients. Further, good aeration of soil coupled with good soil texture ensures adequate supply of oxygen and facilitates early establishment of seedlings. In addition to this, faster the root development in the seedlings the more easily and quickly such seedlings establish in the field.

Light is one of the important requirement of phosynthesis and thus, help in establishment of seedlings through quick root development. However, requirement of light varies from species to species. Therefore, plants can be classified based on their light requirements which are as follows:

i) Light demanders (requires abundant light for its best development)

ii) Shade bearers (capable of persisting and developing under shade) and

iii) Shade demanders (requires, at least in its early stage, some shade for normal development).

Note: Seral species are generally light demanders and their regeneration can be obtained under overhead light conditions. However, climax species or species

which occur in the later stages of succession are usually shade bearers, and their regeneration is best obtained under the shade of some over wood.

5.4.2 Natural Regeneration from vegetative parts

Natural regeneration from vegetative parts in forest trees is mainly attained from coppice shoots, natural layering, suckers and detached vegetative parts.

5.4.2.1 From coppice shoots

The regeneration from coppice shoots is carried out by two ways i.e., seedling coppice and stool coppice.

Seedling Coppice is defined as, "the coppice shoots arising from the base of seedlings that have been cut or burnt back". This method of regeneration is applied to woody shoots and established reproduction which has not made satisfactory progress. It is generally used in case of Sal and Teak. In situations where advance growth of Sal or Teak remain stagnant, it is cut back and given proper light conditions to help grow fast.

Stool coppice, on the other hand, is the coppice arising from the stool or a living stump. Regeneration in this method is obtained from the shoots that develop from the adventitious buds of the stump of felled trees. The reproduction through stool shoots is made use of in the coppice silviculture system.

5.4.2.2 From other vegetative parts

Natural regeneration other than coppice occurs in forest tree by natural layering, suckers and detached vegetative parts, however, species of this kind are very few. Regeneration in mulberry sometimes arises by natural layering, whereas beech and black locust often reproduce from root suckers. Reproduction of certain willows and *Opuntia* are examples of natural regeneration from detached vegetative parts.

Check Your Progress 1

1. Define forest regeneration. Discuss in brief the methods of regenreations.
2. What is natural regeneration? Discuss natural regeneration from seed.
3. Discuss the various factors affecting seed germination.
4. What do you understand by 'viability of seeds'. Discuss in brief.
5. Write a note of germination capacity and plant percent.
6. Why is there need of care after seed germination? Discuss.

5.4.3 Factors affecting Natural Reproduction

There are a number of factors which directly or indirectly affect the establishment, growth and development of forest crops. Method of harvesting is most important factor which control the establishment of natural regeneration. Other factors include climatic conditions, supply of seed, and occurrence of forest fire, and influences of biotic factors (i.e, that of animals, insects, and fungi). In order to ensure successful natural reproduction there must be:

- Abundant seed supply in excess of that destroyed by rodents, insects, and other agencies
- Favorable conditions for germination of seed
- Favorable conditions for the growth of seedlings

Theoretically, the reproduction method to large extent controls both the species composition and the arrangement of species in the new stand, however, practically it has been observed that the degree to which this control can be exercised is governed by the reproduction method employed, by the complex of factors affecting the establishment of reproduction, and by the degree of intensity with which in a given place silviculture is applied.

Natural Regeneration in Virgin Forest

After attaining maturity in a virgin forest, the trees die and fall on the ground. The small openings so created here and there may receive seed from the surrounded seed trees. The other sources of natural regeneration are stool shoots, natural layering, suckers or detached vegetative parts. In such places, the soil happens to be in excellent condition for seed germination. Suitable light and soil conditions in the openings results in the germination of thousands of seeds and thus, seedlings fill every opening. However, in the presence of some external disturbances or agents which destroys a large number of trees at one time, it is usually seen that natural regeneration occurs very slow and with difficulty.

5.5 Natural regeneration from seed under various silvicultural systems

5.5.1 What is silvicultural system?

Silvicultural system as defined by Troup (1928) is " the process by which the crops constituting the forest are tended, removed and replaced by new crops resulting in the production of woods of a distinctive form". Based on the origin of forest crop, the various silvicultural systems are broadly categorized in to two categories:

A) **High Forest Systems:** Those having origin from seed or transplants. It includes Clear-felling system, Shelterwood system and Selection System

B) **Coppice Systems:** Those which have their origin from coppice shoots. It includes mainly coppice system and coppice with standard systems. However, there are other variation also.

5.5.2 Natural regeneration under clear felling system

In clear-felling system, the mature crop is removed in one operation and site becomes bare. If reproduction in the cut over site is planned to be established through natural regeneration, then it can be obtained by one or more of the following methods:

- Seeds from trees adjacent to the clear cut area;
- Seeds lying dormant on the ground or left in the slash and debris;
- Seeds borne by the trees in the coupe of the year before they are clear felled;
- Advance growth already existing in the annual coupe as a result of previous seed years.

5.5.2.1 Seeds from trees adjacent to the clear cut area

While undertaking adjacent trees as seed source, following point should be kept in mind:

- Seeds of the desired species must have mobility and should be dispersed in sufficient quantity to reach the extreme end of the clear felled area
- If seeds have low mobility, the clear cut area should be in the form of narrow strips
- The cutting should be done from the opposite end of the direction of wind
- The cutting should be done before seed-fall
- The species must be the one having good seed years annually

5.5.2.2 Seeds lying dormant on the ground or left in the slash and debris

- The seeds should be capable of lying dormant in the soil without loss of viability and germination power, e.g dehiscent fruits of Teak
- The felling refuse scattered all over the area should not be disposed by burning and may be collected from places of limited extent so that dormant seeds are not destroyed.

5.5.2.3 Seeds from the clear felled trees of previous year

- The felling refuse should be disposed of and the shrubs cut and burnt down so as to provide a clean ground for natural regeneration to come up

5.5.2.4 Advance growth of previous seed years existing in the annual coupe

- If the advance growth does not coppice, disposal of felling refuse by burning all over the area has to be ruled out.
- If the advance growth is a coppicer, and is sufficient to restock the area, burning of slash may be done in the area.

5.5.3 Natural regeneration under shelter wood system

In shelterwood system, the mature crop is removed in a number of harvestings or stages depending on the progress of regeneration. The first felling is known as **seeding felling** whereas the last one as **final felling**. All other felling, if any, are known as **secondary felling**. The interval between the seedling felling and final felling on a particular area such as a compartment is called **regeneration period**. The Shelterwood systems are also of various kinds such as Uniform Shelterwood system and Group Shelterwood System. The basic principle of all the shelterwood systems is to allow regeneration to grow up under the shelter of seed trees so that appropriate protection is provided to the developing regeneration. The various operations carried out in order to augment natural regeneration are as follows:

- **Adequate supply of seeds:** In order to ensure adequate supply of seeds for natural regeneration in the felled areas, suitable number of middle aged trees with well-developed crown are retained. However, number of trees to be retained varies from species to species. For example, in case of *Adina cordifolia* one to two seed trees are sufficient to supply ample seeds per hectare whereas in case of *Shorea robusta thiry to* forty trees per hectare are usually needed.
- **Adjustment of light:** The function of the overwood is not only to supply seeds, but also to permit optimum light reaching the forest floor for germination. This is primarily achieved by suitable manipulation of canopy, that is by removal of certain trees of overwood which are not required for supply of seeds. As light is obstructed by the middle storey and undergrowth as well, middle storey is suitably thinned, and undergrowth density is reduced to admit sufficient light to the forest floor. The standard method of

containing the density of undergrowth consists of regular cutting back, uprooting, controlled burning, use of weedicides etc.

- **Soil condition:** Soil needs to be permeable to help the tap roots of seedlings reach the depths of permanent soil moisture. It may therefore be necessary to undertake site specific soil working measures to improve the permeability and porosity of the soil. In order to correct the condition of moisture deficiency, soil works like contour bunds may be done.
- **Weeding and cleaning-** Immediately after the germination of the desired species, weeding is done to protect the young seedlings against weeds which compete with desired crop for light, nutrients and moisture. Generally weeding is done before the weeds get a chance to suppress the regeneration of desired species. When regeneration grows up to the stage of sapling, cleaning is undertaken. Cleaning consists of removal or topping of inferior growth and climbers etc when the latter interfere with the growth of the favoured species.

5.5.4 Natural Regeneration under Selection System

Selection system, in its simplest form, consists in harvesting the trees which have attained exploitable diameter/ rotation age. The trees are selected from the whole forest after defined period for felling and felling of which results in creation of gaps. In these gaps, natural regeneration is allowed to come up. However, keeping in view the large are of forests, it is not advisable to have such operations in entire area. But for the ease of convenience, such forests are divided into a number of coupes (cutting sections) in which harvesting and regeneration is carried out at defined interval of years. This defined interval is known as **Felling Cycle (F.C.).** Felling cycle may be manipulated to obtain regeneration of a desired crop. For example, selection system with a short felling cycle is suitable for regeneration of climax shade-bearing species, while a long felling cycle may be utilized for securing regeneration of sub-climax light demanding species. Selection system requires not only harvesting of selection or exploitable sized trees, but also undertaking of simultaneous thinning in all the age classes in the coupes so that normal distribution of age classes is maintained in the resulting regeneration.

5.5.5 Natural regeneration from coppice under simple coppice system

Simple coppice system is defined as, "the Silviculture System based on stool coppice, in which the old crop is clear-felled completely with no reservation for sheltered wood or any other purpose". It is applicable to species which coppice vigorously. The coppice rotation is usually kept as 20 to 40 years. In the year following the clear felling, coppice shoots of inferior species which are found to interfere with the favoured species are removed. If the number of coppice shoots per stool is more than two, the most promising two shoots are kept and the rest are cut back. After a year or two, only one shoot per stool is retained by cutting down the other. As stumps cannot continue to give out coppice shoots indefinitely, natural seedlings appearing at the site are allowed to grow. The blanks are regenerated by sowing or planting.

5.6. Assisting natural regeneration (ANR)

5.6.1 Gap planting in barren patches

When the forest area in question is not regenerated fully during the regeneration period, forest managers are presented with two alternatives. One is to increase the regeneration period and wait for the area to be regenerated over an extended period of time, and other alternative is to fill up the gaps artificially and complete the process of regeneration. The usual practice is to choose the second alternative and take up the failed patches of regeneration area for sowing or planting. It is always advisable to undertake the filling up work as early as possible, as otherwise the blank patches get quickly occupied by grass and weeds.

5.6.2 Tending Operations

As a measure of ANR, the regenerated crop is subjected to tending operations. The object of tending operations is to reduce the degree of competition for light, food and water among between the desired species and the undesired ones, and also among the individuals of the desired species.

Tending is 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 (L S Khanna 1999)". It covers operations both on the crop itself and on the competing vegetation. Tending includes

weeding, cleaning, thinning, improvement felling, pruning, climber cutting, girdling of unwanted growth and coppice thinning etc.

5.6.3 Soil and water conservation measures

A growing natural regeneration, like any other developing forest stand, would require favourable soil and water conditions for optimum growth and early establishment. The natural regeneration will, therefore, be aided considerably if soil and water conservation measures are undertaken at the regeneration site. The measures may include construction of suitable earthen dam, contour bunds or trenches and gully control measures, etc.

Check Your Progress 2

1. Discuss the various factors affecting natural regeneration.
2. Discuss the natural regeneration from seed under clear-felling and shelter wood systems.
3. What is ANR? Discuss in brief.

Summary

In the previous unit you came to know about germination, growth and development of trees which ultimately result into a mature forest. In this unit, forest regeneration and its types have been discussed. A detailed discussion on natural regeneration of forest crop has been carried out. It can be summarized as follows:

- Regeneration is defined as, ”the renewal of a forest crop by natural or artificial means”. In other way, a reproduction method is, “an orderly procedure or process by which a forest is renewed or established either naturally or artificially or a combination of both”.
- There are broadly two activities involved in the regeneration process which are - harvesting of the mature forest crop and re-establishment with new crop
- There are two methods of forest regeneration - natural and artificial, however, in practice, a combination of these two methods is also sometimes practiced. Thus, regeneration in a forest may be brought about by- **Natural regeneration, Artificial regeneration and through a combination of these two.**
- Natural regeneration may be obtained from the two sources such as f**rom seed and from vegetative parts.**

- Success of natural regeneration depends upon the availability of sufficient amount of fertile seeds, viable seeds and dissemination of seeds to desired places.
- Success in seed germination depends upon various internal and external factors. The internal factors include permeability of water, maturity of embryo, viability of seeds, size of seed and Germination capacity whereas external factors include Temperature, Moisture, Air /oxygen, light and soil depth above the seed.
- Another important step that ensures plantation success is seedling establishment which is affected by soil moisture, soil nutrients, soil humus, soil aeration, development of root system, light conditions, grazing, browsing, forest fires and weeds etc.
- Seral species are generally light demanders and their regeneration can be obtained under overhead light conditions. However, climax species or species which occur in the later stages of succession are usually shade bearers, and their regeneration is best obtained under the shade of some over wood.
- Natural regeneration from vegetative parts in forest trees is mainly attained from coppice shoots, natural layering, suckers and detached vegetative parts.
- Natural regeneration under clear felling system can be obtained by seeds from trees adjacent to the clear cut area, seeds lying dormant on the ground or left in the slash and debris, seeds borne by the trees in the coupe of the year before they are clear felled and advance growth already existing in the annual coupe as a result of previous seed years.
- Natural regeneration under shelter wood system is obtained from the seeds available from shelterwood. Here the mature crop is removed in a number of harvestings or stages depending on the progress of regeneration. The first felling is known as **seeding felling** whereas the last one as **final felling**. All other felling, if any, are known as **secondary felling**. The interval between the seeding felling and final felling on a particular area such as a compartment is called **regeneration period**. The basic principle of all the shelterwood systems is to allow regeneration to grow up under the shelter of seed trees so that appropriate protection is provided to the developing regeneration.

- Natural Regeneration under Selection System is obtained in the gaps created by harvesting the mature trees which have attained rotation age. The trees are selected from the whole forest for harvesting and it results in creation of gaps. In these gaps are filled up through natural regeneration.
- Natural regeneration under simple coppice system is obtained from the stool coppice which arise in the stool resulting from the harvested tree. This is possible only in species which coppice vigorously. The coppice rotation is usually kept as 20 to 40 years.
- Assisting natural regeneration (ANR), is the gap planting in barren patches when the forest area under natural regeneration has some patches remain incomplete due to some reason like failure or injury or other reasons. Such areas are regenerated through sowing or planting.
- Tending Operations are carried out as a measure of ANR. The objective is to reduce competition for light, food and water among the desired species and also with the undesired ones. Tending includes weeding, cleaning, thinning, improvement felling, pruning, climber cutting, girdling of unwanted growth and coppice thinning etc. Further, soil and water conservation measures are also essential for successful regeneration. These are also part of ANR in natural regeneration.

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Unit 6 Forest Regeneration: Artificial Regeneration I

Unit Structure

6.0 Introduction

In the previous unit, we discussed about forest regeneration and its kinds. The two kinds of forest regeneration are – Natural and Artificial regeneration. Natural regeneration was also discussed in detail.

In the present unit, we will discuss about artificial regeneration. It is a kind of regeneration in which humans play a major and important role. Artificial regeneration refers to involvement

of human beings in all processes such as seed collection, germination, sowing, and other measures in nursery and fields. Thus, in artificial regeneration, regeneration of desired crop is carried out from the seeds collected from some seed source or transplants developed by sowing seeds in a nursery which are then sown or transplanted in plantation site by humans or by machines. In this unit, we will discuss the principles of artificial regeneration, methods and activities in artificial regeneration.

6.1 Learning Objectives

After completing this unit you will be able to:

- define artificial regeneration
- explain artificial regeneration
- list out various activities which are carried out in regeneration site
- identify the various factors which influence it

6.2. Artificial regeneration and its objectives

Artificial regeneration is defined as, "the renewal of forest crop by sowing, planting or other artificial means or methods". The crop resulting from artificial methods of regeneration is commonly known as 'plantation' or 'plantation crop'.

As far as objectives of artificial regeneration are concerned, they are reforestation and afforestation activities. **Reforestation** means re-establishing or stocking of an area which has been harvested earlier or otherwise cleared whereas **Afforestation** means establishment of a forest stand or crop of desired species in an area by artificial methods where forest vegetation has always or long been absent.

Reforestation is carried out for:

- Supplementing natural regeneration (ANR)
- Replacing natural regeneration, where natural regeneration of the desired species has not been successful or in areas where plantation has been failure or cannot be accomplished within reasonable time and money

- Where there is need for changing species' composition and objective is to increase the proportion of a more valuable species in order to derive more benefits
- Introducing valuable exotic species

Afforestation is carried out for fulfilling one or more of the following objectives:

- **Productive purpose** (raising a particular kind of forest crop, for example, afforestation of wastelands, afforestation of grasslands
- **Protective purpose** (conservation of soil and water, for example, afforestation of catchment and swampy areas)
- **Bio-aesthetic objects** (conservation of biodiversity, wild life and recreation purpose for example ecological parks)

Artificial regeneration demands appropriate planning, time and investment of money. Therefore, it is adopted when these basic requirement particularly time and money are available and is expected to give more benefits in return. Artificial regeneration is adopted when there is/ are:

- absence of natural seed source for the desired species
- a need to change the species composition of the forest stand
- a need to make genetic improvements in the species
- strict requirement to have adequate density or spacing of the crop
- need to control time and duration of establishment period
- repeated crop failures

6.3 Preliminary activities before artificial regeneration

Certain preliminary activities are required to be carried out before the start of artificial regeneration activity in an area or land selected for the purpose. Broadly, these preliminary works or activities include following three categories:

- Choice of species.
- Fencing.

- Reclamation of the soil.

6.3.1 Choice of species

The first preliminary requirement for artificial regeneration is judicious selection of species for regeneration. It is this step that is important in order to be successful in meeting the object of management under a given set of conditions. Once a selection is made and plantation is done, one cannot rectify the mistake, if any, done in selection of species. .

Artificial regeneration in an area demands large amount of money, labour and other technical inputs, therefore, selection of species is one of the important consideration. The choice of species for artificial regeneration in an area is usually governed by the following factors:

1) Climate and micro-climate: Species that are suitable for local climatic conditions are generally preferred. Such species are generally indigenous or native ones and which grow well in the nearby areas, and are also observed to have performed well in such localities. However, if exotic species are planned to be opted for artificial regeneration, then the climatic conditions of their land of origin should be suitably matched with the local climatic conditions of plantation site and only after climate is matched such choice should be made.

(2) Soil conditions: Choosing species well adapted to the soil and moisture conditions is another important factor on which the success of a species depends. Such species grow better and tend to have less health related issues. In immature soils, seral species which come early in the succession are selected, and in mature soil, climax species which come in the advance stage of succession, are selected. The undergrowth growing on a site also sometimes gives a good indication of species that can be successfully raised.

(3) Object of management: Object of management is another factor that governs the choice of species. For example, if the objective is to raise pulpwood, the species which can yield pulp of good quality and quantity (Example- Popular) may be chosen. If the object is to produce timber, a major part of planting stock could be of *Dalbergia sissoo* (Shisham) or *Tectona grandis.* (Sagaun) or *Shorea robusta.* (Sal). Objects of forest managements are usually written on working plan along with prescription of the species to be raised.

(4) Market requirement or stakeholders' requirement: It is generally the market requirement on which depends the choice of stakeholders. Therefore, choice of species is dependent on market demand and stakeholders' requirement. Besides the Forest Department of the State, members of the Joint Forest Management Committee (JFMC) are the major stakeholders in the forest management. The requirement of the JFMC members should, therefore, be ascertained while making choice of species.

(5) The silvicultural system: The silvicultural system under which the forest stand is to be worked, forms a guiding factor. For example, strong light demanding species are preferred in clear-felling system, whereas species of intermediate light requirement are preferred in shelterwood system. In selection system, shade-bearing species are found suitable.

(6) Availability of suitable exotics: If indigenous species cannot meet some specific demand of the locality or some industrial demand, exotic species with proven suitability for the site can be selected. Examples are *Eucalyptus* and *Acacia auriculiformis* in the south-western part, *Casuarina equisetifolia* in the coastal area, and *Cryptomeria japonica* in north Bengal hills.

(7) Growth rate: The growth rate also influences the decision on choice of species. To meet the increasing demand of industrial timber and fuelwood, fast growing species must be selected.

(8) Ease of establishment: The ease with which a species can be established affects the choice of species. Examples are choice of *Eucaluptus* in the south-west Bengal, and Dhupi and Utis in north Bengal hills. While there is reason to favour the species that can be raised easily, such consideration should not overplay in ignoring those indigenous species which have great ecological or medicinal value or are otherwise important.

(9) Effect on site: The long-term effect on the site factors should be considered while making the choice of species. A species, apparently attractive, may in the long run prove to be causing deterioration of the site. In the hill catchment area, where the aim is to get maximum usable water, species with low transpiration rate should be favoured. For arid and dry areas, non-exacting species are preferable. Pure Teak may not be good for soil health; it should be mixed with suitable shade-bearing and soil improving species like bamboo, Swietenia etc.

Important consideration

In artificial regeneration such species are never taken up for plantation which are outside its natural range until and unless such species has been tested practically and results favour it.

6.3.2 Selection of site

Selection of site is one of the important consideration and needs study of a number of factors in order to ensure success of plantation activity, if, afforestation is to be carried out in barren areas or grasslands or other areas whereas clear-felled or otherwise cleared area, this step is automatically skipped as the plantation site is predefined. In case of afforestation of barren land or other lands, it is very important to select the site according to the species. It is on this selection in which success or failure of the plantation depends. Bio indicators are sometimes advantageous in this process as such species give some indication about the soil conditions and suitability of soil for particular species.

6.3.3 Methods of artificial regeneration

Artificial regeneration in the plantation site can be carried out either directly by sowing seeds or by transplanting seedlings or cuttings raised in nursery or by adopting a combination of sowing as well as planting methods.

As far as planting vs direct seed sowing are concerned, the former:

- tends to have higher costs of operations
- is adopted only when natural regeneration is likely to receive failure
- is adopted when important considerations like species selection and genetics are the main objectives

In practice, a combination of these two is practiced.

6.3.3. Choice between sowing and planting

Choice between sowing and planting methods depends on:

- **The species to be raised:** Generally slow growing species or the species whose seeds remain enclosed in a hard coat are preferably raised by planting method.
- **Conditions of the site:** In areas with poor soil conditions or adverse climatic conditions, the method of plantation is by planting method due to higher probability of success than seed sowing method.
- **Availability of seed:** Species having poor seed production or hard to regenerate are preferably raised by planting.
- **Cost:** The factor of cost has to be considered together with degree of success of the method. The method which gives success at reasonable cost is preferred.

6.3.4 Spacing

Spacing is the distance between the plants in the plantation site. In order to describe the spacing, the distance between line to line and plant to plant is mentioned. For example 4 m X 2 m spacing means the distance between lines to line is 4 meter whereas distance between plants in a line is 2 meter. The working plan of coupe should have clear mention of plant spacing. Generally 2m x 2m plant spacing is adopted, however, it may vary from place to place. A spacing of 2m x 2m means 2500 plants per ha whereas 2.5m x 2.5m spacing gives a crop density of 1600 per ha. However, considering that there are blanks in the plantation area in the form of inspection path and blank strip around the boundary, the actual crop density would be slightly less than the figures mentioned above.

6.3.5 Arrangement for staff and labour

Plantation is a programme which is impossible in the absence of suitable labour force. It requires all kinds of labour i.e., skilled, semi-skilled as well as unskilled in order to carry out various plantation activities. Therefore, before any plantation activity is undertaken, the arrangement of labour force is a prerequisite and it is on this availability in which success of plantation depends.

6.4 Seed collection, extraction, drying and storage

6.4.1 Collection of seeds and seed sources

In order to collect seeds, first requirement of the identification of suitable seed source. Ideally, the seed source should be a tree which is genetically superior. Superiority of species can be judged from certain physical parameters like size, length, shape of stem, height, diameter, volume increment, timber quality, resistance to disease and other specific desired qualities. However, it is very difficult to ascertain the internal traits of a tree as those are determined by its genotype. Therefore, collection of seeds are carried out from middle-aged trees with good phenotypes (as physical appearance of an organism is reflection of its genetic makeup). These seed trees of good phenotypes are called **Plus trees** and are marked with paint, there location, species and visible characters are also recorded for future reference.

Plus trees are isolated trees in the forest and cannot fulfill the seed requirements of large scale plantation activity. Furthermore, it is not advisable to have dependency solely on few plus trees on account of their vulnerability to damage by many factors, particularly biotic ones. However, in order to meet the seed requirement of large areas, seed orchards or seed production area or seed stand are established from the seeds obtained from plus trees. Seed production area or seed stand is defined as, “a crop of vigorously growing middle-aged to mature trees of good quality, properly thinned and left to contain trees of good vigour and well developed crowns, with clear boles and managed exclusively for seed collection (Khanna, 1999)”. Only those areas are selected as seed stand where the proportion of desirable trees is high. After selection of the seed stand or seed production area, following operations are generally undertaken:

- The best phenotypes are identified and distinctly marked with a paint in circle. The remaining trees are removed or marked with different paint so that they may be removed in future. Thus, only the best phenotypes are retained for seed production.
- If there is congestion even after removal of inferior trees, the selected trees are properly thinned so that the trees retained have sufficient space to develop good crowns so as to maximize seed production.

- Inferior trees in vicinity are removed in order to prevent cross pollination. This is usually obtained by creating an **isolation strip of width 100 to 150 m** around the seed stand and all the inferior trees of this strip are removed.

6.4.2 Seed production- seed tree and seed orchard

Seed stands are created from the seeds obtained from superior phenotypes of the existing crop (whose origin is not known) and is just an interim arrangement in order to meet immediate or short term seed requirements. However, in order to ascertain the superior seed quality, seed orchards are established from genetically superior seeds. Seed orchards are thus, defined as, "a plantation of genetically superior trees isolated to reduce pollination from genetically inferior ones, and intensively managed to produce frequent, abundant, and easily harvested seed" (Khanna, 1999). There are two kinds of seed orchards:

(1) Clonal Seed Orchard (CSO): CSO are raised by **grafting clones** in the form of a scion or bud of plus trees on the stock of 2 or 3 year old seedlings, or by planting rooted cuttings of plus trees at proper spacing.

(2) Seedling Seed Orchard (SSO): These are raised from the seedlings obtained from the seeds of plus trees.

Clonal Seed Orchard (CSO) starts producing seeds earlier. Since CSO is obtained by vegetative propagation of genetically superior plus trees, the resulting trees are likely to be sound and healthy and bear seeds of good genetic quality. However, seeds from individual CSO trees should be put to trial by planting seedlings from such seeds in experimental plots. If the performance of any seedling on several replications is found to be unsatisfactory, the corresponding seed source, that is the tree in CSO is identified and removed from the CSO. Similarly seedlings of SSO origin are put to trial, and if some are found to under-perform, their parent trees in the SSO are identified and removed. Thus, individual trees in CSO or SSO which breed inferior seedlings are eliminated and the chances of getting superior plants from the seeds of CSO and SSO are enhanced.

Advantages of seed orchards

i) Seed orchards produce superior seeds;

ii) Seed collection becomes a concentrated activity, and therefore becomes an easy operation and less costly;

iii) They can be used for controlled crossing programme between selected clones to achieve improved seed source.

Isolation of seed orchard is carried out in order to exclude the chance of pollen contamination from inferior trees of the same species. This can be done by:

(1) keeping a strip around the orchard free from any plantation or self-grown tree of the same species, or

(2) by screening off the orchard by planting a belt of some other suitable species which does not intercross with the species of the orchard.

6.4.4 Season or time of seed collection

Seed should be collected on maturity before dispersal. It means that proper time for collection of seeds is immediately after ripening when they are ready to fall from the trees. Change in colour and softening of the tissues of the fruit give some indication that the seed is approaching maturity. Most fruits turn reddish brown when ripe; pulpy fruits start getting soft and wrinkled skin. Most of the species have a fairly definite period in which they ripen and such information can be obtained from the literature. However, time of seed maturity of a species vary with locality, and sometimes varies from year to year in the same locality due to change in climatic conditions. Therefore, constant field observation is necessary for reaching at appropriate time of seed collection apart from knowledge as mentioned in the literature. The seeds which ripe very early or very late are often found to be infertile, therefore, such seeds should be avoided.

6.4.5 Method of seed collection

There are mainly three ways of collection of seeds which are as follows:

(1) Collection of fallen seeds from the ground: it is applied to large fruits and heavy seeded species. One has to take care that only freshly fallen seeds are collected. The ground should be made clean by removing previously fallen seeds. Examples: Sal, Teak, Gamar, Kadam, Oaks etc.

(2) Collection of seed by lopping the branches: This method is applied to fruits which are too small to be economically picked from the ground, or which are easily wind dispersed. Example: Betula, Khair, Sissoo, Albizzia, conifers etc.

(**3) Collection of seed from standing trees:** Seeds which are likely to be damaged in falling with branches are collected from standing trees by hand or with a sickle tied to a bamboo carrying a small bag. Example: *Acer*, *Morus,* etc.

6.4.6 Seed extraction

Although most of the seeds or fruits can be sown or stored as such as collected from the source but in some species, there is a need to separate fruits from the seeds before they are sown.

1) Seed extraction or sowing from dry fruits

There are three categories of such species:-

- The entire fruit is sown with seed contained in it, e.g Teak, Walnut, Oak etc. Dry fruits of this category do not require any extraction.
- Part of the fruit is sown with seed contained in it, e.g Sissoo. Fruits are placed in gunny bag and given beating to break each fruit into as many parts as contain a seed or two.
- Seeds are sown, e.g Conifers, Leguminous species, Lagerstroemia, Acer etc. In this category of fruits there is a need to extract seed completely from the fruit. Usually fruits are dried in sun which results into coming out of the seeds.

2) Pulpy and fleshy fruits

The pulpy portion should be removed as early as possible. The method depends on the kind of fruit. The usual method is to keep the fruits in water in a container for some time, followed by pounding and squeezing while still under water until the seeds are freed. The soft pulp floats on water and the seeds sink to the bottom. The two can be separated by decantation. After the seeds have been extracted and dried, they should be cleaned off in order to free it from all foreign materials by winnowing or sieving. They are now ready for grading, sowing or storage.

6.4.7 Drying of seeds and Seed storage

There are different methods of seed storage depending upon the kind of species. Storage of seeds become necessary if the time of ripening of seeds does not coincide with time of

sowing. Naturally, seeds need to be stored after collection till the time of sowing. Seeds having long viability should also be stored for use in lean (poor) seed year. In general, the ideal storage condition should be similar to the environment in which seeds of the species are stored in the nature. **Species with seeds of short viability** must be sown immediately after their collection like neem and sal. However, if it becomes necessary to store such seeds for a short period, they are stored in shade by spreading the seeds, if possible, sprinkling with water from time to time. Sal and most of the Dipterocarps can be stored in this manner.

There are some **species whose seeds ripen in autumn and germinate in spring.** Such species are found in temperate regions and they seed in autumn. Seeds after falling to the ground remain lying under the snow all through the winter. Such seeds germinate when snow melts in spring. If seeds of such species are collected, they required to be stored in low temperature. Conifers, generally, require dry cold storage. However, broad-leaved species are reported to require wet cold storage i.e., moist and cold condition. Darjeeling district seeds of *Quercus*, *Machilus* and *Juglans* are stored in pits. **Species whose seeds ripen in winter or summer and germinate in the following summer:** Most species of the plains fall in this category. Seeds can be stored either by spreading them out in dry places with good circulation, or by light packing in loose gunny bags, and occasionally spreading them out in the sun to prevent dampness. For storing large quantity of seed, a special shed is built up. The shed may be fitted with bamboo shelves and movable trays to facilitate drying. The shed should be so constructed that it is not exposed to excessive damp or over-heating.

6.4.8 Testing of seeds and Pre-sowing Treatment

In order for plantation to be successful, seed germination should be quick and uniform. There are some pre-sowing treatments that ensure and hasten germination process. These are as follows:

1. **Cold water Treatment**: For seeds which need lot of water for germination, and at the same time have certain chemicals inside, which inhibit germination, the cold treatment is a good method. Examples: Pine, Aonla, Kanchan, Kalasirish, Patka sirish, Khair etc. In the process seeds are put in water, five times the volume of seeds and allow

the seeds to soak for 1-2 days, change the water every 12 hours. Discard the seeds that float on the top. All the swollen seeds are ready for immediate sowing.

2. **Hot water treatment:** The method is applied for seeds which contain hard seed coat, such as *Cassia*, *Sesbania* and *Albizia*. In this process, five times the volume of seeds are taken and allowed to soak in a boiled water after it has cooled for 10 minutes and keep the seeds in this water for 2 days or until most of them have swelled. Discard the seeds that have floated on the top. Change the water every day with cold water. Once the seeds swell, sow them immediately.
3. **Boiling water treatment:** The method is applied for seeds which contain very hard seed coat, such as *Acacia*, *Albizia*, *Prosopis*, *Oaks* etc. It includes boiling of a volume of water that is five times the volume of seeds. Take the container off the fire and soak the seeds immediately for 1-2 minutes only. After 2 minutes replace the hot water by cold water and allow the seeds to soak for 2-3 days or until the seeds swell. Keep changing the water every day. Sowing is carried out immediately once the seeds swell.
4. **Alternate wetting and drying:** Seed is alternately wetted for some hours and then dried. This is used for Teak.
5. **Passage through animals:** Seeds are passed through the digestive system of animals or poultry. It is applied for treating *Santalum album* (Sandal tree), *Azadirachta indica* (Neem), and *Acacia arabica* (babool) seeds.
6. **Cow dung slurry treatment:** Fruits of *Terminalia chebula* and *Melia azedarach* are mixed with cow dung and slurry is made. It is then kept in pits for about 7-14 days in order to remove the thick seed coat. This process also helps to overcome seed dormancy.
7. **Chemical treatment:** Soaking in various chemical solutions softens the hard seed coat and hastens germination. Some chemicals are H_2SO_4, HCL, H_2O_2, etc.
8. **Mechanical treatment:** Shell cracking - Seeds of some species needs to be cracked using a wood or light hammer before sowing e,g, *Zizyphus spp.*., *Sapindus spp., Juglans spp.* etc.

9. **Other specific treatment:** Some tree spp. require specific treatment to seeds for initiation of germination:
   - Dry fruits of *Arjun* need to be placed in sunken bed and covered with straw. Watering is done in regular intervals till germination. Germinated fruits are put into polypots / root trainers.
   - Fruits of Raktachandan are placed on sand bed under straw cover and kept wet by regular watering. Then germinated fruits are put into filled up polypots / root trainers for further germination.

6.5 Artificial regeneration by seed sowing

6.5.1 Methods of seed sowing

Artificial regeneration by sowing involves the sowing of seeds collected from some seed source either form nature or from existing seed trees. Seed sowing is carried out in various ways in the plantation site. These are as follows:

1. **Broad-cast sowing:** This is the simplest method of sowing in which seeds are broadcasted manually or by machine in the whole area. The seeds are scattered after ploughing or digging up and levelling of soil in the plantation site. This kind of sowing is used for stocking burnt areas, desert areas, landslides, grassy blanks and rocky barren sites. Various thinning operations become more important in this method because of crowding of seedlings or future young crop.
2. **Line sowing:** In this method, sowing is carried out along the lines. After digging and weathering the soil-levelling of the soil is done and in this levelled soil, lines are drawn at regular interval. A drill, i.e a shallow depression, is made on the filled up earth with a hoe or a wooden peg. When the drill runs continuously from one end of the plantation to the other end and sowing is done along the drill, it is called continuous line sowing. The line sowing can be continuous, interrupted or staggered.
3. **Strip sowing:** Here sowing is done on narrow strips prepared usually at definite intervals from one another. The soil is dug up in strips, allowed to weather and then made into seed bed. Seeds are sown in two or more rows along the strip. Like line sowing, strip

sowing may be continuous, interrupted or staggered. As there are multiple rows along the strip, chances of failure of germination is very less. This method is very suitable for areas infested with grass and other weeds. Strip sowing is done in Sal plantations wherein strip of 30 cm width sowing is done in three rows 10 cm apart.

Advantages and disadvantages sowing

Advantages

- **It is cost effective and takes less time than planting.**
- **As seeds are sown directly on the site, there is no disturbance to roots which normally happens while transferring planting stock from nursery to planting site.**

Disadvantage

- **It requires large quantities of seed. Birds and animals may destroy or eat away the seeds.**
- **Seedling mortality is quite high.**
- **The resulting seedlings require intensive weeding over a relatively longer period, which increases the cost of plantation.**

4. **Patch sowing:** It is sowing of a number of seeds in specially prepared patches made at regular intervals. Soil is dug upto a depth of 15 to 25 cm and filled back after weathering. Sufficient number of seeds, depending on the seed-size, are sown, though one is expected from each patch. This method requires less seed compared to line or strip sowing. Seeds are less damaged by birds or animals on account of the scattered nature of the patches. The method is useful for rough sites covered with stones, stumps etc where line or strip sowing is not feasible.
5. **Dibbling:** It is defined as sowing of seeds in shallow holes made with suitable instruments or a wooden stick at regular intervals. Soil working and sowing is done simultaneously. It is applied for large and heavy seeded species.
6. **Ridge or mound sowing:** In moist soils, in high rainfall areas, sowing is done on ridges or mounds, and it is called ridge or mound sowing.
7. **Trench or Pit sowing:** In dry or low rainfall areas, seed is sown in trenches or pits and accordingly it is called trench or pit sowing. In Sal plantations in south-west Bengal, Sal seeds are sown in contour trenches.

6.5.2 Time of seed sowing

As a general rule, sowing should be done shortly before the time when the seed germinates in nature. It provides the seed with an opportunity of using the maximum length of growing

season and also reduces the risk of seeds being eaten by birds and rodents due to reduction of exposure to risk (birds and rodents). In temperate zones, seeds are sown before snow fall whereas in tropical deciduous forests it is carried out before the rains or just after the first shower. This way the regeneration gets maximum time period for growth.

6.5.3 Depth of sowing

As a general rule, the seeds should be sown so deep as to have a covering not more than its minimum diameter. A drill of the required depth is made with the help of a wooden stick or iron hoe and seed is sown. The seed is then covered by shifting the soil of the sides of the drill by hand. Minute seeds are sown on the slightly leveled top of the ridge and covered by sprinkling fine earth over them.

6.6 Artificial regeneration through plantation

6.6.1 Methods of plantation

This is carried out by the following ways:

i) **Planting natural seedlings from the forest:** Natural seedlings of *Michelia champaca*, and *Anthocephalus cadamba* can be used for plantation work. However, as a rule, use of natural seedlings is discouraged.

ii) **Planting nursery grown seedlings:** In this method, plants are grown from the seed bed in the nursery and the entire plants are directly planted in the field without transplanting or pricking out. This method can be used for many species under favourable conditions.

iii) **Planting of transplants/containerized seedlings:** These are plants which have

Advantages and disadvantages planting

Advantages

- **Much less quantity of seed is required.**
- **Damage to seeds by birds is eliminated**
- **Damage to seeds by animals is considerably reduced.**
- **Success rate is high**
- **Weeding is less cost-intensive**
- **Through proper screening or culling of nursery seedlings in the nursery, it can be more or less ensured that only healthy planting stock is transferred to planting site. The resulting crop is likely to be of good health and quality.**

Disadvantage

- **Planting is costlier than sowing**
- **It requires more labour, particularly skilled labour**
- **It requires maintenance of a nursery.**

been hardened in the nursery and then planted out in the field. The recent practice, however, consists in pricking out seedlings from the mother seed bed and transplanting into polythene bag or root trainer. That is, pricked out seedlings are not transferred in transplant beds, rather put in polythene bag or root trainer. For many species, seeds are directly sown in polythene bag or root trainer. The transplants in containers, when ready for planting, are taken to the field.

iv) **Planting root and shoot cutting or stump planting:** This is used for Teak and many other species. In case of Teak, one or two year old stumps are used.

v) **Planting branch or stem cutting:** Some of the species can be artificially propagated by branch and stem cuttings. For example, *Ipomea, Vitex, Lannea, salix, Dalbergia*, *Dendrocalamus* etc. Clones obtained from stem cuttings in nursery are usually used on a large scale for *Eucalyptus* plantation. Cuttings are placed in the rooting medium in root trainers in a mist chamber. The object of the mist chamber is to produce a micro environment of high humidity and moderately high temperature. Such environment facilitates early rooting. When the cuttings have developed a sufficient root system, they are taken out of rooting chamber and placed in hardening chamber for about 15 days before they are considered ready for planting in the field.

vi) **Planting root cuttings:** Sections of tap root of *Stereospermum* and *Bombax* can be used in plantations.

6.6.2 Season of planting

The season or time of planting depends upon local climatic conditions, the silvicultural characteristics of species and method of planting. However, based on season, the planting can be classified into following categories:

i) **Monsoon planting:** This is the main planting season in India, as most parts of the country receive bulk of the precipitation from south-west monsoon. Planting should be carried out as soon as the monsoon has fully set in, so that the regeneration gets full advantage of the rains. Planting is normally done in early to mid June to early July depending upon the climatic conditions which vary from place to place. The ideal condition of planting is when the sky remains overcast or there is a little drizzle.

ii) **Pre-monsoon planting:** Where irrigation facility is available or when there are good showers in the summer, pre-monsoon planting of certain species can be done.

iii) **Winter planting:** Planting is done during winter rains which usually occur in January-February. Winter planting has been reported to be successful in north Bengal for many species, e.g. *Toona, Chukrassia, Cinnamomum, Dalbergia latifolia* etc. (L.S Khanna 1999).

iv) **Spring planting:** Spring planting of conifers is done in parts of Kashmir where southwest monsoon does not reach. As the snow melts during this time, the resulting water is used in irrigating the plantation area.

6.6.3 Pattern of planting

A number of planting pattern are in practice which vary from place to place. The pattern to be adopted in a working circle is usually prescribed in the Working Plan of the area and accordingly the planting operation is done. It is advisable that the pattern adopted should be simple and easy to implement by the work force at the grass root level. Of the various planting patterns, the one which is most common is the 'square planting'. The different kinds of planting patterns are discussed as follows:

i) **Line planting:** In this pattern of planting, lines are drawn on the site in specified distance apart and the plants are planted at a specified spacing in the lines. The distance between successive plants in a line may or may not be the same as distance between two adjoining lines. Therefore, a rectangle is formed by the planted plants. In the line planting, the number of plants required per hectare is calculated as follows.

$$\text{Number of plants per hectare} = \frac{100X100}{dXD}$$

Where, d = distance in meter between plants in a line,

D = distance in meter between the lines apart,

ii) **Square planting:** In this pattern, plants occupy the four corners of each successive square. In other words, in this pattern the spacing of plants in a line is the same as the distance between the lines. In this case, the number of plants required per hectare is calculated by the following formula:

$$\text{Number of plants per hectare} = \frac{100X100}{d^2}$$

Where, d = Length in meter of a side of the square or 's' is distance between successive plants in a line or distance between the two lines, which are identical in square planting.

Summary

- This unit deals with artificial regeneration in which all the operations from sowing or planting till tending are carried out by human beings. Here the regeneration of desired crop is carried out from the seeds or from transplants raised in nursery. The objectives of artificial regeneration are reforestation and afforestation activities.
- Preliminary activities before artificial regeneration is conducted are choice of species, fencing of the plantation site and reclamation of the soil.
- The choice of species for artificial regeneration in an area is usually governed by climate and micro-climate, soil conditions, object of management, Market requirement or stakeholders' requirement, the silvicultural system, availability of suitable exotics, growth rate of species, ease of establishment and effect on site etc.
- Selection of site is done according to the species to be planted. Artificial regeneration can be carried out either directly by sowing seeds or by transplanting seedlings or cuttings raised in nursery or by adopting a combination of sowing as well as planting methods.
- Choice between sowing and planting depends on the species to be raised, conditions of the site, availability of seed and cost. Next step before plantation is seed collection, extraction, drying and storage. Usually seed sources should be located nearby the plantation area. Ideally, the seed source should be a tree which is genetically superior usually known as **Plus trees. Seed production** is carried from seed tree and seed orchards. In order to ascertain the superior seed quality, seed orchards are established from genetically superior seeds. There are two kinds of seed orchards - clonal Seed Orchard (CSO) and seedling Seed Orchard (SSO), seed orchards have certain

advantages like they produce superior seeds, seed collection becomes easy operation and less costly.

- Season or time of seed collection varies from species to species. Ideally seed should be collected on maturity before dispersal. There are three methods of seed collection namely collection of fallen seeds from the ground, collection of seed by lopping the branches and collection of seed from standing trees. After seed collection seed extraction and drying of seeds is carried out. Thereafter, seeds are stored. Seed testing and pre-sowing treatment are conducted before sowing seed directly in the site or sowing in nursery.
- Based on season, the planting can be classified into four categories as- monsoon planting, pre-monsoon planting, winter planting, spring planting
- Among the important patterns of planting are line planting and square planting.

Unit 7 Forest Regeneration: Artificial Regeneration II

Unit Structure

7.0 Introduction

In the previous unit, we discussed about the artificial regeneration. We discussed in detail about preliminary activities needed before artificial regeneration, seed collection, extraction,

storage. Further, we also discussed about artificial regeneration by seed sowing and plantation techniques in detail.

In the present unit, we will discuss about common activities needed or done at plantation site while taking up artificial plantation operation. We will also study a comparative account of artificial and natural regeneration, advantages and disadvantages of pure versus mixed crop, various kinds of patterns and mixtures. At the last, exotics will also be discussed in brief.

7.1 Learning Objectives

After completing this unit you will be able to:

- define artificial regeneration
- explain artificial regeneration
- List out various activities which are carried out in regeneration site
- Identify the various factors which influence it

7.2 Common activities at plantation site during artificial regeneration

Plantations can be carried out either by sowing or by planting or by both the methods. In practice, plantation involves combination of both the methods. Depending on species, one takes a bigger role than the other. However, for most of the species, plantation is carried out through planting supplemented with sowing. Plantation work is the procedure of artificial regeneration, and aims at renewing of the forest crop by sowing or planting. Whether artificial regeneration is carried out through seed sowing or plantation, it involves certain common activities or operations, which are discussed below:

7.2.1 Selection of site

Selection of site is needed when regeneration to be carried out in a new barren area or a site which is devoid of vegetation for a long time. Else in clear-felled or otherwise cleared area, selection of site is automatically done as the same area has to be regenerated. The major factors to be taken into consideration while selecting a new site for regeneration are aspect, topography and soil conditions.

7.2.2 Survey and Boundary demarcation

After selection of site, the work to be undertaken is survey and boundary demarcation. The boundary of the plantation area is required to be demarcated on ground, and the plantation area should be surveyed. After survey of the outer boundary, a map of the plantation area on a scale of 1: 5000 should be prepared. The map may also preferably indicate nature and topography of the soil. The map should clearly indicate the location and orientation of the site, identifiable objects across the boundaries, area of the plantation etc. It should also include information on latitude and longitudes of the prominent points along the boundary and GPS (Global Positioning System) is used for the purpose. These coordinates should also be mentioned in the map. The map should bear name and designation of the surveying officer.

7.2.3 Geo tagging of site photographs

Geo-tagging is the process of adding geographical identification data to various media such as a geo-tagged photograph or video, websites etc. This data usually consists of latitude and longitude coordinates, though they can also include altitude, distance, and place names. Geo-tagging can help users find a wide variety of location-specific information. For instance, someone can find images taken near a given location by entering latitude and longitude coordinates into a suitable image search engine. Geo-tagging can tell users the location of the content of a given picture or other media, and conversely on some media platforms show media relevant to a given location. Recent guidelines on documentation are to do geo-tagging of the plantation-site photographs so that information on a specific plantation becomes readily available.

7.2.4 Regeneration plan map

On the plantation area map, brief description of regeneration plan should be mentioned. It should also indicate principal species to be established, spacing to be adopted, blocks, if any, or some specific kind of planting stocks like clones etc. The regeneration plan map which carries information about location, area, soil conditions, regeneration plan etc is required to be approved by the divisional forest officer or any other officer, authorized in this behalf, before undertaking plantation work on ground.

7.2.5 Preparation of planting site

The plantation site should be cleaned of felling refuse, slashes, debris and bushes by necessary cutting, burning, stump uprooting etc. Small depressions or rise may be leveled. The object is to obtain a clean and level site as far as possible.

After preparation of the site, it should be divided into suitable number of blocks which usually depends upon plantation area. These blocks should be separated by roads to facilitate inspection of plantation. In case of large plantation, there is needed one or two main motorable paths. Other branch roads may be about 1 metre wide to allow inspection on foot. Besides, a path about 1.5 m wide should be left on the outer periphery of the plantation inside the fence.

7.2.6 Boundary and contour trench

Alignment of individual segments comprising interrupted boundary and contour trenches, and width of the segments are clearly marked on the ground as per approved specifications with the help of spade. When the position of trench segment has been marked on the ground, the trench of required size is dug along the marked line. Normally, the boundary trench has a width of 1 m at the top, 45 cm at the bottom, and a depth of 60 cm. The boundary trenches are dug in interrupted manner, i.e, the trench is not made a continuous one, so that it does not turn into a channel of water flow. The primary purpose of the boundary trench is to have the plantation boundary demarcated. Whereas **contour trenches** are short staggered trenches, 5 to 10 meters long laid in rows along contours with suitable interspace between them. Usually, an interspace of 5 meters is left between two 5-metre long trenches in a row. The trenches in successive rows will be staggered in such a manner that the interspaces in the upper row are directly above the trenches in the lower row. The optimum spacing or the distance along ground between two successive rows depends on the slope and the rainfall. The section of the trench may be trapezoidal or square depending on the nature of the soil.

The dug up earth is arranged as a ridge on the lower side of the trench. Sowing and planting are done in the rainy season on the ridges as well as in trenches (partly filled) to make allowance for the vagaries of rainfall. In extremely wet seasons, the plants on the ridges do

well, but in drier monsoons, the plants in the trenches survive and establish better. (R.C.Ghosh 1976 Handbook on Afforestation Techniques)

7.2.7 Staking out

Having done the inspection path, the boundary and contour trenches, the position and alignment of sowing/planting lines and pits are clearly marked on the ground by fixing wooden or bamboo pegs as per spacing envisaged. This operation is known as staking out. It is necessary in order to maintain the planting lines in system and to maintain proper spacing. For digging trench for sowing, the ends of lines are marked by stakes and a rope is stretched between the two stakes to mark out the straight line with spade. When the line has been marked on the ground, the stakes and the rope are removed and trench of required size is dug along the marked line. For digging pits for planting, their positions as per envisaged spacing along the line of planting are marked by stakes. Pits of required size are dug around each stake. The stake may be retained beside each pit in order to provide support to the plants in post-planting stage against wind pressure.

7.2.8 Fencing

Even as soil work starts, the plantation site should be fenced. A few commonly used fences are described below:

i) **Cattle proof barbed wire fence:** This is the normal type of fence used to keep out domestic cattle from forest plantation. It comprises of 4 to 5 strands of barbed wire, starting at about 30 cm above ground. Wooden stakes of a durable species are employed to support the fence. Iron rods or cement concrete posts are also used for the purpose.

ii) **Game-proof fence:** This is a fence of special type meant to protect the plantation from wild animals. The lower part of the fence consists of 1.25 m high woven wire, and the upper part comprises 3 to 4 strands of barbed wire.

iii) **Stone-wall fence:** This fence is constructed by laying stones, one above the other, without using any cementing material. Such fences are erected in areas where stones of required shape and size are available.

iv) **Brushwood fence:** When fencing is required to stay for a short period, say for the first year of plantation, an economic method is to go for brushwood fencing. The purpose is to keep away the cattle during the first growing season. Brushwood fence include thorny branches of bushes.

7.2.9 Cattle proof Trench

When the dimensions of the boundary trench are enlarged (top width 2 metres, bottom width 1.25 m and depth 1.25 m), it may serve the purpose of cattle proof trench. Since erecting barbed wire or other type of fence is a costly operation, digging of cattle proof trench is preferred in many occasions. However, one major disadvantage of cattle proof trench is that soon it tends to become partly filled up with the loose soil that has been dug, and the very purpose of having the trench to keep away the cattle gets defeated.

7.2.10 'Dig and plant' method

In this method, planting is normally done by digging pit and planting process simultaneously. This is carried out in order to prevent the fertile soil eroding away alongwith monsoon rains. In this method no soil work for pits is done prior to planting. With the onset of monsoon, soil is dug out to the required depth with the help of spade at the places identified by stakes and the seedlings are planted. It is usually practiced in north Bengal. As it does not require elaborate soil work, and this way some expenditure is also minimized.

7.2.11 Digging advance pits before planting

Pits are usually dug in advance before taking up plantation. The soil is dug up to a required depth and size about a couple of months before the planting time. The soil is heaped up on the side of the pit to weather. Weathering of the soil is done with the following objects.

- Soil structure is improved; bigger clods are broken into smaller ones.
- The roots of the weeds dry up and thus menace of the weeds is reduced.
- Birds feed on the injurious insects.

Size of the pit (rectangular), normally adopted, is as follows:

- Length – 60 cm at the top, 45 cm at the bottom

- Width – 45 cm presumed to remain unchanged along the depth
- Depth – 45 cm.

7.2.12 Filling up of pits

After weathering the pits are filled up with the dug up soil in such a manner that the soil makes a raised heap. Unless the dug up soil left for weathering is partly washed away, the raised heap of soil is obtained naturally in view of the increase in bulk volume of the loose soil after digging. During filling up of pits, sometimes basal dose of manuring is done. Earlier, the method of core manuring was in practice. In this method, the pits are filled with pulverized soil leaving a blank space of about 10 cm at the center. Farm yard manure is then placed at the core with the help of two concentric tin cylinders. The seedling with the potting medium is planted in the center of the pit. As an alternative, manuring in the pit is done by mixing intimately the manure with the filled up pulverized soil.

7.2.13 Sowing of seed

After preparing the site sowing is carried out. Methods of sowing and other details have already been discussed in 6.6 of the previous unit.

7.2.14 Planting or transplanting

After filling up of the planting pits, the plantation site becomes ready for planting which of course has to be done at the appropriate time. The different methods of planting have been described in previous unit under 6.7.

7.2.14 Dispatch of plants for planting

Only those seedlings which are fit for planting should be transferred from the nursery. Only the balanced medium sized seedlings with sturdy stems, and well-developed fibrous root system are the quality stock because they have a higher survival rate and they make better initial growth than do either larger or smaller seedlings. The quality nursery stock should be set apart for transfer to the plantation site. Before transferring from nursery, the seedlings should be irrigated so that the potting medium does not get dislodged from the root on movement during transport and planting. The mode of transport is more often determined by the availability of transport and the cost. Carriage of seedlings by humans is usually

undertaken but is a costly affair. The criteria for selection of transport should be such that it is able to reach the site and dispatch the seedlings within reasonable time. Tractor or small motorized van can be a convenient mode of transport if terrain of the site allows it.

7.2.15 Plantation in the field

As soon as the monsoon gets steady, planting stock is transfrred to the field which by this time with filled up pits is ready for the planting operation. Individual potted seedling of specified species is placed beside the pit where it has to be planted. It should be properly supervised that the seedlings have taken appropriate position beside the right pit as per approved planting pattern.

Before putting a plant in the pit, the plant needs to be freed of the poly tube which has so far held the plant. The tube which is normally open at both ends is removed by giving a vertical cut down its length with the help of a blade or a sharp instrument. In case of a root trainer, the plant can easily be taken out of the container by gently tapping from outside. A cylindrical space of required depth is made by hand at the center of the pit. The plant with the mass of potting media around its root is carefully placed in the space at the center of the pit. After this, soil is pressed and consolidated from all sides taking care that the plant remains in a vertical position and the plant collar is about 5 cm above the general ground level with soil sloping all around.

7.2.16 Weeding-Cleaning

Immediately after the planting operation, the next activity is weeding and cleaning. As explained earlier the object of weeding and cleaning is to remove and cut back plants of unwanted species which otherwise would interfere with the growth of the desired species. During the operation, the grasses and weeds are removed from around the base of the plants and the space between the plants is cleaned of unwanted species, climbers etc.

In areas, where weeds is a serious problem, they often completely suppress the desired species and results in mortality. Thus, in order to save the seedlings of desired species from the weeds, the operation of weeding and cleaning is required to be carried out at appropriate time. The number of weeding/cleaning to be carried out in a plantation depends on the intensity of growth of weeds and unwanted species. Generally, cleaning is required to be

done 5 times in the first year. Cleaning with progressively fewer frequencies is carried out till the plantation becomes 5 years old. It is to be borne in mind that the requirement of weeding and cleaning is situation specific i.e., the more the weed density and more the frequency the more frequency of weeding and cleaning operations needed, and it is a very important operation for establishment of the plantation.

7.2.17 Fertilizer application

Application of fertilizer is not conventionally practiced in forest plantations. Since, in general, the forest land is fertile and rich in organic matters, use of fertilizer is not considered necessary. However, while raising plantation on infertile lands, or undertaking afforestation outside forest area, application of fertilizer becomes necessary to establish the plantation. For example in most of the forest land in laterite zone of south west Bengal, the soil lacks in nutrients, thereby necessitating addition of nutrient from outside is needed. In general, application of NPK fertilizer is carried out in the plantation in the first year. About 40-50gm of fertilizer is applied per plant either in single dose or at times in two split doses. Fertilizer is applied while carrying out the weeding and mulching operation. The first weeding-mulching operation is normally done 3 weeks after the planting (during the 4th week). The operation consists of:

i) Cleaning of weeds from the base of the plants

ii) Over a circular area of about 45-60 cm around the base of the plant, the soil is lightly worked with a spade. The soil around the base is loosened and bigger clods are broken with the head of the spade. Due care is taken that the base of the plant is not damaged in the process.

iii) The fertilizer in desired dose is applied uniformly along a ring around the plant at the center ensuring that the raw fertilizer does not come in contact with the plant. The ring of fertilizer is covered with light soil.

iv) The best time to do mulching with fertilizer is after one or two heavy shower so that the fertilizer gets dissolved into the soil easily. If considered necessary, the second dose of fertilizer is given during the second weeding mulching which is normally undertaken after about a month or two. Forking in the base of the soil improves soil

aeration, improves water infiltration and breaks the continuity of micro-pores, thus, reduces the loss of soil moisture through evaporation.

7.2.18 Irrigation

Forest plantations are mostly rain-fed. Conventionally, the plantations are not irrigated, as it does not require irrigation. However, there may be exceptions for plantations in dry arid areas where soil moisture goes very low during part of the year. The situation of moisture stress is often found in the laterite tract of south-west Bengal. From the month of December till the next monsoon, the soil becomes so dry that young seedlings, particularly those of the exacting species, suffer mortality. In fact, one major reason for failure of several attempts in the past to regenerate Sal artificially is the moisture stress the young Sal seedlings had been subjected to. Lately in south west Bengal Sal has been successfully raised by irrigating the plantation during the dry season in the first and second year. It has also been noticed, and was so expected, that growth and health of other species associated with Sal improved considerably due to irrigation.

7.2.19 Casualty replacement (Beating up)

There is no guarantee that sowing or planting will be 100 per cent successful. Casualty replacement is the operation of restocking blanks in a plantation area by sowing or planting. Following points are important while the operation is carried out:

i) Blanks may be identified in the sown area soon after the normal germination period is over. Sowing should be done immediately. If there is still mortality or some blanks are identified late in the growing season, it should be replaced by planting

ii) Blanks in the planted area are filled up by planting only

iii) If some blanks exist even after the growing season is over, they should be filled up in the next monsoon by planting, preferably with seedlings that have been maintained in the nursery for about a year

iv) There should be appropriate stock available in the nursery for casualty replacement

7.2.20 Nurse Crop

Nurse crop is the crop of trees or shrubs grown to foster the growth of another and more important tree crop in its early stages. Its function is to help the growth of principal species which may remain tender in the initial stages. As soon as the purpose is served, the nurse crop is removed. It has been an old practice to raise *Cajanus cajans* (Arhar) between two seedling and close to lines in Sal plantation in south-west Bengal. On account of drought tolerance of *Cajanus cajans,* it grows rapidly and thus, provides shelter to young Sal seedlings and also reduces evapo-transpiration. Being a leguminous crop, it also serves nitrogen fixation and helps enriching the fertility of the soil.

7.2.21 Fire and general protection

The plantation requires close supervision for protection against fire and grazing in the first couple of years. Cattle and animals can be kept away from the plantation by erecting and maintaining fences. During the dry periods after January onward, the plantation becomes highly prone to fire damage. A preventive measure is to create fire lines around the periphery of the plantation. The width of the fire line should be at least three (3) meters. Fire lines of shorter width (about 1.5 m) should be made within the plantation also. In fact, the network of inspection paths already created can be cleaned of vegetation and dry matters, so that it also serves as fire lines within the plantation.

7.2.22 Plantation Journal

Plantation Journal is a register in which all activities and works carried out in plantation area related to plantation are recorded from time to time. Generally following information is recorded in plantation journal:

- The administrative beat, range and division in which the plantation has been carried out
- Location with boundary
- Regeneration plan map with certification about survey, checking of the area, brief regeneration plan and approval by the authorized officer
- History of the site, that is whether clear felled coupe or barren land etc.

- General topography, soil and climate (temperature, rainfall etc.)
- Details of planting stock species wise
- Advance soil work done that is, information about boundary trench, contour trench, pits with spacing
- Sowing and planting done with dates
- Details of inputs applied
- Weeding-cleaning-mulching with dates
- Financial data/Expenditure for each work in every financial year.
- Pages containing remarks of inspecting officer and action taken there upon

7.3 Artificial vs. natural regeneration

The choice between natural and artificial regeneration is governed by the following considerations:

- **Risk of deterioration of soil:** Natural regeneration involves least exposure of soil, while artificial regeneration exposes the soil for a longer period. Long exposure of soil may result into soil erosion, particularly in hilly slopes, which in turn affect soil fertility.
- **Crop composition**: Natural regeneration does not give the desired proportion of valuable species, whereas in artificial regeneration, it is easy to manipulate the crop composition. Artificial regeneration has become the standard practice to enrich the crop with larger proportion of valuable species and increase the productivity.
- **Crop quality:** In natural regeneration, despite exercising the best control, one is never sure that regeneration comes from only genetically superior trees, but in artificial regeneration, one has the option to use seeds and clones from genetically superior trees and produce a quality crop.
- **Risk of damage by pests:** In general, mixed crops resulting from natural regeneration are far more resistant to attack by insect pests than those resulting from artificial regeneration.

- **Time factor:** Time is the factor that predominates other factors most of the time while making a decision between natural and artificial regeneration. Natural regeneration is a long, uncertain and prolong process. The gaps may be invaded by weeds, or the sites while remaining exposed may undergo serious deterioration through intensive leaching, erosion and desiccation. On the other hand, artificial regeneration can bring vegetation cover quickly in open barren areas. One great advantage of artificial regeneration is that it is independent of occurrence of good seed years and can continue every year if there is available good stock of seeds or transplants.
- **Cost:** This is definitely an important factor of consideration. Artificial regeneration is apparently a costly method, as it involves elaborate operations like procurement of seeds, creation of planting stock, maintenance of nursery, carriage of seedlings, fencing, planting , tending etc. all of which require spending on account of material and labour. In contrast, natural regeneration does not involve any initial cost of formation except slash disposal and fencing, where necessary. However, in natural regeneration the weeding and shrub cutting may have to continue for a very long time and may turn out to be very costly. Cost has also implication in the operation of harvest. In natural regeneration, removal of mature trees has to be deferred till regeneration has been obtained on ground. As a consequence, some of the mature trees may become over mature and unsound, resulting in financial losses. Besides, in natural regeneration, harvest of mature trees is done over a number of years in several stages, and it is done after taking due care of not damaging the young regeneration. This makes the operation of logging and extraction costly. Artificial regeneration allows removal of mature trees without any loss in the value of timber. Besides, logging and extraction becomes short and simple operation without any chance of damage to young reproduction.

There is no thumb rule to decide as which method of regeneration to be adopted. The choice should be made keeping in view the above factors in consideration. It is suggested that natural regeneration may be followed for a reasonably short period and then regeneration

operation may be completed by supplementing natural regeneration with artificial regeneration. However, the recent trends are in favour of artificial regeneration.

7.4 Pure vs. mixed crops

While making a choice of species to be raised in artificial regeneration, it will be worthwhile to assess the merits and demerits of pure and mixed crops. The ultimate object of having a mixed crop is to obtain the maximum sustained yield of crops in terms of value. The 'value' may mean financial returns or local requirements (A.B. Lal, 1967). The main arguments on the question of choice of pure or mixed crop are summarized below:

(1) Soil deterioration: it is believed that pure crop, particularly of light demanding species, adversely affects the soil conditions and soil fertility. However, there are different opinions on the subject, and the belief perhaps needs to be grounded on more sound scientific data than what is now available. The trend of preferring mixed and irregular crops is largely based on the belief that mixtures of dead leaves of various kinds produce a favourable type of humus and keep the soil in a better state of fertility than the pure crops. Following points are important to note:

- **Teak is an exacting species,** it remains deciduous for a number of months in a year. As the soil remains exposed during the period when the crop is nearly leafless, in such periods the soil gets deteriorated. Therefore, teak is usually planted in the mixture.
- Pure Eucalyptus plantation in south-west Bengal forests renders the soil compact and devoid of humus.

(2) Resistance to disease: it has been observed that pure crops are more likely to be damaged by insects and pests. In West Bengal, pure crops of *Michelia champaca* are observed to have been attacked by *Urostylis punctigera* (sap sucker); those of *Toona ciliata* by shoot borer *Hypsipyla robusta*; pure *Gmelina* plantation by *Loranthus*. Mixed crops are supposed to minimize epidemic attack due to:

- the mechanical separation of the sensitive species, and
- providing a reservoir of parasites and predators which feed on the main pest

(3) Damage by wild animals: The species of a pure crop may be a favourite food for any wild animal available in large population in the locality. In such a case, the plantation may be damaged severely. For example, bamboo plantations in areas having elephant population are generally destroyed by them. Again, choice of species in a mixed crop may be such as to invite damage by wild animals. For example, if Teak is mixed with *Gmelina* or *Dalbergia latifolia*, the wild animals which browse the latter, damage the latter by rubbing against them. Thus, the key issue of consideration is the susceptibility of the desired species as well as accessory species to be damaged by local animal population.

(4) Total yield: In pure crops, the site qualities are not fully utilized resulting into reduction in volume yield per unit area. In the mixed crops, the soil and the atmosphere are utilized in a greater extent and so there is more volume production per unit area compared to pure crops. However, necessary conditions for achieving enhanced crop production in mixed plantation are:

- that the species in the mixed crop should be compatible and do not cause any interference with each other's growth and development, and
- that they should get matured more or less at the same time. However, if the more number of species are planted in the same site, in such case it becomes difficult to satisfy these conditions.

(5) Difficulty in management: If the species in a mixed crop have varying silviculture requirements particularly the rate of growth and rotation (exploitable age), the crop management becomes tedious or difficult. For example, if a fire tender species is mixed with a species which needs controlled burning, the controlled burning becomes a risky operation. Thinning operations become difficult if fast growing species is mixed with slow growing species. Again if the crop contains species of different rotation age, felling has to take place in more than one operation, and removal of shorter rotation crop creates gaps inviting grass and weeds. Thus, in general, mixture of species with different silviculture requirements, varying rates of growth and rotations should be avoided.

(6) Conservation of biodiversity: Object of management is not always to have maximum production of tangible resources. While part of forests may be worked for production of

timber and other marketable produce, other parts may be worked with the object of conservation of biodiversity. Focus of management in the latter case is to sustain the regulating and supporting services of forest ecosystem. It is obvious that mixed crop being richer in biodiversity serves this focus much better than the pure crop.

7.5 Kinds and patterns of mixtures

Mixtures may be of two kinds, viz. **Temporary Mixtures** and **Permanent Mixtures**. **Temporary Mixtures** are those in which the secondary species remain with the main species only for a part of the rotation period. The purpose is (a) protection of the main species from adverse influences like browsing, frost and insolation, (b) providing crown competition in the early stages in order to get better bole form, and (c) providing additional revenue.

Permanent mixtures are those in which the mixed species remain with the main species for the entire rotation period. Permanent mixtures are again of two kinds, namely, Horizontal or Even-aged mixtures and Vertical or Uneven-aged or Storied Mixtures.

i) **Horizontal or Even-aged mixtures** are those in which species mixed are in the overwood and of the same height. For example, in north Bengal Sal plantation, the main species Sal is mixed with many associates and the association is horizontal and even-aged. The main species Sal and the associates are worked on the same rotation.

ii) **Vertical or Uneven-aged or Storied Mixtures** are those in which the main species is in the top canopy while the accessory species are in the middle canopy. This may be due to varying rate of height growth or late sowing or planting of accessory species.

Patterns of mixtures

The mixtures may be of the following patterns:

(1) Intimate mixture: Intimate mixture is one in which all species are raised throughout the area. For example, seeds of all species are mixed together and then sown.

(2) Line Mixture: Line mixture is one in which one line is sown or planted with one species and other lines with other species. Thus, different species occupy different lines as against intimate mixture where all species occur in every line.

(3) Strip mixture: Strip mixture is one in which the mixed species are raised in different strips. In case of sowing, seeds may be sown in the strips in lines or scattered all over. In case of planting, each strip will consist of lines in which seedlings are planted.

(4) Block Mixture: Block mixture is one in which different species are raised in different blocks of the plantation.

7.6 Exotics

Exotic species are introduced when indigenous species cannot meet the fast growing requirement of industrial timber or any specific requirement of a forest area. However, exotics are normally discouraged as they pose negative impacts in the ecosystems and also pose threat to the native species. In cases where there plantation is inevitable, certain points are taken into consideration while selecting such species. An exotic:

- should serve the purpose in view better than an indigenous species.
- must be suited to the climatic and soil conditions of the locality.
- should be easy to grow and regenerate.
- must not suffer from local risks.
- must be more valuable than the indigenous species
- One has to be sure that the exotic is not vulnerable to attack by an indigenous parasite against which it may not possess any resistance, and that it should not inadvertently introduce a foreign pathogen.

Any exotic that is to be introduced, should pass the experimental trial to prove its suitability to the local conditions. It is also to be borne in mind that performance of an exotic over a short period may not guarantee that it will have disease-free life cycles in the long run, because pathogens and pests take time to build up. Examples of successful exotics are *Cryptomeria japonica* in Darjeeling hills, though large scale plantation (carried out in the past) is now discouraged; *Acacia auriculiformis* in south-west Bengal; *Eucaluptus hybrid* in

south-west Bengal; *Casuarina equisetifolia* in coastal areas. Example of failed exotics are *Paulownia* tried in north and south-west Bengal; *Acacia mangium* and *Acacia holosericea* tried in south-west Bengal (Govt. of West Bengal, 2016)

Summary

This unit deals with various activities required in a plantation site during plantation operation whether by seed or by transplants. Such activities are common to both. Further, advantages of artificial regeneration and natural regeneration are explained. The choice between natural and artificial regeneration is governed by the certain considerations like risk of soil deterioration, crop composition, crop quality, risk of damage by pests, time factor and costs. However, there is no thumb rule to decide as which method of regeneration to be adopted. The choice should be made keeping in view the above factors in consideration. At last, a brief about exotics has been given. The purpose of plantation of exotics is that in certain cases indigenous species cannot meet the fast growing requirement of industrial timber or any specific requirement of a forest area. However, exotics are normally discouraged as they pose negative impacts in the ecosystems and also pose threat to the native species. However, exotics may be selected for plantation after considering certain points that such species serve better than an indigenous ones, better suited to climate, and must be more valuable than the indigenous species.

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Unit 8: Tending operations- Intermediate cuttings

Unit Structure

8.0 Introduction

After the establishment of a forest, best care is needed in order to provide the crop favourable conditions for the growth and development so that desired objectives of management may be achieved. The young crop is exposed to several harmful effects from external agencies which may impair with desired returns. Therefore, suitable care of crop is needed right from the time of its formation till the time it is finally harvested. In other words, a continuous monitoring of the crop is needed and accordingly suitable measures are to be adopted to maintain appropriate composition of crop all the time from regeneration and establishment till final harvesting. This care of forest stand is known as "**Tending of Forests**" and is one of the most important silvicultural operations on which depends the ultimate success of objects of forest management.

In this unit you will get to understand the various tending operations in detail. We will discuss concept of tending, types of intermediate cuttings, need and time of intermediate cuttings, and finally we will discuss in detail about weeding, cleaning, liberation cuttings, improvement felling, salvage cuttings, thinning, pruning and their importance.

8.1 Learning Objectives

After going through this unit, the learner will be able to:

- define tending
- explain the concept of tending
- describe the various kinds of tending operations

8.2 Concept and definitions

During the establishment of regeneration and subsequent development of the forest crop till its maturity, several operations are required to be carried out in order to maintain the desired structure and composition of forest stand. These are particularly required in order to provide healthy and favourable environment to the forest crop for its growth and development at various growth phases. The concept of tending is to provide crop with best conditions of nutrients, space and light by reducing unnecessary competition offered by weeds, diseased and weak plants, branches, climbers or undesirable plants of other species or undesirable individuals of the same species. Tending mainly includes weeding, cleaning, improvement felling, pruning, thinning and control of climbers and undesirable plants. In general, tending operations are carried out in order to improve site or locality factors with an objective to achieve best growth of desired forest crop.

In any crop production activity, there is need to preserve physical and chemical conditions of the soil in which a healthy and vigorous growth of crop depends. In case of agricultural crops, it is maintained through soil working and manuring, however, same is not possible in silviculture on account of being expensive (except where the increased returns of valuable species are the objects of management). Although trees are less demanding in comparison to field crops, yet a sufficient depth, a suitable degree of porosity, suitable moisture and chemical compositions of soil are needed for proper growth and development of forest crops also. In silviculture, these conditions can be maintained by preserving suitable canopy cover, preserving natural soil cover through enriching soil humus.

The main fact is that the soil health and a speedy development of the crop growing on it are closely co-related and are complementary to each other. In tending operations, the basic concept is to ensure appropriate preservation of the soil fertility particularly in case of fully stocked forests or newly established forest crops. However, when forest crop reaches full

canopy stage then steps for opening up leaf canopy are required to be undertaken in order to enhance the soil health. In addition to this, in the initial stages of crop establishment different set of factors or harmful factors operate in the site which are eradicated through tending whereas most of these harmful factors disappear in the later stages.

8.3 Need of tending operations and time of application

Forests in various stages of their growth and development need various kinds of tending operations as mentioned in 7.3 of unit 7, for protection from various harmful factors or for preserving the proper density or composition in order to achieve the desired objects.

8.3.1. Tending of forests during early growth

By early growth period is meant for the initial stage up to sapling stage. In this stage, the forest crops need to be protected from a number of external harmful factors such as:

- **Protection from wild animals** such as deer, rabbits and hares. This is achieved either by keeping their population down or through creating fences around the forest crop. Other measures include application of noxious substances such as tar, glue, fluid lime, and evil smelling preparations which keep these animals away from the crop. However, the cost of these chemicals is a limitation for their usage, therefore, fencing is the cheapest and most effective in long term.
- **Protection from fire:** Fires poses threat in all the stages of growth of forest crop from seedling till harvesting, however, threat during the early growth phases is more devastating. Therefore, protection from fire during the early period of growth is necessary as the young seedlings and saplings are very much sensitive to fires. It is achieved by removal of all inflammable material and checking fire events even smaller ones. Additionally proper watch of area is needed so that in case of fires they may be promptly extinguished.
- **Protection from frost and drought:** The young regenerations require artificial shelter for tender species. It is particularly important in open areas which are created post clear felling. Protection is ensured by **special shelter-wood or nurse crops**. The trees selected for this purpose should essentially be frost-hardy and should possess a thin or moderately dense crown. The nurse trees should be present evenly over the entire area, or may also be placed in alternate lines. The nurse crops

are removed as soon as the tender species reach a stage when no more protection from frost or drought is needed.

- **Protection from cold winds:** The cold wind and frost are usually disastrous for young crops, therefore, shelters are needed. This is ensured either by adjoining forests of sufficient height and density, or otherwise by erecting artificial shelterbelts or wind-breaks. As far as possible such species should be selected for wind breaks which are evergreen and have a tendency to form dense crowns. Under the selection system, trees of all ages are intermixed on the same area. In such case lateral protection to the young growth is provided by middle aged / younger trees and vertical shelter by the old trees.
- **Protection from noxious weeds:** Noxious weeds are also very much harmful and impair with the growth of young regenerations. Therefore, they need to be eradicated from the area during weeding and cleaning process. However, moderate degree of weeds act beneficially by providing shelter to young crops.
- **Protection from insects and fungi:** Although insects and fungi offer dangers to standing crops throughout its life, however, young crops particularly seedlings and saplings are much more sensitive. Therefore, regeneration areas are required to be carefully watched for harmful insects. If such insects are seen, a prompt action is needed in order to destroy them as soon as they make their appearance. In case of attacks by fungi, the diseased plants should be removed and destroyed as promptly as possible.
- **Preservation of proper density of crop:** In the process of regeneration of crops, some of the individuals do no succeed, thus, results in small or large blank spaces. Therefore, blanks should be filled up as promptly as possible so that the required density and composition is maintained. In case of young crop originating from direct sowing or from natural regeneration, it is often seen that they are densely stocked in the absence of any action, it is possible that the young trees have a weak development as they start competing with one another for light, space and moisture. However, some of them needs to be removed so that suitable room is provided which may, in turn, result in adequate density and composition of the crop.

- **Cleaning of young crops:** The objective of cleaning is to remove all growth which impairs the proper growth and development of the main forest crop. It may include stool shoots of seedling trees, spreading young trees, accidentally established trees and diseased trees. At this stage some pruning may be done. Where double leaders have been produced, one must be removed.

8.3.2. Tending of forests in fully stocked forests (after early growth period)

At this stage, different set of tending operations are needed. As soon as the crop reaches this stage, several sources of injury disappear, i.e., weed growth is subsided by the effect of the trees, effects of frost and drought damages are reduced to a minimum and fire effects also get minimized. The main purpose of tending is to provide best conditions of space, light and moisture for attaining best density and composition of the desired crop. Thus, the focus of tending operations is directed towards removal of dead, injured, or otherwise undesirable trees. Pruning of over-canopy trees is done in order to avail the below canopy species with suitable light, and space for growth. In thinning operation, those trees are removed which are not in dominant position so that dominant or better canopy trees may get more suitable conditions for their growth and development.

8.3.3 Time of tending operations

The application of the kind of intermediate felling or cutting varies from species to species. It is also not true that all kinds of intermediate cuttings are required in all species. It may or may not be required. The weeding is generally required in initial stages whereas cleaning and liberation cuttings are carried out in young stands (not past the sapling stage). Whereas Improvement felling, Salvage cutting and thinning are carried out in young stands after the sapling stage particularly in fully stocked stands. Pruning is advisable only in special cases.

8.4 Types of tending operations

The various kinds of tending operations (or intermediate cuttings) which are conducted in different phases of growth and development of forest crop from germination to establishment till harvesting are as follows:

1. Weeding and cleaning
2. Liberation cutting
3. Improvement felling
4. Salvage cutting

5. Pruning
6. Thinning

These are explained separately in the following sub-heads.

8.4.1 Weeding and Cleaning

It includes **removal of undesired individuals or species** from the forest crop, however, both these terms are not synonyms. **Weeding** is "the removal of competing growth in seedling phase whereas **cleaning** is "the removal of inferior individuals from a sapling crop, i.e., a crop over three (3) feet height." The main purpose of both the activities is to free the regeneration area from weeds and inferior individuals for the advantage of the better individual of the desired species in the stand.

In even-aged pure crop, the cleaning is meant to remove individuals showing poor growth as evident from their form. Thus, cleanings are the first cuttings made in newly regenerated stand after the crop has established. It should be carried out as soon as it is observed that the individuals of desired species are having trouble directly or indirectly from injury or from undesired species. Cleaning includes the removal of:

- trees and other plants of undesirable species
- sprouts of a desired species
- advance growth of a desired species having inferior form
- shrubs and vines

In sub-tropical and tropical regions, cleanings is required to be carried out in the first year of regeneration after establishment. This is needed so early because such climate is very favourable not only for the growth and development of desired species but also for un-desired or unwanted species and obnoxious weeds. In such areas, not only early cleaning is enough but several such cleanings operations in a year are needed to control unwanted species else they would impair the growth and development of desired crop. On the other hand in temperate conditions, the first cleaning is usually carried out in the third year and till tenth year. General rule of cleaning practice is that it should be carried out as soon as the need of it is felt. Any delay in cleaning operation would only add to the cost, and the overtopping trees would cause irreparable injury to desirable trees very quickly.

One important point to note here is that the undesirable species are harmful only after certain stage i.e., after the crop has established itself. But in the initial seedling stages, these

undesirable species may be beneficial to the small seedlings of desired species as they provide a shelter or protective cover. They should be removed only when the individuals of desired species reach a stage when the overtopping individuals hinder their growth and may cause the death of the better individuals. It is at this stage when direct competition between these sets in. Sometimes mechanical injury to desired individuals is caused by the overtopping tree branches of undesired species.

The number of cleaning operation depends upon the climate and site conditions. Usually 2 to 4 cleanings are carried out at an interval of 3 to 5 years. However, sometimes one cleaning is sufficient to regulate the mixture whereas more frequent cleanings are needed in case of trees with better sprouting ability.

8.4.2 Liberation cuttings

Those cuttings which are made for the purpose of freeing the young growth from older overtopping individuals in a young stand before the sapling stage, are known as **Liberation cuttings**. The purpose of such operations is to free the young growth from older overtopping individuals usually referred to as "wolf trees". **Liberation cuttings are also made in the forest stand during the same period in which cleanings but they differ in the sense that they take out trees larger and older than the young stand whereas cleanings remove trees of approximately the same age as those young stand.** The trees removed in a liberation cutting are either individuals which were left standing when the previous stand was harvested, or on open lands which have been reforested. Liberation cuttings should be carried out as soon as possible in young stands when the shading and protection offered by these ceases to be beneficial and no longer needed. In the absence of such operation the overtopped young desired tree individuals may die.

8.4.3 Improvement and Salvage cutting

Improvement cuttings include those cuttings which are made in a forest stand after the sapling stage. The purpose of improvement felling is to improve the structure, composition and character of the stand by removal of undesirable trees which occupy dominant positions in the main crown and canopy are likely to interfere with growth and development of desired

species. It is only conducted when reasons are sufficient that such action will create better conditions and assist the growth and development of desired stems or species.

As far as number of improvement cutting is concerned, usually only one such cutting is sufficient to regulate the mixture in the stand. However, sometimes removal of many trees in one felling of undesirable species or individual with poor form may result into severe opening up of the canopy. Therefore, in order to avoid such situation second and even third improvement cutting may be carried out.

Improvement cutting vs selection thinning

An improvement cutting is almost identical with a selective thinning but the distinction between the two is that an improvement cutting is applied mainly for the removal of undesirable stem of desired species, whereas in selective thinning removal of the larger trees which are inferior in form to adjoining co-dominant or intermediate individuals is carried out.

Another distinction is that selection thinning, like all other thinning, is made within an even aged stand or group whereas an improvement cutting finds application in both regular and irregular stands.

Early cleaning operations carried out carefully and timely usually eliminate the need of having improvement cuttings at a later stage. Therefore, from the point of view of silviculture and cost of operations, emphasis is given on careful and timely cleaning operations which results in escaping of improvement cuttings.

Improvement cuttings may be carried out in even-aged stands as well as in stands of irregular form. In fact, best outcome of such cuttings is seen in irregular forests where irregularity in the stand structure as well as accumulation of undesired trees competing the desired ones, has taken place. Improvement cuttings are almost always needed in building up forests with better shape and composition.

In case of irregular forest stand, improvement cuttings are applied with an objective of improving the existing crop as primary consideration whereas reproduction is only secondary consideration often not needed at all

The types of trees usually removed in an improvement cutting include:

- over mature trees
- crooked, extremely limby, or otherwise badly formed trees
- trees seriously injured by insects and pests or other causes
- inferior species and climbing vines

Usually it is impossible to remove all such trees at one improvement cutting and therefore, the improvement cutting should be repeated at an appropriate interval, usually not less than 10 years.

In our country, the large areas under forests are mismanaged, have irregular stand structure and accumulation of inferior trees. In such forests, improvement cuttings should be done frequently. As applied in India (Champion and Trevor 1938, pp. 278-281, 341-343), improvement cuttings function both as a silvicultural operation in tending the crop and as a provisional silvicultural system that will later lead to management under one of the standard methods i.e., shelterwood or selection system. While executing improvement cutting, removal of dead, dying, over mature and poorly formed trees and inferior species is mainly done.

Salvage cuttings includes removal of those trees which are **killed or damaged** by various injurious agencies i.e., fungi, insects and fire. These are also applied at the same stage in forest stand as improvement cuttings. It is also a kind of improvement cuttings but the difference is that here removal of those trees is done that are killed or damaged by various injurious agencies such as fungi, insects and fire. It is also sometimes referred to as "Damage cuttings". There are many agencies present in the forest which are continuously involved in damaging the wood. These include fungi, insects, fire, wind, snow, frost and others. It is through salvage cutting by which damaged individuals are removed. Salvage cuttings, as the name indicates, attempts to utilize the injured trees with the idea of minimizing the loss. The amount of cutting depends upon the proportion of the stand occupied by the damaged ones. Therefore, a salvage cutting may be a light cutting to a heavy clear cutting**. It is important to note here that salvage cuttings are not carried out unless the material taken out is expected to meet at least the expenses of the operation.** However, there are exceptions to this rule when it becomes essential for the safety reasons of other surrounding forests to remove un-merchantable trees attacked by insects or fungi. Wherever extensive injury has taken place, reproduction cuttings should be initiated and a new stand be established provided that the condition of the stand permits it. In case larger area of the stand is injured, it is a better idea to harvest all the trees including healthy ones because too much open canopy may injure few healthy standing trees. After heavy salvage activity, regeneration of undesired species, weeds or grasses take place and

this is more so when the area had a recent fire injury. Artificial regeneration is often required after a salvage cutting operations. Although injury from fire, fungi, insects or wind takes place accidentally yet injuries from these causes is commonly seen and therefore, salvage treatment is carried out frequently.

The removal of trees injured by their neighbors in the struggle for existence does not constitute a part of salvage cutting but falls under the operations of thinning

8.4.4 Thinning

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.

Generally, with an objective to stock the area quickly a much larger number of seeds are sown or transplanted. This is particularly for preserving soil nutrients and soil moisture. However, with passage of time growth and development of individuals in horizontal and vertical direction results into intense competition among the same species. In such forest stand, following four (04) kinds of individuals of trees may be noticed:

- Dominant trees forming topmost canopy which enjoy full sun light
- Dominated trees below the dominant trees
- Suppressed trees which are alive but over shadowed
- Dead and dying trees

In the thinning operations, the selection of the trees is based on the following considerations:

- Relative position and condition of the crown
- The character and condition of the bole

- The health of the tree

The above mentioned considerations are mainly applicable for pure stands, however, in mixed stands the choice between species affects the selection.

In general, individuals of the same species with same age occupying the topmost canopy are the most suitable to retain, however, some of the top canopy trees may also be infested by various kinds of diseases. Similarly, character and condition of the bole is closely associated with individuals placed in top canopy yet they are also influenced by factors as density of the stand and by injuries to the bole by insects, diseases, fire and other causes. Therefore, a need was felt of having crown classification based on points mentioned above. According to Society of American Foresters, there are certain recognized crown classes for the purpose of thinning. These are as follows:

a) **Dominant**

   i) Individuals of desired tree species with crowns extending above the general level of the crown cover

   ii) Receive full light from above and partly from the side

   iii) Larger than the average trees in the stand and,

   iv) Crowns well developed but possibly somewhat crowded on the sides

b) **Codominant**

   i) Individuals with crowns forming the general level of the crown cover

   ii) Receive full light from above but comparatively little from the sides

   iii) Usually with medium-sized crowns more or less crowded on the sides

c) **Intermediate**

   i) Individuals shorter than those in the two preceding classes but with crowns extending into the crown cover formed by codominant and dominant trees,

   ii) Receive a little direct light from above but none from the sides

   iii) Usually with small crowns considerably crowded on the sides

d) **Overtopped (**suppressed)

   i) Trees with crowns entirely below the general level of the crown cover

   ii) Receive no direct light neither from above nor from the sides

In practice, most priority should always be given to trees having injuries from any source that affects the bole and health of the desired species. As far as timing of trees is concerned thinning should be carried out as soon as struggle among the individuals of the same species sets in and it becomes injurious for the health of forest stands. This condition arises after establishment of forest crop in the first year in a densely stocked stand in tropical climates. There are some factors such as stock density, productivity of the site, type of species, habit of species and tolerance of species which necessitate early thinning. High density of stock results into severe intraspecific completion among the same individuals for light, space, nutrients and moisture. Therefore, as soon as such signs are observed, thinning should be carried out.

8.4.4.1 Objectives of thinning

The main objective of thinning are as follows:

- Production of quality timber from desired species
- Enhancing the production capacity of the site by felling of unnecessary competing inferior class of individuals
- Maximizing the returns or profit from the land
- Reduction of fire hazards
- Fulfilling of the market requirement of small timber
- Reduction in rotation period

8.4.4.2 Advantages of Thinning

The advantages of thinning are as follows:

- 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.
- Thinning raise the quality of the product composing the final crop as inferior trees are removed from the lot.
- 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.

- 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.
- The expansion of the crown and root system after thinning process increases the power of trees to become resistant to wind, ice, snow etc.
- It keep the stand free of unhealthy and dying trees, in which insects and fungi find the best opportunities for development.
- Thinning may favorably affect water yield from forested areas by increasing snow storage and lengthening the period of snow melting.

8.4.4.3 Types or methods of Thinning

The methods of thinning are as follows:

- Mechanical thinning
- Low thinning method or ordinary thinning (German Thinning)
- The crown thinning (French Thinning)
- Selection thinning
- Free thinning
- Maximum thinning
- Advance thinning

Mechanical thinning is the removal of trees in rows, strips at fixed intervals. It is applied as the first thinning in young stands that are densely crowded or relatively uniform with little differentiation into crown classes. However, the method is less useful when the crop starts differentiation and the size and quality of the trees increases. While conducting such thinning in rows, the trees are cut in lines or strips at fixed intervals throughout the stand or in other words, the trees at fixed intervals are chosen for retention and all others are felled.

The low thinning method is also known sometimes as " thinning from below," or the " ordinary thinning" or " German thinning" method. It is the removal of trees from the lower crown classes to favor those in the upper crown classes. It removes only suppressed to intermediate trees and thus, facilitate utilization of the trees that would probably die due to suppression. , but the release of the remaining trees from competition is minimal. However, heavy low thinning which is generally recommended, removes suppressed, intermediate, and the poorest codominant trees. This creates canopy openings and releases the crowns of crop trees to stimulate their growth.

The crown thinning differs from the low thinning in two respects:

1. ***In crown thinning the principal cutting is in the codominant or dominant classes, and***
2. ***The bulk of the intermediate class and the healthier portion of the overtopped class remain after each thinning.***

The crown thinning method is also known as '**French method**' because of its origin in France. Other names to this method are 'high thinning', 'Danish thinning' and 'thinning in the dominant'. The principle of the crown thinning method is to cut in the upper crown classes in order to favor the development of the most promising ones in these classes. This way the best trees of the crop get favourable conditions of light and space, thus, opportunity for continuous and rapid growth and development. This is characteristic feature of crown thinning method.

<u>The advantages of the crown thinning</u>

- *Bigger timber can be produced in the same time or timber of a required size in a shorter time*
- *It gives higher immediate cash returns from the thinning because the material removed is larger and better in quality*
- Any part of the area not occupied by the main stand is utilized by the understory trees which are able to continue growth, slowly producing cordwood as the principal product.

The selection thinning is the kind of thinning in which the largest dominant trees and the overtopped trees which are likely to die before the next thinning, are removed. It was developed by Borggreve in 1891. The dominant trees to be removed are selected on the basis of their form and the quality of the timber they can eventually produce as compared with their associates. This method has certain clear advantages and disadvantages in contrast to low thinning and crown thinning.

Advantages and disadvantages of Selection thinning

Advantages

- The thinning returns are better due to thinning carried out at late stage.
- Thinning product is easily saleable in the market on account of having appropriate size of product.
- Lumber is the main product in this kind whereas it is mainly cordwood under other methods.
- The quality of timber produced is better as only clean-bole and small-branched trees are allowed to remain until the end of the rotation.

Disadvantages

- The rotation must be long enough to secure timber of a given size.
- Removal of larger individuals is done in this kind of thinning which demands skill as well as high cost.
- One has to wait for longer time as given dimensions of timber is produced in longer duration
- There are chances of damage to other standing crop during felling of larger trees
- Transportation of comparatively larger crop is not easy. Further, probability of damage and injury to standing crop is higher during transportation.
- Removal of most vigorous individuals may result in occupancy of the area by less vigorous race (Hartley 1927).
- A large opening is created due to removal of larger trees and may also be filled up by trees of inferior crown classes.

8.4.5 Pruning

Pruning is **the kind of** cuttings in which green or dry branches are removed from standing forest crops or trees for the purpose of increasing the quality of the final product. Based on the kind of branches removed (dry or green), pruning is of two types- pruning of dry branches and pruning of green branches.

Another way of classifying pruning is based on natural or artificial means involved in pruning operation. Therefore, two kinds are recognized i.e., natural pruning and artificial pruning. In natural pruning natural agencies such as wind, storms, snow, falling boulders etc., causes removal of dry or green branches from trees. It is also known as 'self-pruning'. Whereas artificial pruning is carried out by human beings or silviculturist in naturally regenerated or artificially regenerated forest crops.

Since pruning is a costly affair, therefore, pruning is carried out only for those crop species where principal aim is to obtain knot-free timber with clear bole. Further, the cost may also be minimized if the operation is carried out during young stage when cutting of branches is comparatively easy. Additional cost minimization may be affected by selectively choosing the best trees of the lot.

Another way of pruning is 'bud pruning' in which buds are removed as soon as they arise in order to reduce no. of branches. This is a very cost effective measure of pruning.

The branch pruning is done by the following methods:

- Climbing the bole of the tree and pruning from this position. This is carried out by reaching near the branches to be pruned with the help of climbing irons or ladder and pruning progressively upward. The other way is by climbing the tree and pruning progressively downward. This method is also known as **Tarzan method.**
- Standing on the ground and pruning to desired height with tools mounted upon poles.

Different kinds of tools are available in market for pruning purposes. These tools include Saws (hand, pole, power), Edge tools which cut by impact (axes, billhooks, brush hooks, chisels and pullers). In both methods branches within the reach are cut off with a hand tool. The best pruning is achieved when the cuts is done close to the tree trunk and flush, leaving no splinters of wood and made without tearing or loosening the bark around the branch and without wounding the stem of the tree. Therefore, for good pruning it is important to select a good tool. A good pruning tool can be the one which has ability to satisfy the requirements of good pruning, with a minimum time, minimum energy and highest safety to the operator.

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Unit 9: Silvicultural Systems: Clear-felling and Shelterwood systems

Unit Structure

9.0 Introduction

After the crop has attained maturity, it must be harvested with least injury and in such a way so as to increase its safety and usefulness. This necessity has resulted into the evolution of certain procedures for forest harvesting which are known as **silvicultural systems**. Forest crops may be either produced directly from seeds or from other vegetative parts such as sprouts from stumps or roots already in the ground. A forest having origin from seeds is called a **seed forest or seedling or high forest** whereas the forests which arise from sprouts is known as **a sprout or coppice forest.** Coniferous forests normally have their

origin from seeds and rarely from sprouts. Many of the broadleaved trees have good coppice power and therefore, such forests have origin from coppice sprouts.

In this unit, we will define and explain the silvicultural systems. A detailed elaboration will be on various types of silvicultural system and the specific characters and requirements of important silvicultural systems.

9.1 Learning Objectives

The main objectives of this unit are to acquaint the learner with:

- the definition and concepts of silvicultural systems
- various types of silvicultural systems
- specific characters and requirement of important sylvicultural systems

9.2 Silvicultural Systems: Concept, definitions and classification

According to Manual of Forestry, a silvicultural System may be defined as "the systematically arranged methods of formation, regeneration, tending and utilization of the forests. Silvicultural systems are categorized in three major categories based on the method of formation or regeneration. These are as follows:

A) High forest systems (seedling forests)
B) Coppice forest systems
C) A combination of high and coppice forest systems

These three systems have further sub-categories based on variations in factors of the locality, the composition of forests, and various purposes for which they are grown. These are as follows:

I. Principal Systems

A) High forest or Seedling forest

1. Clear felling system
2. Shelter-wood system

B) Coppice forest systems

C) Combination of seedling and coppice forest

II. Auxiliary systems

D) High forest with standards

E) Two-storied high forest

F) High forest with soil protection wood

G) Forestry combined with the growth of held crops

H) Forestry combined with pasture

I) Forestry combined with the breeding of deer and other game

Check Your Progress 1

1. What is a silvicultural system? Define it and explain the concept.
2. Give a brief classification of silvicultural systems in India.
3. Differentiate between clear-felling and shelter-wood systems.
4. How will you differentiate between high forest system and coppice systems?

9.3 Clear felling System

9.3.1 Concept and definition

The forest crop in an area may be a product of direct sowing or planting or sometimes by the seeds from adjoining forests. In such forests or regenerations, all the young trees are almost of same age and same height but as soon as the branches begin to grow, the trees take a shape of continuous leaf canopy at the top. In the course of time, the canopy is elevated more and more above the ground and the space below the canopy is occupied by branchless trunks or boles of the trees. In such forests or at this stage of forest, because of full canopy cover, the sunlight reaches only in the upper parts of the crown which results into height growth and the formation of clear boles. When the forest crop attains maturity, it is clear-felled leaving bare land which is re-cropped or regenerated later on with the same species or other depending upon the requirement and objects of the owner. This kind of system of harvesting all the forest crop at the same time is known as **clear felling system**. It may be defined as, **"a method of harvesting forest crop in which all the forest crop is clearly removed from an area resulting into bare area which is re-stocked with the same tree species or other as per the objects of owner"**.

9.3.2 Regeneration under clear felling system

Clear felling operation in an area results into bare land, therefore, regeneration is needed as soon as possible so that loss of soil by wind or water may be arrested. Regeneration in such areas can be carried out either **naturally or artificially**.

Natural regeneration may take place by seeds reaching the area from some seed source available in nearby locality or sometimes from the felled trees itself. It is important to note that the area to be regenerated must be free from all the harvested crop (i.e, lumber, logs,

and debris) and residues before regeneration activities are carried out. This is mainly done in order to check damage to the young plants during transportation of harvested crop and residues and also to diminish fire hazards offered from crops debris.

Artificial regeneration includes regeneration from seeds or by planting of seedlings raised in nurseries. This is the most commonly practiced way of regenerating crop under clear-felling system. Sowing or planting whatever the case may be, is carried out as soon as clear felling of crops is over. This is particularly because the clear-felled area has a tendency to get invaded by grasses, weeds or undesirable species which unnecessarily enhances the cost of operations in the later stages. However, in certain situations when there are chances of damage to new stand more due to insect pests, the area needs to be enriched with humus, the regeneration is delayed for some time. In some other areas, artificial regeneration is carried out along with field crops as well.

In order to carry out artificial regeneration in clear felled area some prerequisites are as follows:

- appropriate seed supply if direct sowing has to be done
- nursery operations for raising plants from seed
- transplanting of plants in the clear-felled areas

One should remember certain points while planning for artificial regeneration through the seeds. These are:

- Quality of seeds is a prerequisite for the success in artificial regeneration. Seeds should have appropriate certification with information on purity of the seed, weight of 1000 clean seeds, the number of seeds per kg, and also the germination capacity (energy) of the seed
- Germination tests in order to know the germination capacity of the seeds. This ensures the success of regeneration
- If a forester has sufficient fund for purchasing than they should purchase good seeds instead of sourcing it from nature. However, in the absence of funds, the seeds must be collected from the nearby localities with abundant seed trees especially from sound or vigorous trees only.

- It is economically cheaper to collect seeds from felled trees than from standing trees. It is the old trees which are generally preferred over young trees for the purpose of seed collection. According to Allen (1942), the minimum age of seed-tree from which seeds may be collected should be 20 years.
- Viability test for seeds (germination capacity of the seeds) collected from natural sources should be conducted before sowing.

The second important step in artificial regeneration is nursery operations when regeneration is planned from transplants. Following points should be kept in mind while starting nursery operations:

- Selection of suitable site for the nursery for production of transplants. The site should be located near or within the area where plantation has to be carried out.
- The soil should be of the sandy-loam type, deep, moist and well drained. An acidic soil is preferred for developing coniferous transplants whereas for broadleaved transplants heavy soil is preferred.
- Land should be leveled and free from stones. It should be such that it results in lowest production costs.
- There must be an adequate supply of water for watering the seedlings.
- Availability of electric power supply
- Availability of good supply of labour for carrying out various nursery operations
- Nursery should be adjacent to a road
- The size of the nursery depends upon the target plantation site and the kinds of plants
- Buying is particularly preferred where only a small area is to be planted as raising transplants in nurseries unnecessarily enhances cost of operations

9.3.4. Choice of species

Choice of species under clear felling system should be done considering the following points:

- Species should be suitable for the climate and the site. Usually the species which are not well adapted to local conditions result into plantation failures.
- Species should be promising in terms of economic returns.
- Species should:

- be fast growing
- be having low cost of establishment and management
- be economically useful and yielding valuable products
- not be susceptible to injurious agencies

- As far as possible native species should be selected. Sometimes non-native species are also considered, however, introduction of an exotic species particularly from a foreign country should never be undertaken unless substantial evidences are there regarding its adaptability to the local climate and conditions of site.
- Usually pure stand are preferred in clear-felled areas over mixed species as the later demands much technical knowledge.

9.3.5 Characteristics of the forest crop established under clear felling system

The characteristics of forest crops developed under clear-felling system are as follows:

- It results into production of very high quality forests / wood when compared with other high forest systems.
- This system produces long clean non-tapering boles.
- It is an economic method and can be applied in those forest stands where all trees are of merchantable size. Such forest crop or stand would be either even-aged or may contain several age classes.
- The new stand originating on a clear-felled area will be even-aged, irrespective of whether the timber before the cutting was irregular or uneven-aged.

9.3.6 Protection of germination

As soon as seeds germinate, they have to face various kinds of dangers offered from nature. Therefore, the requirement is to protect the newly germinated crop through application of physical or chemical measures. The problems and protection measures are discussed as follows:

- After germination, seedlings are prone to be attacked by fungi and other harmful organisms. The fungi active in the surface soil may bring about large scale mortality in the young plants. In order to protect the young plants from damping off disease caused by some fungi (*Phytopthora, Pythium* etc.), the chemical treatment of soil in seed beds

is necessary. For the purpose various acid solutions are used such as sulphuric acid, formaldehyde, aluminum sulphate or Dry Bordeaux mixtures.

- Protection from rodents is essential in order to bring about successful plantation. Rodents destruct the seeds and thus, plantation may be a failure before germination particularly in direct seeding both of hardwoods and conifers. Although systematic poisoning of seed beds or transplant area is carried out for control of rodents but is not very effective. Coating seeds with repellents or poisons has not usually proved thoroughly effective as it kills many rodents which eat the seeds but this happens only after they have eaten the seeds. Another way of controlling the rodents is by placing a wire cage or dome of hardware cloth over each seed spot. The wire domes may have favourable effects on germination and seedling survival as it controls light intensities and soil temperatures on the surface covered. Although wire cages are effective against birds and small rodents however, it may be overthrown by larger rodents and other animals. Another way of controlling damage by rodents is pre-germination or sprouting of seeds before they are sown which may reduce the amount of damage done by rodents as the chemical changes taking place in the germinating seeds may make the sprouted seed less palatable to the rodents.
- The physical or external dangers to the germination include the dangers from frost, drought, insects and storms. In winter, and especially in spring and autumn, frost threatens the young plants of species which are frost sensitive. In summer the uninterrupted exposure to the sun may dry up the soil and plants which may also cause serious injury to seedling or young plants.
- The greater dryness of the soil attracts insects, which concentrate their breeding places on the area. Higher number of insects cause greater amount of damage to the plants.

9.3.7 Effect upon Locality Factors

Effect of locality factors differs much during the several periods of the life of the wood. During early youth, before a complete leaf canopy has been established, the soil is exposed to the effects of Sun and air currents, both of which act highly injuriously on the soil. Subsequently, when a good cover is established, the very opposite effect is produced in a high degree. Later on when the crowns develop, the sun is still kept out, but there is no impediment to air currents striking through the wood, so that moisture is carried away. In case of shade bearing

hardy species with dense crowns, the system yields evidently much better results than in case of light demanding species with thin crowns. The length of the rotation also affects the results.

Check Your Progress 2

1. Briefly explain the concept of clear felling system.
2. Write a brief note on 'regeneration in clear felling system'.
3. What are the various points that should be considered while making a choice of species in clear-felling system?
4. Explain the characteristics of a crop under clear-felling system.
5. Write a note on protection of germination in clear-felling system.

9.4. The Shelterwood or Uniform System

9.4.1 Concept and definition

In this system, the new forest crop is established under the shelter of the old crop and is retained for some years until the young generation is safe enough against injurious agencies and other external influences, and has established itself in the area. Shelterwood system may be defined as "**a natural reproduction that starts under the protection of the older stand and is finally released from this shade and protection when able to tolerate the exposure**". The other terms used synonymously for shelter-wood system are '**progressive felling'**, **'uniform system'** and, '**compartment system**'.

9.4.2 Regeneration under shelterwood system

The regeneration may be brought about naturally from the seeds available from the shelter trees (also sometimes known as mother trees), or it may brought about artificially by means of sowing or planting.

Under natural regeneration, one seed year is not sufficient to bring about regeneration in whole area, therefore, normally two or three such seed years are needed. Sometimes it needs to be assisted artificially through sowing or planting in order to bring about uniform regeneration in the whole site. Therefore, this system results in the new crop which has variations in age ranging from 2 to 5 years. However, such differences in age becomes invisible in course of time when the crop approaches principal height growth and for all practical purposes, such crops are considered as even-aged.

9.4.3 Protection of germination

Generally the protection to young crop is afforded by shelter-wood or old crop retained in the site for the purpose. It particularly reduces the various kinds of dangers from frost, drought and weeds. After the crops gets established, there exists no difference in this system and clear felling system except that the woods raised under this system are less attacked by insects than those raised on clear felling system. One important point to note is that the shelter or mother trees are liable to be thrown away by storms in the absence of other vegetation in the area which may adversely affect regeneration activities in the area.

9.4.3 Method of harvesting in shelter wood system

As explained earlier, under shelter-wood system, the regeneration is established under the shelter of old stand. The shelter-wood besides being source of seeds, affords shelter or protection to the young regenerating crop. As soon as the young crop gets established in the area, the shelter-wood needs to be removed as its role is over and it often poses hindrance with the growth and development of the established crops. A minimum of two cuttings are required in the simplest application. Under intensive management several cuttings often more than ten (10) may be required in the process of removal of shelter-wood from the site. These cuttings are categorized into following three types:

i) **Preparatory cuttings**

ii) **Seed cuttings**

iii) **Removal cuttings**

9.4.3.1 Preparatory cuttings

The objectives of preparatory cuttings is to create optimum site conditions for the germination of seeds, optimum seed production from better seed trees and to develop wind firm trees which can safely be left isolated. Thus, preparatory cuttings results in exposing of thick and dry forest floor. This results in disintegration of litter with more light and better air circulation and thereby making better conditions for seedling germination and establishment. Opening of canopy also results in enlargement of shelterwood (or seed trees) and its crown, which in turn results in increased photosynthesis, thereby increased seed production. Generally, three to ten years are required in dense stands to achieve the objects of preparatory cuttings. **In preparatory cutting such trees are selected which are overtopped and those which are diseased or defective ones.** Finally, if more opening is

needed, then individuals of undesired species and individuals of desired species with overdeveloped and spreading crowns are also selected.

9.4.3.2 Seed Cutting

The purpose of seed cutting is to remove the seed trees or shelter after seeds have germinated and seedlings are established. The shelter-wood now start interfering with further growth and development of established new crop. Before harvesting seed trees, one should wait for a good seed year and cutting of shelter-wood (or seed trees) is conducted only when seeds are matured. The logging activity serves to spread the seed thoroughly into the thin humus and mineral soil where it finds an ideal germinating bed with an abundance of light and heat made available as a consequence of the reduction in the forest cover.

9.4.3.3 Removal Cuttings

Removal cuttings are made in order to free the area and new crop from shelter of old wood thereby, giving an opportunity is given to new young crop for having complete possession of the area. It may involve one or several cutting in intensive management. The last cutting is called the final cutting. The severity of the removal cuttings and the intervals at which one follows the other are governed by the degree to which the young stand needs protection or is suffering from too much shelter.

In order to find out hindrance by shelter-wood to establish regeneration, the whole area is monitored for indications of poor growth condition. Certain points such as unhealthy foliage color, reduction in height growth or bending of seedlings towards the light, indicate that it is time to release the shelter. However, these indicators may not be found uniformly over whole areas at one time but a patch here or a patch there may indicate the need of having removal treatment. Therefore, all the removal cuttings are not made at one time in the whole area. It is done as per requirement of the patches of regeneration and according with the need these cuttings are made. A group may be cut clear in one place and a few trees thinned out in other places; elsewhere there may be no cutting. After few years, a similar cutting will be needed, and the process continues until all the old timber is harvested. Removal cuttings are likely to be needed at intervals of 2 to 5 years and to cover a period of 2 to 20 years.

9.4.3 Characteristics of the forest crop established under shelterwood system

The characteristics of forest crop produced under shelter wood system are:

- The crop constitute even-aged stand, thus resembling the clear felling and seed-tree methods. The quantity of total production is almost the same as in clear cutting system and seed tree method.
- In some cases the reproduction cuttings may extend (when the rotation is long) over a period of 40 to 60 years, which tends to create a wider range in the ages of the individual trees than the other two methods. Usually the regeneration period cannot be less than 10 or more than 20 years. Even with a long regeneration period the stand still remains essentially evenaged.

9.4.5 Advantages and disadvantages of shelterwood system

Advantages

1. The unfavorable effect of sun and air currents during the early youth of the wood disappears under this system as the shelter-wood protects the soil until the new crop is established. Better protection to the seedlings from frost and such desiccating agencies as sun and wind also aids in securing more certain and complete regeneration.
2. Species with heavy seeds as well as light seeds can be successfully reproduced by this method. Therefore, it has an edge over clear-felling and seed-tree methods under which it is difficult to secure adequate dissemination of heavy seeds.
2. Reproduction is ensured completely due to the presence of greater number of seed trees in the site and thus, all parts of the site get fully stocked.
3. The site always remains under vegetation cover and therefore, protection is ensured against erosion, landslides and rapid runoff during the period of regeneration and this protection remains available until regeneration crop is fully established. Further, excessive growths of weeds and grass remains under check. It has also been observed that insects causes less damage to the young crop under this system.
4. The aesthetic beauty of the site remains maintained under this system whereas in other high-forest systems (clear felling and seed-tree systems), due to clear felling of all the tree crop, the site gets bare and aesthetic beauty is impaired or compromised.
5. Since shade and shelter is available in this system, therefore it is the best method of regeneration (among the various high-forest methods producing even-aged stands) for those species which can be regenerated naturally.

6. Under unfavorable climatic and soil conditions (infertile soils), the shelter afforded to young crop results in higher production. Although the growth of regeneration or young plants is faster in clear felled sites, yet the crop under shelter-wood system establishes earlier and it has been observed that it yields higher increment growth.

Disadvantages

1. The system cannot be applied in conditions where chances of danger from wind throw or breakage are more.
2. Greater technical skill is needed in this system when compared with other high forest systems such as clear-felling and seed-tree methods.
3. There are chances of damage to young regeneration in the process of removal cuttings. Therefore, additional care is needed during removal cutting which in turn increases the cost of logging operations.

Check Your Progress 3

1. Briefly explain the concept of shelter-wood system.
2. Write a brief note on 'regeneration in shelter-wood system'.
3. Discuss 'protection of germinating and young crop in shelter-wood system'.
4. Discuss the various kinds of cuttings in shelter-wood system.
5. Write an extended note on shelterwood system.
6. Discuss advantages and disadvantages of shelterwood system.

9.5 Modifications in shelter wood system

Basic shelter-wood system has been modified differently as per the need of species and as per demand of site conditions. These modifications are mainly classified based on their application in the stand. These classes are as follows:

1. The Uniform System (uniformly applied in the entire area)
2. Strip Shelterwood System (applied in strips)
3. Group System (applied in groups)

The details as discussed under shelter-wood system relate particularly to the uniform system. Although in the strip and group modifications, the principle is essentially the same except that a given cutting is extended over a portion only, instead of over the entire stand.

9.5.1 Strip-Shelterwood Method

This method was developed by Wagner (1923). He applied it in the management of a

Norway spruce forest located at Gaildorf in Wurttemberg. In his modification, he applied removal cuttings in strips instead of applying uniformly throughout the whole area. Thus, removal cuttings were concentrated in certain strips only in a given time whereas other portions of the stand remain untouched for some time. This method involves the following steps:

Step I: Preparatory cutting in strips starting from one side of the stand

Step II: A removal cutting in the first strip whereas seed cutting in the adjoining strip.

Step III: Final cutting in the first strip after few years of step II and removal cutting in the second strip whereas seed cutting is initiated in the third strip and this process continues till the last strip is reached. Thus, the process involves various cutting operations from first strip of stand to last strip. The strips are usually kept narrow, preferably not above twice of the height of the mature timber.

The strip shelterwood system has several advantages over the uniform shelter wood system. These are:

- It affords better protection against windfall part of the intact stand and acts as a windbreak.
- It results in better reproduction since extra amount of seeds are available from the adjoining strip of trees.
- Protection against evaporation is afforded from the adjoining strip and it also helps in conservation of soil moisture.

9.5.2 Shelterwood Group System

The wood is formed, or regenerated, under the shelter of the old crop, but instead of treating a whole (or several) compartment in an uniform manner at one time, with a view to its simultaneous regeneration, only certain groups of trees, scattered here and there over it, are dealt with in the first step. When these have been regenerated, others are treated in the same way, and so on, until the whole compartment has been regenerated. The regeneration period extends over not less than thirty years, and often forty or fifty years during which the old wood is gradually led over into the new wood. At the end of the regeneration period, the new' wood consists of a series of groups, ranging in age from one to thirty, forty, or fifty years, and it presents a picture of unevenness which is preserved throughout life. The wood

grows on until the next regeneration comes round, when operations are commenced in the oldest groups and gradually extended to the youngest, similar to the procedure followed in the first instance. During regeneration, all seed years are taken advantage of and artificial help, where necessary or desirable is also applied.

Summary

A silvicultural System is simply systematically arranged methods of formation, regeneration, tending and utilization of the forests. Silvicultural systems are categorized in three major categories based on the method of formation or regeneration. These are as follows: A) High forest systems (seedling forests); B) Coppice forest systems; C) A combination of high and coppice forest systems.

Important systems among the high forest systems are Clear felling System, Shelter-wood and selection systems. In clear felling system, the forest crop in an area which has attained maturity is felled all at one time Therefore, it may be defined as, "a method of harvesting forest crop in which all the forest crop is clearly removed from an area resulting into **bare area which is re-stocked with the same tree species or other as per the objects of owner"**. Such forests are even-aged forests.

In Shelterwood or Uniform System, the new forest crop is established under the shelter of the old crop. The old crop forms a shelter for new crop and is retained for some years until the young generation is safe enough against injurious agencies and other external influences, and has established itself in the area. Thus, Shelterwood system is "a natural reproduction that starts under the protection of the older stand and is finally released from this shade and protection when able to tolerate the exposure". The other terms used synonymously for shelter-wood system are 'progressive felling', 'uniform system' and, 'compartment system'. Shelter-wood system are generally classified as- The Uniform System, Strip Shelterwood System and Group System

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Unit 10: Silvicultural Systems II: Selection and Coppice Systems

Unit Structure

10.0 Introduction

IN the previous unit, we discussed about silvicultural system, its definition, concept, and various kinds of silvicultural systems. There are mainly two kinds of systems i.e., those which arise by seedling and those which arise by coppice and respectively known as high forest systems and coppice systems. Further, a detailed description of two high forest systems namely clear-felling and shelterwood systems was also made.

This unit mainly deals with the third type of high forest system i.e., selection system, its various modifications. Further, advantages and disadvantages of the system are also explained. Another major category of silvicultural system – coppice system is also explained in detail. Lastly, we have also discussed various modification of coppice system.

10.1 Learning Objectives

After going through this unit you shall be able to:

- Explain the selection system
- Elaborate various modifications of selection system
- Differentiate between selection system and coppice system
- Elaborate the concept of coppice system and explain various modifications of coppice system

10.2 Selection System

10.2.1 Concept and definition

The concept of selection system is based on the philosophy that the oldest or largest trees in a stand are selected for harvesting. Similar harvestings are conducted after one or more years and the process is repeated at intervals throughout the rotation. This system of harvesting always maintains green cover in the area of operation and never results in denudation of the area. Since single mature tree or groups of mature trees here and there over the whole area are removed from the forest, the new crop always remains under protection or under shelter of other neighboring trees and this process goes on throughout the whole length of the rotation. In such a forest, all age classes from one year old to the oldest are usually present all the time.

10.2.2 Method of selection system

The methods of selection system includes selection of the oldest and largest age class of trees and their harvesting each year and repetition of the same process year after year. Trees of the adjacent area act as seed source and also render protection to the young crop. The openings created by selective harvesting gets filled up with seeds from adjoining seed source and soon regeneration comes up.

Continuous harvesting and regeneration of crops results into different age classed in the area. Thus, the crops or individuals regenerated after harvesting in the first year, get matured by the time all the age classes in the stand are harvested once. Thus, in this system oldest age class (scattered here and there) ready to be harvested remains available each year. Since the trees making up the oldest age class are single and scattered individuals,

therefore, it is necessary to conduct harvesting, logging and regeneration process in the whole stand or forest. There are certain practical difficulties in this method which are explained below:

- Logging operations become expensive as operations are scattered over in a large area
- Some species do not seed every year
- Seedlings face difficulty in becoming firmly established when the area is cut over each year

In order to overcome above mentioned difficulties, the concept of **cutting cycle** evolved. According to this concept, the entire forest is not harvested each year. As the whole area cannot in practice gone over every year. It is divided into number of blocks, one of which is worked over each year. The number of blocks determine the period of years elapsing between two successive felling over the same block. This period is known as felling cycle**.** Generally, cutting cycle is ranges from 10 to 60 years depending on the places or countries.

Normally in each stand, there will be many age classes which is equal to number of cuttings during the rotation. In order to find this number, rotation age is divided by the cutting cycle. As the interval between cuts is lengthened the amount per acre removed in a single cutting is increased in direct proportion to the increased length of the cycle. However, the actual percentage of the volume that is removed in a selection cutting is subject to great variation, depending on the length of the cutting cycle, and the condition of the stand.

Determining the amount of harvest per acre would have been easy if the stand has all age classes and each age class occupying the proper proportion of the area. Unfortunately such an ideal stand is non-existent and therefore, it complicates the problem of determining the amount to cut. If it is possible to uncover the right proportion of the area each year then it will result into the proper distribution of area between the various age classes. Therefore, regulating the harvesting by means of the area uncovered will involve the sacrifice either of some timber far beyond maturity or of harvesting of trees not yet mature. For these reason, it appears impracticable in the beginning to fix the amount to be harvested by uncovering a fixed percentage of the area.

10.2.3 Advantages and disadvantages of Selection system

Advantages of selection system are as follows:

1. The young crop always remains protected
2. In this system, the mature seed source are always available nearby and thus, are a constant source of seeds and thus, supply of seeds is rarely affected. Therefore, it is easier for regeneration to establish.
3. Rain water is more effectively retained on sloping land under this system than under any other system;
4. Site, vegetation and regeneration always remain protected as it is never clear felled. The system affords protection to soil from erosion or landslide. Therefore, it is generally applied on poor soils, erosion or landslide-prone areas and at higher elevations in order to avoid chances of landslides or erosion and to ensure protection of forest stands.
5. Further, only small opening are created during selective felling and the regeneration i.e., seedlings, coming up in these openings always remain protected from wind, excessive heat or other injurious agencies such as frost or other physical factors.
6. Aesthetic or scenic beauty of the site remains maintained.
7. Storm breakage of standing crop as well as snow breakage are reduced to minimum. The large crowns of mature trees offer resistance to storms and thus, they are more or less wind-firm and provide shelter to the young trees.
8. It always maintains the uneven-aged character of the forest stand.
9. Danger of disastrous fires are comparatively less in this system. All time presence of continuous forest cover coupled with light selective cuttings, maintains high moisture level and thus, prevents the degree of disastrous fires. However, in case of severe fire outbreak, the unevenaged forest are the one which would get affected more, reason being continuity from ground level to crown level as all the vertical layers of growth forms remain present in unevenaged forest stands, results into crown fire and which are most devastating in nature.
10. The uneven-aged forests are better and desirable places for wildlife which helps in conservation of wildlife or biodiversity as a whole.

Disadvantages of selection system are as follows:

1. Logging and transportation cost is higher in selection system as one has to move to different places inside the forest to collect the logs.
2. Injury by logging operations and transportation are more to the regeneration and young trees.
3. The timber produced has more knots due to greater crown development or more branches, thus, the timber is of comparatively of low grade.
4. This system demands skilled personnels or foresters and other members owing to the complex nature of the stand not only from the point view of felling mature tree but also to reduce the damage to the undergrowth during harvesting, logging and transportation process.

10.2.4 Modifications of the Selection Sytem

There are many modifications in selection system which are as follows:

- Group selection
- Strip Selection
- Improvement Selection and Maturity Selection
- Selective Logging or Selective Cutting

In Group Selection, all efforts are concentrated in tending the individual trees, improving site conditions, and providing a continuous cover without ever exposing the soil. The individual trees are provided ample room for fast growth and are retained just so long as their growth is satisfactory and they are not interfering with better individuals. The removal of the large tree creates a gap in which reproduction has an opportunity to develop. The excellent soil conditions maintained by the method make natural regeneration easy.

Strip selection is a silvicultural system in which attempt is made to bring together all the trees of each age class in the entire stand. This is best done in the form of a long, very narrow strip and is, therefore, known as strip selection. The adjoining age classes on the two sides are respectively younger and older to the strip. The strip system results into a complete series of age classes from regeneration to mature timber. This is beneficial as logging activity can be carried out at one place and logging operation causes least damage to the young crop.

Selective harvesting is a system in which the species expected to pay highest or satisfactory timber is only harvested. This profitable timber may occur as logs in individual trees, as entire scattered trees, as clumps of trees or even as large areas of timber. Allocation of the areas according to time of cutting so as to get the best profit is also included. In selective harvesting, the profitable timber is selected and harvested while leaving the remainder crops as unprofitable timbered areas, single trees, and portions of trees. In mixed stands, however, selective logging poses serious danger as the area becomes devoid of better species and poorer species find scope for its spread. Selective logging by single trees, or groups of trees, in un-evenaged stands often results into good silvicultural conditions.

Improvement Selection System is name given by Pearson (1942) for a selection system in which the light type of cutting is carried out. He describes in his own words as, "Improvement selection is, as the name implies, a form of selective cutting which stresses improvement of the remaining stand. In addition to economic utilization of the crop, it strives to create a better growing stock with each successive cutting. It favors the class of trees which promises the greatest contribution in growth and value to the stand as a whole."

Maturity selection system is a form of tree selection system in which the removal of those trees is carried out which are biologically and financially most mature. This is normally judged by mortality probability, quantity and quality of growth rate, and carrying charge (or interest) based on current capital value.

Check Your Progress 1

1. What is selection system? Discuss.
2. Discuss the concept and methods of selection system.
3. Write a brief note on advantages and disadvantages of selection system.

10.3 The Coppice system

10.3.1 Concept and definition

Most of the broadleaved species have capacity of regenerating from sprouts originating from root/ stool/ stem. Under favourable conditions, the sprouts develop from cut stem or stool which has the capacity to develop into poles or mature trees. This characteristic of the species is utilized in developing new stand of forest without seed sowing or transplanting. Thus, in coppice system forest regeneration or renewal of the forest is done principally

through sprouts springing up from stumps. This way timber and other products can be obtained continuously for a long period without completely uprooting the species. Thus, coppice may be defined as shoots arising from stump or cut stem more or less close to the ground level a coppice system is "the system of regenerating forest stand through coppice crops". A coppice system usually develops an even-aged forest stand provided that clear-felling method has been used for cutting of all the trees of the stand at stump level, because in such stands the sprouts would regenerate and develop into new stand with same age class.

10.3.2 Methods of coppice system

In this method, all the tree crops of the stand is cut at stump level in one cutting. Sprouts start coming up within a year. One of the important prerequisite of this method to be practiced is the ability of species to sprout and sprouting capacity has been observed more in broadleaved species than conifers. This is the reason that this method is more prevalent in broadleaved species than the coniferous ones. The coppice sprouts mainly originate from dormant bud, however may also originate from adventitious bud. Budding may initiate from root collar or side and top of the stump. However, sprouts arising from root collar are the most abundant and develop into the best trees. Some species may also sprout from the roots. One of the important thing to note here is that a species capable of sprouting does not always mean that it produces quality stand. This sprouts having capability of regenerating forest stand of good quality depends upon various several factors. These are as follows:

- Age or size of the tree at the time of harvesting
- Harvesting season when stumps are produced
- Stump height
- The characteristics of the stumps

Sprouting ability of trees decreases with age and size. Possible reason is that with maturity tree loses its ability to produce potential dormant or adventitious buds. However, this varies from species to species.

The best time for coppice harvesting is the period when trees are in dormant phase. Further, the presence of sap in the wood at harvesting time increases its susceptibility to infections and injuries such as tearing, breaking off of sprouts and frost injury. Forest harvesting to

form stumps is particularly fruitful in the late fall and winter when vigorous sprouting takes place.

Harvesting done in early summer, result in stumps which may sprout in the same season, however, such sprouts (being late) have a very weak growth and often are damaged by frost. After midsummer harvesting and resultant stumps most likely do not produce sprouts or furnish unproductive sprouts or furnish sprouts only in the following year.

Height of the stumps is one of the important factor determining the development of vigorous sprouts. Therefore, stumps should be cut as low as possible and cut should be smooth and slanting. Such stumps result in sprouts in root collar region, which in turn enables the sprouts to form independent root systems quickly. Further, such stumps have better chances of getting protections from litter and snow.

The instrument preferred for harvesting in order to get quality stumps is axe than saw. It is easy with an axe to make a smooth and slanting cut so that water leaves the stump quickly and thus, ensures sound health of the stump for longer duration. On the other hand, felling with saw leaves causes rough surface of the stumps.

Since the vigour of sprouts deceases with age of harvesting, therefore, rotation in coppice system is kept short, however, it also varies from species to species. Generally, rotation of 10 to 40 years is preferred in order to get vigorous sprouts. In order to augment the sprout crop, some amount of seedling reproduction is also advisable from time to time, even in a stand fully stocked with sprouts. It is particularly useful and important for the species in which the sprouts are more susceptible to disease or other injuries.

Seedling reproduction is carried out through healthy transplant planted in the site where the sprouts have failed to establish. After planting and establishment, transplants should be cut back to the ground level. Such cutting results in vigorous sprouts which compete better than the original transplants.

In coppice system clear felling of forest stand is carried out which results into bare sites therefore, large cutting areas are avoided in order to prevent higher exposure to the site. Where there is more danger associated with harvesting, the felling or cutting is done in narrow strips arranged alternately or progressively.

Pollarding: Pollarding is an act of trimming or lopping of sprouts with an intention of reproducing a fresh growth of sprouts from the portion of the tree remaining. The sprouts

are generally harvested when they are small, and another crop is started. The height of pollarding is usually between 4 and 12 feet. Thus, Pollarding may be described as the coppice method operated on a short rotation and with abnormally high stumps. Pollarding is usually practiced where an additional advantage of other benefits are planned to be derived like partial use of the land for grazing or agricultural crops.

Application of the Method: Coppice with its small growing stock, low investment, and quick returns appeals to private land owners, but it is not a satisfactory method for meeting Industrial demands where the quality lumber is required for greater production.

10.3.3 Advantages and disadvantages of Coppice system

Advantages of this method are as follows:

1. low financial investment needed
2. Net return on the investment is relatively high, owing primarily to the short rotation and the small investment
3. In this system, advantage of rapid growth during early youth is taken particularly for small products. Therefore, the amount of wood produced is usually greater than the amount of wood produced in high-forest systems.
4. It is subject to comparatively few injuries as the growth is faster in young stage. In case of frost damage, it is more easily repaired in coppice crops, as new shoots replace those injured during the first year.
5. Coppice is simple and ensure certain crop in comparison to high forest systems.

Disadvantages are as follows:

1. Coppice yields mainly fuelwood and small timber. Therefore, it is only applicable for species yielding such small products. It cannot be applied for quality timber yielding species. Further, coniferous species which lack in coppice capacity, it cannot be applied.
2. It is practiced only in small area with low growing stock, therefore, the constant and comparatively higher industrial demand is difficult to achieve.
3. The available mineral resources gets exhausted on account of continuous yield of the same species and that too species of small branches and young wood which contain a greater proportion of minerals than larger and older wood.

4. The coppice sprouts are susceptible to frost damage. Frost injury renders the method to be useless and inapplicable for the sites which are subjected to frost occurrence particularly higher altitudes and higher latitudes.
5. Coppice crops suffer a lot from injuries by game, especially deer and rabbits. Mice also are injurious to coppice crop.
5. Aesthetically the forest arising from coppice system are poor in scenic value.
6. Owing to the rapid growth of the shoots and the quick establishment of a complete cover, coppice woods protect the soil well after the first few years, but when the land is laid bare at much shorter intervals than in the case of high forest. Further, the coppice species are fast growing and have a tendency to exhaust the minerals and water of the soil.

10.4 The Coppice with Standards System (Stored Coppice)

10.4.1 Concept and definitions

The system of coppice with standards is a combination of simple coppice system and high forest selection systems in which coppice forms even-age crops and high forest selection systems represents uneven-aged crops. The two systems constitute underwood and over - wood, respectively and both are managed under different rotations. Generally, harvesting operations are made at the same time in both underwood and over wood i.e. when the underwood has arrived at the end of its rotation, it is cut over, and at the same time those standards are removed which have reached the end of their rotation. New standards essentially are then planted through seedlings and not through coppice shoots. This results into several gradations of the over wood with difference of period between age gradations being equal to one rotation of underwood.

The system, thus, may be defined as a silvicultural system in which reproduction is largely from sprouts as in the coppice method, but the area is never cut entirely clear as some select trees (i.e., standards) are left over standing at the end of each coppice rotation. The method is also sometimes known as **compound coppice system**.

10.4.2 Methods and types

Before discussing the methods, following important points be kept in mind:

- The standards and coppice may belong to same species or may belong to different species. If species are selected as different species, then for standards light-foliaged species are preferred so that they may not check the light requirements of underwood coppice species and coppice species are selected as those species which are capable of thriving under a partial cover.
- The species selected for underwood crop are generally maintained for the purpose of obtaining cordwood and other minor products whereas species for standards are for lumber. A conifer of high timber value may be employed as a standard over hardwood coppice.
- According to Kittredge 1920, rotation period for the coppice usually ranges from 20 years to 40 years depending on the soil condition. On rich soil species grow faster, therefore short rotation is kept whereas contrary to this on poor soils, large rotation period is opted.
- As far as the no, of standards to be left per acre of area is concerned, it depends upon the silvicultural habits of the species, particularly the spread of the crown and also on the objects of management for forest.

In coppice-with-standards, initially simple coppice is introduced but at the end of rotation, except some select individuals, all other individuals are harvested to stump height. These stumps sprout and form a distinct story under and between the standards. Thus age gradations are formed which are multiples of rotation of underwood. For example if rotation of underwood is 10 years and rotation of over wood is 90 years then the total number of age gradations in over wood will be the multiple of 10 and maximum number of gradations will be 90/10 or 09. Thus, several age classes are found in compound coppice stands. The youngest coppice forms one age class presenting a uniform appearance. Above the coppice are standards belonging to several different age classes, each one of which is a multiple of the rotation age of the underwood coppice. Therefore, the form of stand produced is one of several stories, each even-aged own its own but when view in combined way, and they form an irregular stand with different age classes. Coppice with standards occupies a position intermediate between simple coppice and the high-forest methods. Normally, in this system equal attention is given to both overwood and underwood, and thus, provided with best opportunity for growth and development. However, in practice, a great variety of

modifications are carried out depending upon objects of management i.e., whether the overwood or underwood species form the preferred species.

The standards or the same species or other species have a bigger rotation period and by the time they are harvested and they are too old to sprout from stumps. Therefore, they are always regenerated through seedlings. Further, standards live through several coppice rotations which make them prone to various infections i.e., fungi or viruses etc. if they originate from sprouts. Whereas standards originating from seedlings are less liable to be infected than trees of sprout origin; hence it is desirable that most of the standards have seedling origin.

In fact, mature standards are capable of furnishing large amount of seeds thus, more seedling regeneration in the stand floor. When such natural seedlings are available, then the regeneration of standards after harvesting should be carried out from these seedlings. In case, such seedlings are not available in the area, it is necessary to have new standards by planting seedlings among the stools when the coppice is cut. Such transplants should be strong enough to compete with the sprouts. If such species reproduce vigorously by sprouts, then the transplants after establishment, can be cut back carefully to the ground level. One or more than one sprouts arising from such cutting, compete more successfully with the coppice sprouts than the original transplant could have done. If many sprouts arise from such transplant, the number should be reduced to one. Such sprouts termed as **seedling sprouts**, grow rapidly in the initial stage of growth and are relatively hardier against disease in comparison to trees of seedling origin.

According to Hamm 1896, there are three types of coppice with standards have been recognized based on the relationship between standards and coppice. These are as follows:

a. **Compound coppice approaching simple coppice**, where the over-wood of standards is distributed by single trees of only a few age classes and occupies a small part of the area. Object of management is f**irewood product.**

b. **Normal compound coppice**, in which the sprouts and the standards are of equal importance. Objects of management is to obtain **both cordwood and timber wood**.

c. **Compound coppice approaching high forest**, in which the standards occupy a large part of the area, usually in groups. Objects of management is soil protection through

coppice crop and the major objective is from standards as to get t**imber as the principal product**.

10.4.3 Advantages and disadvantages of standards with coppice

Advantages of this method are as follows:

1. Secures the benefit of rapid growth of individual trees in an open stand without danger of exposing the soil as the standards grow in isolation during a large part of their life, while the coppice protects the site.
2. This system does not demand a large growing stock or financial investment in comparison to other high-forest systems
3. Yield on investment is comparatively higher\
4. It provides best protection to the site as well as to the under-wood against injuries by frost, heat, and wind since a partial cover is constantly maintained for young growth. The over-wood composed of standards are wind-firm and can withstand greater exposure whereas they provide shelter or protection to young coppice from frost, excessive drought, and evaporation
5. Aesthetically it always looks better as site never gets clear cut, therefore it is a desirable method.
6. Compound coppice particularly has more advantages such as abundant seed supply from the standards, abundant production of saw timber

Disadvantages of this system are as follows:

1. It demands high degree of skill and skilled people can only practice this method.

2. There should be a market for small products such as cordwood or other low-grade products.

3. Poor tree form may result due growing of standards in comparatively open areas and may have short clear length and large branching top.

4. It demands comparatively high fertility of the soil.

10.5 Choice of silvicultural system

It has been shown in the preceding discussions that different silvicultural systems have their pros and cons and have variable effects in terms of production of major products, resistance

against external dangers and their effect on the factors of locality. Therefore, while making a choice among the various systems, it is important to make note of the above mentioned requirements and which method is best suited under given conditions. Following are some important considerations while making a choice of species:

- Suitability of the system to the selected species
- The preservation or improvement of the factors of the locality
- Protection against external harmful factors or agencies
- Safety and simplicity of regeneration methods
- Quantity and quality of the produce
- Intensity of management
- Existence or absence of forest rights

10.5.1 Suitability or the System to the Selected Species

This is the most important considerationin all cases where it is desired to grow a particular species. While coniferous species do not have coppice ability and similarly many broad-leaved species have low regeneration under coppice system, therefore, in such cases only high forest systems should be followed. On the other hand, light demanding species with thin crowns are not suited under ordinary simple high forest system. They should be raised as standards in coppice with standards, or in two storied high forest systems, or with a coppice underwood, or in mixture with shade bearing species. Such species are also difficult to raise under shelter-woods. On the other hand, tender shade bearers like Birch and Silver Fir are better adapted to the shelter-wood systems than to the clear felling system. It is also important to note that in a system with two or more crops of different ages on the same area, the over-wood must consist of thin crown and light demanding nature.

10.5.2 Preservation of the Factors of Locality

Another consideration is preservation of the factors of locality. A system that enriches or at least maintains the factors of locality of the site is highly preferred over others. However, in such sites having exceptionally good soil conditions with adequate moisture and suitable temperature conditions, any of the systems can be followed. On all other site conditions and particularly sites with poor quality coupled with unfavourable climate, the first consideration must be the preservation of the factors of the locality otherwise it will lead to steady

deterioration of the site. In such cases, clear felling must be avoided and every effort should be made to keep the area always stocked with forest stands, in other words, shelter-wood system is appropriate for such conditions.

10.5.3 Protection against external harmful factors or agencies

The object of a good management is to produce healthy woods, which are capable of resisting successfully to the external harmful factors or agencies they are exposed to. Where there is danger of erosion, landlisde, avalanches, the object of management is to protect the site and to prevent the chances of landslides, in such cases stands of uneven age are preferred under shelterwood system or selection system or the group system. In respect of frost, drought, and insects, the clear cutting system is worst system instead shelter-wood system is preferred.

10.5.4 Quantity and Quality of Produce

Forest stands yield timber, firewood and a variety of minor products. Where only the firewood is intended, a system that yields the largest volume of produce within a short time span, is preferred. Where the objects of management is the production of timber, it takes long periods of time and it demands more devotion of the staff involved. It should be noted that on fertile soil, with abundant moisture, even-aged systems with longer rotation give satisfactory results for shade bearing species. Whereas on less fertile soils, which demand a lot of care, uneven-aged systems are desirable under a high rotation for the light demanding species. The former produces principally long and clean timber whereas the latter timber of more girth.

10.5.6 Intensity of Management

The more valuable the returns of the forest are, the more intense or careful actions needed in practicing silviculture. The capital invested in a forest differs considerably based on the objects of management, which is greater for high forest systems than coppice, therefore greater care is needed in high forest system. The shelter-wood systems require more skilled labour than the clear felling systems.

Check Your Progress 2

1. What is coppice and coppice system? Discuss.
2. What are the advantages and disadvantages of coppice system? Briefly discuss.

3. Discuss the various factors that affect the choice of species while planning for regeneration of crop.

Summary

This unit deals with selection system and coppice system. Selection system is the third important high forest systems in which only oldest and/ or the largest trees in the stand are harvested and rest are retained.

Selection is generally applied on poor soils, erosion or landslide-prone exposed sites and at high elevations in order to avoid chances of landslides or erosion and to ensure protection of forest stands.

Most of the broadleaved species have capacity of regenerating from sprouts originating from root/ stool/ stem. Under favourable conditions sprouts develop from cut stem or stool which has the capacity to develop into poles or mature tree. This characteristic of the species is utilized in developing new stand of forest without seed sowing or transplanting and such system of regenerating forest crop is known as coppice system. Thus, in coppice system forest regeneration or renewal of the forest is done principally through sprouts springing up from stumps. This way timber and other products can be obtained continuously for a long period without completely uprooting the species. Thus, coppice may be defined as shoots arising from stump or cut stem more or less close to the ground level. A coppice system is "the system of regenerating forest stand through coppice crops". Another type of coppice system is coppice with standards in which some of the coppice trees are retained for longer periods whereas others are cut over after coppice rotation. Thus, there is under-wood as well as over-wood present in such forests and this way multi produces such as minor produces and major produces are derived.

As far as choice of silvicultural systems to be implemented in forest stand is concerned, it depends upon many factors such as suitability of the system to the selected species, preservation of the factors of locality, protection against external harmful factors or agencies, quantity and quality of produce and intensity of management.

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Unit 11: Silviculture of Indian Conifers I

Unit Structure

11.0 Introduction

Silviculture in its simplest sense is growing of forest trees or the various methods of raising, protecting and caring of desired crops particularly tree species. Therefore, it needs species specific knowledge on its preferences for moisture, light, drought, soil types, and climates. Further, knowhow on species specific requirements on germination, conditions suitable for its growth and development, phenology, silvicultural characteristics and harmful agencies are largely required. Silviculture is actually concerned with the practical knowhow of various characteristics of desired species in relation with their environment. It is on these characteristics depends the form and structure of forest crop. Further, it also decides as to which harvesting methods or silvicultural system would be applied to a mature stand. The regeneration which is expected to follow under various favorable and adverse environmental conditions also depends on the various silvicultural characteristics of the desired species. After regeneration, care and protection of desired crop in early and

later stages of development is also required. For this one has to have adequate understanding of various physical and biological enemies of the crop.

In the previous course, we have had a detailed discussion on the above aspects in general. In this and subsequent units we will have species specific silvicultural characteristics in detail. In this unit, we will discuss two important coniferous trees that is Silver fir (*Abies pindrowi*) and Cedar (*Cedrus deodara*) in relation to their silviculture.

11.1 Learning Objectives

The main objectives of this unit are to study the silvicultural characteristics of:

- Silver Fir (*Abies pindrow*)
- Cedar (*Cedrus deodara*)

11.2 Silviculture of Silver Fir

Botanical Name: *Abies pindrow* Royle
Vernacular Names: Raga, Ragu
English Name: Silver Fir
Family: Pinaceae

11.2.1 Origin and Distribution

Silver fir is a native to Himalaya. It is generally found in higher elevations from 2100 to 3600m (7000 to 11000 feet) above mean sea level but sometimes even above 3600 m. It has its distributed extended to Indian Himalayan Region (IHR), Afghanistan and Nepal Himalaya [1], [2] particularly confined in the northern and western aspects of the slopes [3] [4].

11.2.2 General Description

- Silver fir prefers temperate and sub-alpine type of climate. It is found growing in moist habitats with deep and rich organic soils. It is found most commonly in region of heavy snowfall and most preferably on northerly aspects, however, at the higher elevations found on all aspects [2].
- It is a tall evergreen tree with a dense conical crown having dark green foliage, which usually extends almost to the ground. The upper branches are horizontal whereas the lower ones usually drooping with ends curving upwards.

- The length of needles ranges from 2.5 - 6.2 cm. Needles are somewhat flattened with 2 silvery bands on either side of midrib. They are arranged spirally. , sometimes more long, flat, narrow, linear, dark green and shining above, with two whitish lines below, one on either side of the mid rib, apex usually bifid
- Bark on young trees brown to silvery in colour and smooth, whereas old trees have greyish brown to light grey with deep vertical fissures and long, narrow scales.
- Cone-bearing shoots are shorter, not pectinate but arranged more or less round the shoot especially on the upper side and pointing somewhat forward.
- Female cones 10-18cm long, perfectly cylindrical, scales fan –shaped.
- Germination is epigeous type.

11.2.3 Phenology [2]

- The needles (leaf) persist for three to six years. The old needles fall chiefly in May and June
- The new shoots appear in April-May.
- The pollens shed chiefly towards the end of April and in the beginning of May. This is also the time of pollination to takes place. At this time, the scales become open to receive the pollen.
- It takes about six to seven months between pollination and ripening of the cone. Ripening of cones take place in October to early November. After ripening, breaking up of cones take place while it is still on the tree. It results into shedding of seeds along with scales, thus, leaving the central axis on the tree which persists for some years.
- A good seed year is expected about once in every three to four years.

11.2.4 Silvicultural Characteristics [2]

- Silver fir is a shade bearer accordingly the saplings can withstand heavy shade for many years.
- The root-system is superficial, spreading more or less near the soil surface. This is the reason the trees growing on exposed situations are very much sensitive to uprooting by wind. This is the reason it is always found growing where there is adequate shelter.

- Tree is frost hardy in its natural home. However, snow affects the species to some extent as it causes breaking of branches or uprooting of while tree particularly on steep slopes or developing curvature of stem at the base in sapling stage by sliding snow.
- It is very much sensitive to fire injury and badly scorched trees are usually get killed after sometime.

11.2.5 Regeneration [2]

Reproduction in Silver fir is largely happens through natural means, however, it can also be done through artificial means to some limited extent. The requirements and procedure is described in the following heads:

A) Natural regeneration: The suitable conditions for the germination of seeds and growth of seedlings under natural conditions are the availability of well drained porous soil preferably newly exposed mineral soil, absence of excessive moisture, absence of wet sour humus. In the initial stages of growth, the seedlings and saplings need protection in from the desiccating effect of the sun, grazing animals and from fire.

- Under the conditions mentioned above, seed germination takes place in May to early June provided that sufficient seeds are available. Generally, the seeds fall in October and November.
- After the establishment of seedlings, it required sufficient exposure to fair amount of overhead light.
- The natural regeneration is not affected by the presence or growth of moderate shrubs or weeds, and may be beneficial in providing shade and shelter to growing seedlings.
- Among the most general causes of failure of natural reproduction are:
    i) unfavourable soil conditions having an excess of carbon dioxide produced by an accumulation and decomposition of dead organic matter
    ii) the presence of an excess of moisture in the soil
    iii) These unfavourable conditions are sometimes indicated by the presence of large population of *Skimmia laureola,* a shrub.
    iv) Presence of large number of grazing animals which may adversely affect the germination, seedlings and also to the young plants as they are very much

susceptible to damage by trampling or being uprooted by chance or purposefully by some animals.

B) Artificial Reproduction: Artificial regeneration of silver fir is limited. However, when reproduced artificially, transplantation is the best way of achieving it. The transplants are raised in the nursery under shade conditions through direct sowing of seeds. Soil for the purpose should be well drained loam. Freshly collected seeds are sown in the nursery bed during October – November and allowed to grow in controlled conditions for next three to four years in the nursery and then only transplanted in the suitable field locations.

11.2.6 Silvicultural Systems [2]

Generally Selection system is adopted, however, is not proved to be successful except under conditions especially favourable to natural reproduction. In mixed forests of Silver fir with blue pine or broad-leaved species, the fir usually reproduces with freedom, and the only requirement necessary is to open the canopy sufficiently to enable the young fir to establish itself. In places where reproduction cannot be secured by natural means, artificial reproduction has to be resorted to in order to ensure complete stocking.

11.2.7 Economic Importance [2]

- Suitable for house building in higher altitudes
- Wood white, used for building, planking, boxes
- It is suitable for match manufacture and wood-pulp.

11.3 Silviculture of Deodar

Botanical Name: *Cedrus deodara* Loudon
Vernacular Names: Deodar, Diar
English Name: Himalayan Cedar
Family: Pinaceae

11.3.1 Origin and Distribution [2]

It is native to Afghanistan, India, and Nepal. It is found throughout the Wester Himalayas from Afghanistan to Uttarakhand at elevations varying from 4000 to over 10000 ft but most commonly it is found at 6000 to 8500 ft. Deodar forests are also found in Himachal Pradesh and Jammu & Kashmir.

11.3.2 General Description [2]

- Deodar is a large coniferous evergreen tree. It can reaches to a height of 65 m and up to a diameter of more than 4 m. It grows under natural conditions in mountainous regions in moderate slopes to level ground. Although it is found on all aspects but north aspect is considered best for its growth and development, however, on higher elevations it is found only on sunny aspects.
- Deodar is generally a gregarious tree, therefore, is mostly occur as pure forests. But wherever, found in mixed forests, blue pine (*Pinus excelsa*) and the spruce (*Picea morinda*) are the most favourable associate species. At higher altitudes, it is often found alongwith silver fir (*Abies pindrow*). Among the broadleaved species, Oaks (*Quercus incana* and *Q. dilatata*) are the main species [2]
- Majority of the good forests are found where rainfall varies from 40 to 70 inches. In such areas, the monsoon generally arrives from June to September as a result of south west monsoon. Such areas also receive a lot of winter snow falls.
- Crown becomes rounded or broad with slightly ascending or descending branches. The branches in deodar arise irregularly from the stem and not in whorls.
- The bark is greyish brown with vertical and diagonal cracks dividing it into irregular oblong scales.
- Needles (Leaves) solitary, acicular, stiff, sharp-pointed, up to 3.5 cm long, silvery or silvery-blue. They are spirally arranged on the normal long shoots, and on the short arrested shoots in pseudo whorls.
- The male and female flowers in deodar are found on separate branches and in solitary condition. Male flowers are catkin-like, pale green to yellowish green with purplish tinge, oblong or ovoid. Female flowers are found at the end of arrested branch-lets. They are oblong or ovoid in shape and with pale glaucous green in colour. Sometimes pseudo-flowers are developed in long shoots.
- Ripe cone is solitary, erect, ovoid, ellipsoidal or cylindrical. Like *Abies pindrow*, it also breaks up while still on the tree, thus, shedding the winged seeds along with cone scales. Similar to *Abies*, the central axis also persist in the tree for a long time. The size of winged seeds varies from 1-1.5 inches and without wings 0.7 to 1 inches and are triangular in shape. Seeds have high oil content.

- Germination is epigeous type.

11.3.3 Phenology [2]

- The new shoots appear in March or early April,
- The persistence of leaves varies from different age class of trees. In saplings, they do not persist as long as on older trees with slow growing branches. In the saplings, most of the needles fall off the very next year whereas in older trees they may persist for as long as 6 to 7 years. The old leaves shed in mostly hot season mainly in May however, it may also takes place in autumn when the cones mature.
- Male flowers are appear in June. They ripe and shed their pollens in mid of September to the mid of October.
- The female flowers or young cones appear in August and pollination takes place from middle of September to the mid of October.
- Ripening of cones begin in the following June or early July by this time they become of full sized and colour becomes pale bluish green. Colour changes to chocolate brown during August and fully ripen by the end of September to the middle or end of November.
- Seeds are viable only for a short time. But young and fresh seeds are fertile with high percentage. There are about 8000 seeds per kg.

11.3.4 Silvicultural Characteristics [2]

- Seedlings are very sensitive to drought, therefore, extensive mortality has been observed on dry sunny locations. In such places a certain amount of protection from the sun is essential. Young plants can tolerate moderate shade, but after establishing themselves they require full overhead sunlight for their best growth and development.
- Deodar is affected by drought mainly at seedling stage. Wind does not have much damaging effects on account of tree having massive root system.
- Snow causes serious injury in many parts of the Himalaya, mainly causing bending, braking of stems, branches or uprooting as well.
- Fire seldom enter the moister types of deodar forests, but may harm considerably in dryer type locations.

11.3.5 Regeneration [2]

Regeneration in deodar can be brought about by natural as well as artificial regeneration methods. These are described as follows:

A) Natural Regeneration: It has been observed that normally one year in every three years is a good seed-year. Fertile seeds are produced by young as well as by old trees during November or December. As the seeds are viable only for a short time, therefore, seeds, as a rule, start germinating in the following March or April as soon as they receive moisture, however under heavy shade or in extremely cold locations it may be delayed till May. Germination actually takes place under all conditions whether in heavy shade or in places completely exposed to the sun or in deep, moist, fertile soil as well as on bare rock. Although germination percentage of the deodar is very high but most of the seedlings die due to one or other causes at the end of season itself. The most important factor for the high mortality of Deodar seedlings (in the first year of its growth) is drought conditions immediately after its germination has taken place. In dry regions, after the monsoons are over, the seedling has to depend on the heavy snowfall in the winter for its moisture requirements whereas the absence of the same brings about large scale mortality among growing seedlings.

B) Artificial Regeneration: Artificial regeneration can be brought about by both direct sowing and transplantation. Direct sowing of seeds is carried out in November and it remains as such all through the winter and starts germinating in March, however, under failure of germination re-sowing is carried out immediately in April. Although it gives good results yet there are certain disadvantages also, like there are chances of insect attacks on the stored seeds thus, germination is usually delayed. Sowing may be done by broadcast or sowing especially in contour lines. In areas where a lot of weeds is to be expected or a number of shrubs are present, it is better to adopt sowing method.

C) Tending Operations: Tending operations are needed in order to provide best opportunity to the desired species for its growth and development. In deodar plantations, tending operations include weeding, cleaning and thinning activities which are summarized in the following points:

- Tending operations begin with the weeding of herbaceous growth and undershrub in young deodar crops for initial 3-4 years. It is particularly necessary in direct sowings. In

places where heavy weed growth occurs, generally two weeding in the first year are usually required. The first weeding is done in June and the other in August and it may be required to be repeated for three to four years. However, where weed are light, a single weeding in August is sufficient.

- Cleaning and improvement felling activities are the most important tending operations that are carried out in order to free the young deodar trees from suppression by blue pine trees or the overhead cover of other trees of deodar beneath which they are growing. It is important to note that the main objective such exercises is to allow the maximum and full overhead sunlight to the better individuals to get them best opportunities for their growth and development. At the same time, side shade should be retained as far as possible since isolation produces branchy trees.
- Thinning operations are very necessary operation in deodar crops. These should begin early and be repeated at intervals of not more than ten years in order to achieve gradual opening of the crop to make it hardy for snow damage and to remove suppressed and damaged trees [2] [5]. The gradual opening up of the crop ensures safeguarding against damage by snow.

D) Injury and damage: Young deodar plantations are exposed to injury by a number of factors which are as follows:

- Among abiotic factors which damage deodar trees are snow and fire
- Lopping for the sake of litter is a common type of injury. It leads to bushy shoots throughout their length and cone production is decreased.
- Among wild animals bears, porcupines and monkeys are the most injurious. Bears remove the bark of deodar poles and saplings with their teeth and claws for licking of resinous surface beneath. Porcupines also do similar damage but at the base of tree. Monkeys and langurs also gnaw the bark from poles and saplings whereas some brown monkeys have habit of pulling up germinating seedlings.
- Among biotic factors, browsing animals and goats cause much of the injury to young deodar. Among the wild ones, the most injurious are bears, porcupines and monkeys.
- Some climbers like *Rosa moschata* scrambles into the crowns of young trees and suppress their growth and development considerably [6, 2].

- Among parasitic fungi are *Fomes annosus* and *Peridermium cedri* which result into its mortality and formation of witches' brooms on the trees. Among damaging parasitic fungi are *Pestalotiopsis cryptomeriae*, a fungus causes leaf blight on young trees, whereas *Ploioderma cedri* causes foliar infection and premature defoliation in plantations. An epidemic defoliator *Ectropis deodarae* has been reported to cause complete defoliation in this species. Cones and seeds of many conifers including *Cedrus deodara* are seriously damaged by *Dioryctria abietella* in the North-Western Himalayan region of India [6, 2].
- Among the pests which destroy the seeds of the deodar, the worst is the larva of a small brown moth, *Euzophera cedrella* Hampson. The larva bores into the cones, making small round tunnels, the entrances to which are filled with excreta with much resin exuding [2]
- Among the birds, the most destructive are Jays and nutcrackers, which attack the unripe cones from early September onwards, tear the scales in order to reach seeds and consume the same. They continue their attack throughout the period of ripening, thus, destroying considerable quantities of seeds. During the winters, the seeds lying on the ground are consumed by pheasants.

11.3.6 Silvicultural System

Deodar forests or plantations are generally worked upon under selection systems or group selectin systems [2]

11.3.7 Economic Importance [2]

- Deodar provides excellent structural timber wood. It is highly valuable and extensively used for house building, beams, floorboards, door and window frames, furniture and general carpentry, railway sleepers, carriage and railway wagon work and other purposes for which durability is required. The white to light yellowish brown wood with a characteristic odour and oily feel, is straight-grained, medium fine and somewhat uneven-textured. Its average weight is 560 kg/m3. The heartwood is very durable however, sapwood is usually attacked by insects and fungi. It also produces quality plywood.
- It is an excellent fuel in hills.

- Oil is also extracted from deodar and it has medicinal properties as it is known to have antiseptic and anti-tuberculosis properties. Cedrus oil and extracts are also used as insecticides and herbal remedies against many animal diseases in India. The herbal pesticide *Pestoban* is a liquid concentrate of three Indian medicinal plants including *Cedrus deodara*. It is also a potent molluscicide.
- Cedar is a good soil binder, therefore, has a role in soil conservation and erosion control measures

Summary

This unit, silviculture of two important conifers has been described. These conifers are Silver fir (*Abies pindrowi*) and Cedar (*Cedrus deodara*). The unit can be summarized in the following points:

- Silver fir is a native to Himalaya and generally distributed between 2100 to 3600m amsl in IHR, Afghanistan and Nepal Himalaya.
- Silver fir prefers temperate and sub-alpine type of climate in moist habitats with deep and rich organic soils. The regions generally receive heavy snowfall.
- It is an evergreen tree. Leaves (needles) ranges from 2.5 - 6.2 cm and are somewhat flattened with 2 silvery bands on either side of midrib, and are arranged spirally.
- Bark on young trees brown to silvery in colour and smooth, whereas old trees have greyish brown to light grey with deep vertical fissures and long, narrow scales.
- Cone-bearing shoots are shorter, not pectinate but arranged more or less round the shoot especially on the upper side and pointing somewhat forward.
- Female cones 10-18cm long, perfectly cylindrical, scales fan –shaped.
- Germination is epigeous type.
- The needles (leaf) persist for three to six years.
- The new shoots appear in April-May.
- Shedding of pollens and pollination takes place towards the end of April or beginning of May. After about five to six months in October or November ripening

of fruits take place. Ripened fruits break along with scales to release seeds and leaving the central axis on the tree which persists for some years. Generally a good seed year is expected about once in every three to four years.

- Among the important silvicultural characters of Silver fir are – it is shade bearer, root system is superficial, the tree is frost hardy, affected by snow to some extent and very much sensitive to fire injury and badly scorched trees are usually get killed after sometime.
- Silver fir regenerates mainly through natural means by seeds which are produced in abundance in good seed years. Best conditions of seedling establishment are well drained porous soil, absence of excessive moisture and absence of wet sour humus. Generally, the seeds fall in October and November and seed germination takes place in May to early June. In the initial stages of growth, the seedlings and saplings need protection from the sun, grazing animals and from fire.
- Among the most general causes of failure of natural reproduction are unfavourable soil conditions, presence of excessive soil moisture and presence of heavy grazing.
- Although it is possible to regenerate Silver Fir by artificial methods but it is carried out to a very limited extent. It is done by transplantation of plants raised in nursery.
- Selections system is followed.
- Economically it has importance as wood is suitable for house building in higher altitudes, planking, preparing boxes or granaries and also suitable for match manufacture and wood-pulp.
- Deodar is also a native to Afghanistan, India and Nepal. In India, it is found throughout the Wester Himalayas at elevations varying from 4000 to over 10000 ft but most commonly it is found at 6000 to 8500 ft.
- It is a large evergreen conifer which reaches to a height of 65 m and up to a diameter of more than 4 m. It occurs as pure forests however, may also be in mixed with blue pine (*Pinus excelsa*), the spruce (*Picea spp.*) and with silver fir (*Abies pindrow*). Among the broadleaved species, Oaks (*Quercus incana and Q. dilatata*) are the main species.

- The phonological characters of deodar are-
  - New shoots in March or early April, in the saplings, most of the needles fall off the very next year whereas in older trees they may persist for as long as 6 to 7 years.
  - Male flowers are appear in June. They ripe and shed their pollens in mid of September to the mid of October. The female flowers or young cones appear in August and pollination takes place from middle of September to the mid of October.
  - Cones ripen during the end of September to the middle or end of November.
  - Seeds are viable only for a short time. But young and fresh seeds are fertile with high percentage. There are about 8000 seeds per kg.
- Among the important silvicultural Characteristics are:
  - Seedlings are very sensitive to drought, however, wind does not have much damaging effects on account of tree having massive root system.
  - Young plants can tolerate moderate shade, but after establishment need full overhead sunlight for their best growth and development.
  - Snow causes serious injury causing bending, braking of stems, branches or uprooting as well.
  - Fire seldom enter the moister types of deodar forests, but may harm considerably in dryer type locations.
- Regeneration in deodar can be brought about by natural as well as artificial regeneration methods.
- Young deodar plantations are exposed to injury by a number of factors such as snow and fire, lopping for the sake of litter, injuries by wild animals such as bears, porcupines and monkeys, browsing animals to young deodar. **Injuries are also caused by climbers (***Rosa moschata***),** parasitic fungi **(***Fomes annosus***,** *Peridermium cedri***,** *Pestalotiopsis cryptomeriae* ***and*** *Ploioderma cedri***),** epidemic defoliator (*Ectropis deodarae*) causes complete defoliation. Other pest and birds are also harmful.

- Deodar forests or plantations are generally managed under selection systems or group selectin systems
- Deodar has many economic uses such as timber for house building, beams, floorboards, door and window frames, furniture and general carpentry, railway sleepers, carriage and railway wagon work. It yields oil also which have medicinal uses. It is an excellent fuel in hills.

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Unit 12: Silviculture of Important Indian Conifers II

Unit Structure

12.0 Introduction

In the previous unit, we have learnt the silviculture of two important conifers – Silver Fir and Deodar, which are mainly found in higher altitudes of the Himalayas. In this unit, we will discuss the silviculture of an economical important species – *Pinus roxburghii* and *Pinus gerardiana*. The species are known for their economic values. The former yields turpentine oil whereas the later yields the 'Chilgoza' or 'Neoza' nuts of commerce.

12.1 Learning Objectives

The main objectives of this unit are to acquaint the learners with silvicultural properties of:

- Chirpine
- Chilgoza pine

12.2 Silvicultural of Chirpine

Botanical Name: *Pinus roxburghii* Royle syn. *P. longifolia* Roxb.
Vernacular Names: Chir
English Name: Chirpine
Family: Pinaceae

12.2.1 Origin and Distribution [1]

Pinus roxburghii, commonly known as chirpine or longleaf Indian Pine, is a native species to Himalaya and was named after William Roxburgh. It is found between 500m to 1800 m amsl in India, Afganistan, Bhutan, Pakistan and Nepal. In India, it is found in outer ranges in Uttarakhand, Himachal Pradesh, Jammu and Kashmir, parts of Sikkim, West Bengal and Arunachal Pradesh and on the ridges of the Siwalik Hills [1]. Chirpine is found to form pure forests, however, at the upper and lower ranges particularly in ecotones some broad leaved species such as oak, deodar, burans etc. may also remain present. In its habitat, maximum temperature ranges from 33^0C to 40^0C and the minimum temperature is little below freezing point. Annual rainfall ranges from 90 cm to 300 cm. Chirpine occurs in sandstone, quartzite, mica-schist, gneiss and shale. However, its best development takes place in well drained porous soil.

12.2.2 General Description [1]

- *P. roxburghii* (chir pine) is a tall tree, evergreen tree with spreading crown and grows at an altitude of 450 to 2400m which may attain up to 55 m height and 3.5 m girth with elongated crown and the crown looks like a pyramid like shape [1] [2].The oldest chirpine tree recorded from Kulu Forest Division (Himachal Pradesh) and Chakrata Forest Division (Uttarakhand) are respectively of 406 years and 335 years [1].
- . - It generally forms a straight cylindrical bole with a thick and deeply fissured hard-bark around it. The bark thickness may be up to 5 to 6 cm in mature trees, however, comparatively thin in young trees [1] [2] .
- The length of needles varies from 20 to 30 cms long and are found in a cluster of 3. They persist for 1-3 years.

- The flowers are yellowish green before ripening, turning light reddish brown after the pollens are shed.
- Fruits of the conifers are woody and have scales which are arranged spirally.
- The seeds are winged and they lie in pairs at the base of each cone scale. The wings present in the seeds help them in dispersal by wind.
- Every year is usually a good seed year in healthy trees. Each cone contains approximately 40 to 50 seeds.
- Resin is tapped from the stem which is used for making turpentine oil of commerce.
- Germination is epigeous

12.2.3 Phenology [1]

- New needles appear in February-March and old needles fall in May-June.
- The winter buds arise in October to November, and growth ceases till December to early January, when the new shoots begin to appear [1].
- Flowering takes place during February-April.
- Maturity of cones in the month of February or March and this is the time of collection of seeds.
- The fallen seeds germinate with the onset of the monsoon July or August.

12.2.4 Silvicultural characteristics [1]

- Chirpine seedlings are strong light-demanding, however, can also tolerate light shade.
- The species is frost as well as drought resistant.
- Among the Himalayan confers, the pine trees are highly resistant to damage by fire on account of having exceptionally thick bark, however, severe fires may damage the natural regeneration or the young growth. However, the Chirpine needles are the main burning material which at times have resulted into severe forest fires in Uttarakhand and caused a lot of damage to the ecosystem as a whole.

- It grows on bare rock in minimal requirements water and nutrition, however, it is intolerant to badly drained ground.
- tree is wind-firm under ordinary conditions
- It is not affected by snow although it grows in localities where snowfall events are very few.

12.2.4 Regeneration [1]

A) Natural regeneration: The natural regeneration of Chirpine takes place through seeds, which start falling off during February-March. Germination starts at the beginning of the monsoon or soon after the initial rains preceding the monsoon provided that they bring sufficient rain. Temperature conditions are suitable for germination of the seeds in the shade of the pine forests, however, insufficient light may result in rapidly dying of seedlings. Some of the important factors which affect the seed germinations are:

- Although young trees are also capable of producing fertile seeds but these are not sufficient particularly in adverse circumstances. Therefore, ample seeds from mature seed trees should be available in order to bring about effective natural germination.
- On account of being light demander, the best germination comes in open conditions however, light shade of the mature tree does not have adverse impacts.
- Although pine grows in physiologically dry conditions, therefore, can withstand low water conditions but severe droughts affect the germination adversely. Further, the exposure to light, moisture is affected by topography and soil of the area, accordingly it also affects the germination.
- fire incidence and its severity and grazing activity have adverse impacts on regeneration.

B) Artificial regeneration: Artificially, the Chirpine plants may be raised in the nursery by the seeds collected from natural habitats. For the purpose, the cones are generally collected in the months of March or April and placed in the sun for drying up so that scale open up thoroughly. The dried cones are then shaken and beaten to release the seeds from it.

Chirpine is raised by planting seedlings raised in polythene bags. For this purpose, polythene bags of 10 cm in diameter and 15 cm long of 200 gauges are filled with nursery soil and farmyard manure in proportion of 2:1 and are arranged in the nursery beds. In addition, some mycorrhizal soil from chirpine areas is mixed with bag soil to provide the inoculation which is essential for growth of seedlings. Then, two seeds are sown in each bag in April and covered with needles. Regular watering causes germination to take place by July. Transplantation is done during the rains at a spacing of 3mX3m.

The seedlings so raised in nursery are suitable for transplantation in the same rainy season or after one year in next rainy season

The seed-beds should consist of light un-manured soil, generally, stiff clayey ground is avoided. The soil should be dug up to a depth of 1 ft and the beds are well raised above the ground. The seed are sown in March or April in shallow drills with 6 inches apart and lightly covered with fine earth. The watering is generally carried out regularly twice a day during morning and evening hours. The seedlings usually get ready for pricking out in July for plantation in the same year or after one year.

Direct sowing may be considered to be the only practicable method of carrying out the artificial regeneration of the pine on large scale purposes. As a rule sowing in small patches or in contour lines has given good results, but on steep, bare slopes where the wash of water and debris is considerable, these have sometimes been found unsatisfactory owing to the scouring of water and the accumulation of debris [1].

C) Tending Operations: The Chirpine plantations or forest require tending operations such as weeding and cleaning. **Weeding** is required at young stage as weeds compete with seedling and saplings for nutrients, light and space. *Lantana camaera*, an obnoxious weed has invaded entire ranges of chirpine which has a tendency to suppress seedlings and also creates severe root competition for nutrients and moisture. Such weeds are required to be removed continuously up to an age of four years.

Cleaning is carried in order to remove other vegetation consisting of inferior species and climbers in the locality with an objective of reducing competition. Cleaning is particularly carried out when individuals have attained sapling stage.

Pruning is needed in artificial plantations as wide spacing results into branches. Such branches need to be cut in order to get knot free bole. Further, it also reduces fire hazards. Whereas in natural stands, chirpine seedlings get self-pruned due to intense competition for light as they are closely spaced.

Thinning is carried out when individuals attain pole stage. This involved freeing of inferior and suppressed individuals of pine and thus healthy stems grow better as a result of reduced competition.

D) Injury/damage [1]

- Among animals, porcupines and rats do much damage to young chirpine plants. The former eats the roots of seedlings and saplings, and the latter gnaw through the taproots of seedlings, especially in nurseries and plantations.
- Birds do much damage during and shortly after germination. They eat the cotyledons, thereby, kill the seedlings.
- The plant is prone to insect damage at all stages of its growth and the most serious damage is caused by grasshoppers, which feed on the stems. During nursery conditions, it is injured by insect-pests such as *Anomala rufiventris*, *Granida albosparsa, Mimela mundissima* and *Popillia cyanea.*
- During young stage, the main tree defoliators are *Cryptothecia crameri* (Chirpine bagworm) and *Lebeda nobilis.* Among the mains shoot and stem borers include *Dioryctria abietella, Cryptorrainchus rufescens*, *Hylobius angustus* (taller weevil), *Ips longifolia*, *Pityogenes scitus*, *Polygraphus longifolia* and *Melanophila ignicola* etc.
- The species also face fungal attack in all stages of its growth. At the nursery stage, the main diseases include damping off, wilt and needle blight, whereas rust and blight are common diseases of old trees. The commonest fungus species is *Peridermium* (Aecidium) *complanatum* Barel., which appears on the needles in the form of orange-coloured sacs of spores about April-June [1].

12.2.5 Silvicultural System

Initially, the chirpine forests were managed under selection system whereas now a days it has been modified and are being managed under uniform or shelter wood system. The regeneration operations comprises of reduction of the canopy density by felling of a part of mature stands. These fillings are generally referred to as seeding felling, secondary felling and final felling. These felling are carried out as the regeneration establishes and completed over a prescribed period known as **regeneration period**. The area set aside for regeneration during the regeneration period is termed as **Periodic block**. In Chir pine regeneration is considered to be established when plants attain a height of about 4 m and controlled burning has been carried out in the area twice. At this stage the crop safe against grazing and fire. Usually this stage is obtained in about 20 years' time. Rotation period for chir pine forests is usually kept between 90 to 120 years at which a diameter of 50-55 cm dbh is obtained.

12.2.6 Economic importance

Chir pine offers a variety of goods and services to the people and ecosystems. Important of them are as follows:

- It is used for various purposes including house building, as rafters, poles and posts, doors and windows, packing boxes, boards, railway sleepers. It is suitable for boat building, sports articles, matchsticks etc.
- Having high cellulose content, wood is also used in pulp and paper industry
- Wood is also used in making agricultural implements, and also as fuel wood in the hills.
- It yields oleo-resin which is raw material for rosin and turpentine oil.
- Pine needles also yield essential oils
- Needles are also used in preparing particle board.
- Tannins obtained from the chirpine bark is suitable for leather curing.

- Seeds are rich in fatty oil and proteins and eaten as such or used in preparing in sweet dishes.

12.3 Silvicultural of Chilgoza pine

Botanical Name: *Pinus gerardiana* Wall.
Vernacular Names: Chilgoza pine
English Name: Himalayan edible pine
Family: Pinaceae

12.3.1 Origin and Distribution [1] [2]

- It is a native to northwest Himalaya. It is distributed sparsely in North-Western Himalayan region of India (Himachal Pradesh, J&K), Pakistan, Eastern Afghanistan and northern Baluchistan [1] [3]. In India, it occurs mainly in Sutlej Valley in Kinnaur District and some pockets of Pangi and Bharmour area in Chamba district of H.P. Besides this, it is also reported in Dachhin area in the Marwah valley of Doda (J&K), Malari and Bampa area of Garhwal (Uttarakhand) [3]. It often occurs in association with *Cedrus deodara* and *Pinus wallichiana.*
- It grows well between 1800-3400 m altitudes in the dry temperate forest of the Himalaya, where the summer monsoon is weak and precipitation mostly occurs in the form of snow.
- Chilgoza pine is an important ecological and economic species having a restricted distribution in India. It is very much restricted in dry temperate region of North-Western Himalayas between altitudes of 1800 m to 3400 m above mean sea level. It is common in Afghanistan and parts of Pakistan, i.e. Baluchistan. In India, it is found in the upper parts of Sutlej, Ravi and Chenab valley. It mainly occurs in Kinnaur, Pangi and Chamba of Himachal Pradesh. It has its further extension to Kishtwar and Astor in Jammu and Kashmir [4] [5]. The species was subsequently (1839) introduced to England, where it was found to be frost-sensitive [6]

12.3.2 General Description [1]

- A moderate-sized evergreen, somewhat branchy tree, attaining ordinarily a height of 10-20 m (30 to 60 ft) and a girth up to 4 meters (12 ft) or more. Branches usually ascending, not whorled, or only obscurely whorled.
- Leaves in bunches of three, 2-4 inches long, dark green, somewhat stiff, with a basal sheath about 0·5 inches long, which falls by the second year.
- Bark thin, grey, smooth, with a mottled appearance, exfoliating in irregular thin flakes, which leave shallow depressions.
- Wood hard, tough, and very resinous, not much used except in regions where other timbers are not available.
- The chief value of the tree lies in its seeds, which are roasted and eaten; they are collected in quantity for export. In exposed situations and on poor shallow soil the tree is stunted but under favourable conditions it is fairly tall and straight.

12.3.3 Phenology [1]

- The flowers appear in May and June. It is the time of pollination as well.
- After pollination, female flower develops into cone which ripens by September-October of the same year.

12.3.4 Silvicultural characteristics [1] [3]

- Unlike chirpine, chilgoza pine requires moderate light conditions for its growth and development. In the initial stage of development i.e., seedlings, it requires some shade whereas as soon as it enters the sapling stage, light is essentially required for proper growth of Chilgoza in the nursery as well as plantation site [3].
- It is a frost and drought hardy species and can withstand extreme cold conditions [1], however, germination and seedlings are very sensitive to drought and long spell of drought proves fatal for its survival in the nursery and plantation area [3]. On account of having only a thin bark covering, the species in all of its growth stages from seedling to tree are very sensitive to fire.

- The trees are wind firm due to their well-developed root system.

12.3.4 Regeneration [1]

A) Natural reproduction: Natural regeneration of Chilgoza is difficult on account of high economic value of its seeds which are collected by the related community or right holders either for consumption or marketing. For this reason, natural regeneration is very poor or entirely lacking and the most important factor responsible for this is the collection of cones by the locals/right holders [7] [8] [9]. If by chance the seeds are able to germinate the birds bite off the young seedlings because of their fleshy and tasty cotyledons [8]. In addition to these factors, two parasitic insects *Dioryctria abietivorella* (the Fir cone-worm) [10] and *Euzophera cedrela* (the Cedar cone-moth) [11], lay eggs in their cones which later on develop into larvae and consume proteins available in the seeds, thereby destroying the seed.

Additionally, goat grazing is also very unfriendly to natural reproduction, although some seedlings may appear under the protection of thorny bushes [12]. Further, extraction of timber and resinous torchwood have made this important species an endangered conifer of the Himalayas [3].

One of the reason behind poor natural regeneration is the lack of appropriate policy measures on the collection of its seeds. Therefore, the right holders collect each and every cone from its forest and is one of the major reasons for the poor natural regeneration of this pine. Besides this, some left out seeds are immediately eaten up by wildlife such as rats, crows and birds [3]. This species is listed in the “Near Threatened” category of IUCN.

B) Artificial Regeneration [3]**:** The artificial regeneration of Chilgoza Pine is carried out through seeds in nurseries. Seedlings are raised in nurseries and transplanted in the site. For the purpose, cone/ seeds are collected in September to October. The cones are spread on the ground in shady place in a room and left for drying for 15-20 days. In older times, in some villages, people placed the cones in trenches and covered them with soil or thatch and put a fire over the pits for immediate extraction of Neoza nuts for their use. Cones are also kept in cowsheds for about a fortnight period till they open up

and are then taken to open places for extraction of nuts. The nuts / seeds of Chilgoza Pine are generally extracted from the cones manually by the local people.

The seedlings of Chilgoza Pine are generally raised in polybags in the nursery. The healthy seeds are treated with insecticides before sowing in the nursery. The seeds are sown at a depth of 3-4cm in polybags during the month of November-December and properly covered with soil mixture. Generally, two seeds are sown in each polybag in the nursery. Watering of polybags is done to maintain moist condition which is necessary for seed germination. The seeds remain dormant in the polybags all through the winter and start germinating as soon as melting of snow starts during March/April.

Germination percentage of seeds varies from 80-90% depending on the quality of seeds and climatic conditions during seed germination. After germination has taken place, the polybags containing seedlings are covered with shade for proper development till the seedling reaches a stage near to sapling stage when they are brought to sunny conditions. The seedlings are reared in the nursery conditions for the next two or three years as the growth rate of chilgoza is very slow. Pits of size 45cm x 45cm x 45cm at a spacing of 2.5 m x 2.5m or 3 m x 3m are prepared 2 months before planting in the plantation area. Before planting, pits are properly filled with soil mixture. Thereafter, seedlings are transplanted in the pits. The pits containing seedlings are properly covered with soil mixture after planting and are watered frequently before they get established in the field. The plantation area is fenced properly to safeguard the plants from wild animals.

12.3.5 Silvicultural System [1]

The main purpose of growing and maintaining the Chilgoza pine is because of its high values seeds which are edible. Therefore, felling or harvesting of the plant is rarely carried out. Heavy thinning is recommended where it is necessary to stimulate the expansion of the crown in order to increase the production of cones. Harvesting of only those trees is recommended which are severely infested by some parasite or beetle [1].

12.3.6 Economic importance

- Nutritive value of Chilgoza Pine is well known for its edible seeds which are rich in carbohydrates and proteins. The seeds are sold as dry-fruits by the name "Chilghoza" [1]. The edible nuts possess carminative, stimulant and expectorant properties. Chilgoza nut contains carbohydrates (21.6 %), proteins (15.9 %), fats (49.9%), moisture content (7.5 %), fibre (2.2 %) and mineral matter (2.90 %). It is one of the most important cash crops of tribal people residing in the Kinnaur district of Himachal Pradesh and is being presently sold at very high rates Rs1500-2000/kg in the market [3].
- Chilgoza nuts are also used medicinally on account of having highly nutritious and eaten raw as well as in roasted. Having a rich sources of carminative, stimulative and relaxing properties, it improves the general weakness in human. They also help in lowering high cholesterol levels and improve overall lipid profile because nuts contain huge amount of healthy unsaturated fats which are very beneficial for lowering high cholesterol levels [3]. Nuts contain linoleic acid which plays an important role in the heart ailments [3].
- Chilgoza nut possesses antibacterial, antiviral, antifungal, antiseptic, antihypertensive, expectorant and diuretic effect [3].
- Oil obtained from these nuts is used for dressing of wounds, in ulcers, chronic arthritis, respiratory complaints, burns, cough and cold etc.

Summary

In this unit, we have discussed the silviculture of two important Himalayn pines, *Pinus roxburghii* and *Pinus gerardiana.* Both the species are native to Himalaya and found between 450 to 3400m amsl in India, Afganistan, Bhutan, Pakistan and Nepal. Important points are summarized below:

- Chirpine is strong light-demanding species, however, can also tolerate light shade. The species is frost as well as drought resistant. Among the Himalayan confers, the pine trees are highly resistant to damage by fire on account of having exceptionally

thick bark, however, severe fires may damage the natural regeneration or the young growth. However, the Chirpine needles are the main burning material which at times have resulted into severe forest fires in Uttarakhand and caused a lot of damage to the ecosystem as a whole. It can grow on bare rock in minimal requirements water and nutrition, however, it is intolerant to badly drained ground. Tree is wind-firm under ordinary conditions and is not affected by snow although it grows in localities where snowfall events are very few.

- The regeneration of Chirpine can be brought about through Natural means as well as artificial means. The natural regeneration of Chirpine takes place through seeds, which start falling off during February-March. Germination starts at the beginning of the monsoon or soon after the initial rains preceding the monsoon provided that they bring sufficient rain.
- Artificially, the Chirpine plants may be raised in the nursery by the seeds collected from natural habitats. For the purpose, the cones are generally collected in the months of March or April and placed in the sun for drying up so that scale open up thoroughly. The dried cones are then shaken and beaten to release the seeds from it. The seeds are sown in the nursery. The seedlings so raised in nursery are suitable for transplantation in the same rainy season or after one year in next rainy season.
- Tending Operations include weeding, cleaning, pruning and thinning. These activities are carried out in order to give the most appropriate conditions to growing stock for their growth and development.
- There are many sources of injuries to the growing plants. Among the animals, porcupines and rats are most injurious as they can eats the roots of seedlings and saplings. They are followed by birds which damage the seedling during as well as shortly after germination by eating the cotyledons and thereby killing the seedlings. Further, the species is also prone to insect damage at all stages of its growth and the most serious damage is caused by grasshoppers, which feed on the stems. During nursery conditions, it is injured by insect-pests such as *Anomala rufiventris*, *Granida albosparsa, Mimela mundissima* and *Popillia cyanea.* During young standing stage,

the main tree defoliators are *Cryptothelia crameri* (Chirpine bagworm) and *Lebeda nobilis.* Among the mains shoot and stem borers include *Dioryctria abietella, Cryptorrainchus rufescens*, *Hylobius angustus* (taller weevil), *Ips longifolia*, *Pityogenes scitus*, *Polygraphus longifolia* and *Melanophila ignicola* etc.

- The species also face fungal attack in all stages of its growth. At the nursery stage, the main diseases include damping off, wilt and needle blight, whereas rust and blight are common diseases of old trees. The commonest fungus species is *Peridermium* (Aecidium) *complanatum* Barel., which appears on the needles in the form of orange-coloured sacs of spores about April-June .
- Initially, the chirpine forests were managed under selection system whereas now a days it has been modified and are being managed under uniform or shelter wood system.
- Chir pine offers a variety of goods and services to the people and ecosystems such as use in house building, doors and windows, packing boxes, boards, railway sleepers. It is also suitable for boat building, sports articles, matchsticks etc. Other uses include the use in pulp and paper industry, making of agricultural implements, and also used as fuel wood in the hills. It yields oleo-resin which is raw material for rosin and turpentine oil.
- Chilgoza pine is also a native to Himalaya particularly northwest Himalaya (Himachal Pradesh, J&K), Pakistan, Eastern Afghanistan and northern Baluchistan. It grows well between 1800-3400 m altitudes in the dry temperate regions where the summer monsoon is weak and precipitation mostly occurs in the form of snow.
- It is a moderate-sized evergreen. The leaves are found in bunches of three, 2-4 inches long, dark green, somewhat stiff, with a basal sheath about 0·5 inches long, which falls by the second year. Bark is thin, grey, smooth, with a mottled appearance, exfoliating in irregular thin flakes, which leave shallow depressions. Wood hard, tough, and very resinous, is rarely used as timber. The chief value of the tree lies in its seeds, which are roasted and eaten; they are collected in quantity for export. In exposed situations

and on poor shallow soil the tree is stunted but under favourable conditions it is fairly tall and straight.

- Unlike chirpine, chilgoza pine requires moderate light conditions for its growth and development. In the initial stage of development i.e., seedlings, it requires some shade whereas as soon as it enters the sapling stage, light is essentially required for proper growth of Chilgoza in the nursery as well as plantation site. It is a frost and drought hardy species and can withstand extreme cold conditions, however, germination and seedlings are very sensitive to drought and long spell of drought proves fatal for its survival in the nursery and plantation area. On account of having only a thin bark covering, the species in all of its growth stages from seedling to tree are very sensitive to fire.
- Natural regeneration of Chilgoza is difficult on account of high economic value of its seeds which are collected by the related community or right holders either for consumption or marketing. For this reason, natural regeneration is very poor or entirely lacking and the most important factor responsible for this is the collection of cones by the locals/right holders. In addition to these factors, two parasitic insects *Dioryctria abietivorella* (the Fir cone-worm) and *Euzophera cedrela* (the Cedar cone-moth), lay eggs in their cones which later on develop into larvae and consume proteins available in the seeds, thereby destroying the seed. Additionally, goat grazing is also very unfriendly to natural reproduction, although some seedlings may appear under the protection of thorny bushes. One of the reason behind poor natural regeneration is the lack of appropriate policy measures on the collection of its seeds. This species is listed in the “Near Threatened” category of IUCN.
- The artificial regeneration of Chilgoza Pine is carried out through seeds in nurseries. Seedlings are raised in nurseries and transplanted in the site. For the purpose, cone/ seeds are collected in September to October. The cones are spread on the ground in shady place in a room and left for drying for 15-20 days. In older times, in some villages, people placed the cones in trenches and covered them with soil or thatch and put a fire over the pits for immediate extraction of Neoza nuts for their use. Cones are

also kept in cowsheds for about a fortnight period till they open up and are then taken to open places for extraction of nuts. The nuts / seeds of Chilgoza Pine are generally extracted from the cones manually by the local people. The seedlings of Chilgoza Pine are generally raised in polybags in the nursery. The seeds remain dormant in the polybags all through the winter and start germinating as soon as melting of snow starts during March/April. Germination percentage of seeds varies from 80-90% depending on the quality of seeds and climatic conditions during seed germination. After germination has taken place, the polybags containing seedlings are covered with shade for proper development till the seedling reaches a stage near to sapling stage when they are brought to sunny conditions. The seedlings are reared in the nursery conditions for the next two or three years as the growth rate of chilgoza is very slow. Thereafter, seedlings are transplanted in the pits. The pits containing seedlings are properly covered with soil mixture after planting and are watered frequently before they get established in the field. The plantation area is fenced properly to safeguard the plants from wild animals.

- Nutritive value of Chilgoza Pine is well known for its edible seeds which are rich in carbohydrates and proteins. The seeds are sold as dry-fruits by the name "Chilghoza". The edible nuts possess carminative, stimulant and expectorant properties. Chilgoza nut contains carbohydrates (21.6 %), proteins (15.9 %), fats (49.9%), moisture content (7.5 %), fibre (2.2 %) and mineral matter (2.90 %). It is one of the most important cash crops of tribal people residing in the Kinnaur district of Himachal Pradesh and is being presently sold at very high rates Rs1500-2000/kg in the market.
- Chilgoza nuts are also used medicinally on account of having highly nutritious and eaten raw as well as in roasted. Having a rich sources of carminative, simulative and relaxing properties, it improves the general weakness in human. They also help in lowering high cholesterol levels and improve overall lipid profile because nuts contain huge amount of healthy unsaturated fats which are very beneficial for lowering high cholesterol levels. Nuts contain linoleic acid which plays an important role in the heart ailments.

- Chilgoza nut possesses antibacterial, antiviral, antifungal, antiseptic, antihypertensive, expectorant and diuretic effect.

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Unit 13: Silviculture of some important Indian Broadleaved Trees-I

Unit Structure

13.0 Introduction

In the previous units, silviculture of four important species i.e., *Abies pindrow, Cedrus deodara, Pinus roxburghii and Pinus gerardiana*, were discussed. These were the species which belonged to family Pinaceae and are also known as naked seeded plants since their seeds are not covered. One other specific feature of these species is that they have leaves of needle shape and are native species to Himalaya. They are important not only for their timber value but some of them produce highly priced edible seeds i.e., Chilgoza pine.

In this unit, we will discuss some other important tree species which belong to broad leaved category and in contrary to Gymnosperms, they have seeds closed in well defined fruits. These species are also important on account of their highly valued timber of commerce and some have medicinal utility also. These species are Sagaun, Sal, Shisham, Alder and Eucalyptus.

13.1 Learning Objectives

The main objectives of this unit are to acquaint the learners with silviculture of:

- Teak (*Tectona grandis*)
- Sal (*Shorea robusta*)
- Shisham (*Dalbergia sissoo*)
- Alder (*Alnus nepalensis*)
- Sfeda (*Eucalyptus spp.*)

13.2 Silviculture of Teak (Sagaun)

Botanical Name: *Tectona grandis* Linn. F.

Vernacular Names: Sagun, Tegu, Tegina, Teku, Thekku

English Name: Sagwan

Family: Verbanaceae

13.2.1 Origin and Distribution

Teak (*Tectona grandis* Linn. f.) is one of the most important tree that yields valuable timber around the world. It is predominantly distributed in tropical or sub-tropical regions of the world [1]. It is indigenous to Burma and Indian Peninsula, Siam, Java and other islands of

the Indian subcontinent [2]. It has been planted extensively in many localities outside its natural origin particularly in the forest of plains and lower hills in U.P., Uttarakhand, Bengal, Assam, Bihar, Orissa and Andaman. In Uttarakhand, it was planted in many localities including Dehradun and Nainital districts [2].

13.2.2 General characteristics

General characteristics of teak are as follows:

- Teak grows well in deep, well-drained alluvial soils, fairly moist, warm, tropical climate with pH ranges from 6.5 to 7.5 [1] [3] [4].
- It is found in low as well as high rainfall areas, however, best rainfall range is the 800-2500 mm and up to an altitude of about 1,200 m. As far as topography is concerned, it has been observed that most of the teak forests are located in hilly or undulating terrains, however, flat alluvial lands which are well drained are also suitable for its growth and development [2]. On well-drained deep alluvial soil teak sometimes occurs remarkably pure, and attains large dimensions. It also attains very good development on the fertile lower slopes of hills where the soil is deep, but along dry ridges it becomes stunted, as is also the case on shallow soil. Above all, the teak requires good subsoil drainage, and will not endure stiff soil which is liable to inundation or to waterlogging.
- Teak is a large deciduous tree with an average height, often fluted near the base.
- Colour of the stem is pale brown and grey whereas the bark is of light brown or grayish. Bark gets peeled off in thin layers.
- Leaves are large, opposite, broadly elliptic, obovate, stellate, yellowish green, tomentose beneath.
- Leaf size is of 30-70 cm long and 25-40 cm broad, glabrescent above and stellate-pubescent below. Leaf at the base are rounded to acute, in apex obtuse to acute. Petiole stout and 5-6 cm long [2].
- Flowers white, shortly stalked, numerous in terminal large panicles of cymes.
- The fruit is a hard, bony, irregularly globose nut, pointed at the apex and enclosed in a thick and light brown covering, the inflated calyx. It contains one to three seeds sometimes but rarely four also. The nut is enclosed in the inflated bladder like calyx.

- Major tree associates of the tree are *Acacia catechu, Adina cordifolia, Anogeissus latifolia, Bambusa arundinacea, Boswellia serrata, Buchanania latifolia, Butea frondosa, Cassia fistula, Chloroxylon swietenia, Cleistanthus collinus, Dalbergia lalifolia, Diospyros melanoxylon, Emblica officinalis, Gmelina arborea, Lagerstroemia parviflora, Ougeinia dalbergioides, Pterocarpus marsupium, Terminalia tomentosa, Terminalia chebula, Terminalia bellirica* and *Xylia xylocarpa.*

13.2.3 Phenology [2]

- Leaf shedding occurs from November to January and remain leafless for long time (3 to 4 months). The new leaves appear from April to June according to dry or moist locality. However, when the trees grow in moist conditions, they remain with full foliage and become leafless for a short period only for about month.
- Flowering occurs during rainy season from June to August or September according to season and locality, however, in very wet conditions flowering begin as early as April.
- Ripening of fruits occur from November to January.

13.2.4 Silvicultural Characteristics [2]

- Teak is a strong light demander, therefore, teak seedlings are very sensitive to shade and do best in open sunny conditions, however, in dry localities they may require to be protected from direct sun from side.
- Good seed years in the species are observed almost every year.
- Flowering, fruiting and production of fertile seeds start at an early age. It takes place even in nine years in coppice shoots [2]. Some authors have reported that such seeds are unfertile whereas other have reported that such seeds are equally fertile, however, old trees are capable of producing fertile seed.
- The seeds often fails to germinate in the first year, particularly if sown late, and may lie dormant in the ground for one or more years before germinating. Seed stored for a year is usually found to germinate more freely than fresh seed. The vitality of teak seed is remarkable and may remain dormant for many years, retaining its fertility.
- Germination in teak is epigeous **type. Splitting of nut results in se**paration of central axis like valves followed by emerging out of radicle which descends to soil, thereafter,

the cotyledons emerge out in upward direction leaving the testa inside the nut. One nut usually produces one to four seedlings.

- Teak is fire resistant and young teak plants are have a wonderful power of recovery from damage by fire. Even after frequent fires and killing back of stems for many years, the resultant much thickened root-stock is able to produce a permanent shoot under favourable conditions.
- Teak has a great potential of overcoming from various kinds of injury on account of having good coppice power.
- The young teak plants are rarely affected by browsing, however, are very sensitive to any suppression by weeds. Therefore, regular weeding is desired.
- Teak is a strong light demander and requires complete overhead sunlight relatively high light intensity, i.e. between 75 and 100% of the full sunlight for better growth and development [2]. Although it is observed that saplings are able to grow under the light shade of bamboos and even to some extent under other trees, but the growth of such plants is retarded in comparison to plants having complete exposure to overhead sunlight as well as a fair amount of side room for its proper development.
- Teak grows best in moist and warm climate, however, waterlogged and damp conditions affect negatively in which case seedlings are liable to be killed due to rotting of stems.
- Teak grows well in deep, well-drained alluvial soils, fairly moist, warm, tropical climate with pH ranges from 6.5 to 7.5 [4] [3]. Teak flourishes well on granite, gneiss, schists, and other metamorphic rocks in the hills in the Indian Peninsula [2].
- The teak produces a large deep root-system. At first a long thick taproot is formed which may persist or may disappear, but in either case strong lateral roots are produced.
- Teak seedlings or coppice shoots are very sensitive to frost, however, young trees can withstand frost.
- Teak is prone to many insect attacks. The most important among the insects is the larva of a moth- *Duomitus ceramicus* Wlk. It bores into standing trees and results in the large holes, termed as **'bee-holes'**. Another lepidopterous borer is *Cossus cadambae* Moore. It also does much damage by making tunnels inside the young

stems of one or two years old. Among the commonest defoliators are the caterpillars of *Hyblaea puera* Cram. and *Pyrausta machaeralis* Wlk. The former consumes the whole leaf except the midrib and the main lateral veins, while the latter skeletonizes the leaves by eating all the parenchyma except the all veins. Another defoliator is the caterpillar of *Paliga damastesalis*, Moore, the ' **teak-leaf roller** ', does a considerable amount of defoliation in some localities particularly on dry hill-sides. In some localities teak also suffers from the attacks of *Loranthus*, a tree parasite [2].

13.2.5 Regeneration methods [2]

Regeneration in teak can be brought about by both natural as well as artificial means. Natural regeneration starts as early as twenty years of age.

A) **Natural regeneration:** The important points regarding the natural reproduction of teak includes spread of seed, factors influencing germination and factors influencing the survival and development of the seedling.

- After the shedding of seeds or fruits in December or January, the seeds remain in and around the trees. Germination occurs when the conditions become favourable whereas in hilly terrain where sufficient soil-covering of grass or other plants is absent, many seeds and fruits get washed down the slopes early in the rainy season.
- The germination of the seeds is influenced by many factors such as temperature, availability of sufficient moisture, soil aeration and burial of seeds inside the soil.
- The temperature sufficiently high to induce ready germination may be produced generally by the heat of the sun or sometimes by fire. In the absence of sufficient sunlight, teak seed germination is difficult and usually seeds lie dormant for years. Germination takes place only when the direct sun rays are admitted to the ground by the opening up of the canopy and the clearing of undergrowth.
- Aeration of soil is another factors that influences seed germination effectively.
- Another important condition for seed germination is that the fallen seeds should get buried inside the soil so that radical do not get dried up or eaten by insects or birds before it penetrates the soil.
- After germination there are many factors which influence the growth and development of seedlings. The main factors influencing the establishment of

natural reproduction are light, soil-aeration, soil-moisture, weed-growth, grazing and fire.

- Light is one of the most important factors in the establishment of natural reproduction as the teak is a strong light –demander. Although saplings may persist for a time under the light shade of bamboos and other overhead cover, their development is slow and they become readily suppressed.
- Soil-aeration is important for proper growth and development of seedlings. Under excessive moist or water logged conditions, death of teak seedling take place, many seedling during rainy season die due to this cause. The aeration of the soil by loosening of soil has a marked effect on the development of young plants, and in dry localities it is a useful means of stimulating a strong and healthy growth which enables seedlings to survive drought.
- Soil-moisture is another factor that greatly influences the establishment of natural regeneration particularly in dry forests. If seedlings face drought immediately after wet season, the natural regeneration of the teak fails. Therefore, there is required some kind of artificial assistance to such seedlings.
- Weed-growth is one of the most serious obstacles to the establishment of natural reproduction. In areas where weeds are prevalent, many weeds also arise and give a strong competition to the teak seedlings. Therefore, weeding is needed during the rain and also after the rains are over. Such weeding are further required at certain interval of time till danger from weeds is over.
- Light grazing is useful in for the natural reproduction of teak as it helps keeping down the heavy grass and weeds. However, heavy grazing may impact adversely.
- Controlled fire helps in keeping the other undergrowth and other inferior species in check and thus, promotes germination, growth and development of teak species.

B) **Artificial regeneration:** Teak is a long rotation crop about 50 to 80 years. However, the rotation period may be reduced by adopting suitable silvicultural practices. Artificial regeneration of teak may be described in the following points:

- **Seed collection:** Ripening of seeds starts from December - January. Good seed years are of occasional occurrence, therefore, while collecting seeds, surplus

seeds are collected. Seeds (fruits) can be stored in gunny bags for about two (02) years. Seed weight varies from 1400 to 1420 per kg.

- **Seed treatment:** Seeds are required to be treated before sowing as they have hard seed coat. There are normally two methods employed for seed treatment. These are as follows:

  i) In first method, soaking of seeds in water is carried out for about two days (48 hours) followed by drying in direct sun for two days (48 hours). This process of soaking and drying is repeated which lasts from 12 to 15 days.

  ii) The second method is pit treatment method which includes treatment of seeds in pit and is the most commonly used method. In this method a pit of size 90X90x60 cm^3 is dug. The all the sides and bottom of pit are covered with teak leaves and then filled up with water. Seeds which are presoaked in water and dried in sun for 48 hours, are put in the pits with alternate layers of teak leaves and seeds. The last cover of 15 cm by soil. Bamboo pipes are put in four corners and one center point of the pit in order to distribute water uniformly in all layers and keep seed moist. Seeds are kept inside the pit for about 10 days and watering is given in alternate days. After 10 days normally 10 % of the seeds are found to be germinated which are then transplanted into nursery bed and later on in the plantation site.

- **Transplantation:** Stump planting is most commonly used. In this method, the teak seedlings are raised up to 2 years in a nursery to produce the straight and unbranched tap-root. The nursery should be unshaded and not laid out in beds. Seedlings of two year old are sufficient enough for making stumps. Stump for planting is prepared by cutting off lateral shoots and lateral roots and this way stump with main tap-root is dug in the plantation site. The optimum size of stumps for planting is normally of 1.0 to 2.0 cm collar diameter. Stump so prepared is planted in the plantation site by digging a hole equal to the length of the root and the stump is inserted and the soil is firmly pressed so that no air spaces are left below or around the root. Usually plantation of stumps is carried out at spacing of 2m x 2m. Teak is generally worked on 50 years rotation period.

- **Tending operations:** Plantation raised through stump plantation usually required 3 weeding in the first year, 2 in the second and 1 in the third year. However, frequency of tending depends upon the nature and amount of weed as well as on the requirement of other species in the plantation. In pure teak plantations, thinning is needed in order to provide adequate light and space for the growth and development of teak plants.
- **Injury or damage:** Teak seedlings are sensitive to drought and frost. These are also very sensitive to shades and weed suppression. Rats and pigs are very harmfull at seedling stage whereas bison, sambhar, cheetal and elephants are harmfull in sapling and young stage of growth. Caterpillars of *Hyblaea puera* and other defoliators often defoliate Teak leaves. A plant borer, *Dihamus cervinus*, is common in young plantations [2].

13.2.6 Economic importance [2]

- It is one of the most valuable tree species on account of its timbers quality which has high demand in the market. It is one of the most durable timbers in the world, practically, impervious to fungus and white ant attack and resistant to decay. It is unique for ship building, extensively used for bridges, buildings, piles, cabinet work, beams, poles, decorative paneling, carving, general carpentry etc.
- The wood is dark golden when freshly cut, ageing to brown or almost black, moderately hard, extremely durable, takes a beautiful polish.
- Timber is easy to air-season, easy to work and saw. Excellent plywood is manufactured- the teak ply.
- Wood yields tar oil for which scraps and other wastes are utilized.
- The various parts of the tree have medicinal uses.

13.3 Silviculture of Sal

Botanical Name: *Shorea robusta* Gaertn. f.

Vernacular Names: Sal

English Name: Sal

Family: Dipterocarpaceae

13.3.1 Origin and Distribution

Sal forest are distributed on the plains and lower foothills of the Himalayas including the valleys [5]. Sal forests cover 10 million ha in India [6]. This forest type extends from a few metres to 1500 m above mean sea level. Sal requires well drained sandy loam soil with water retention capacity of 85%. Soil with pH value between 5.6 and 7.8 is best suited for Sal. The sal forests are distributed in north along the Gangatic plains and in north east region along the Brahmputra River.

13.3.2 General Description [2]

Plant description of *Shorea robusta* can be explained in the following points:

- *Shorea robusta* is a large, gregarious and has been paradoxically described as deciduous, semi-deciduous or evergreen tree which can attain a height of 120 to 150 ft. and a girth of 12-25 ft or more under favourable conditions.
- Subtropical and tropical type climate with widely varying temperature and rainfall is suitable for sal. In the western Himalaya, it is found in places of snowfall regions and in the valleys of the western sub-Himalayan tract and in regions exposed to severe frost. It is also found in Bhabhar and Tarai belt of Kumaun, Uttarakhand and also in Garhwal region. It is also found in places where frost is absent and temperature rises up to 40^0C such as Chota Nagpur Plateau.
- Sal requires well drained sandy loam soil with water retention capacity of 85%. Soil with pH value between 5.1 and 6.8 is best suited for Sal [5].
- Sal forests are found both in hilly regions as well as in plains regions. However, it grows best on the lower slopes and in the valleys where the soil is deep, moist and fertile.
- Sal trees generally have a clean, straight and cylindrical bole.
- Bark of saplings greyish brown, smooth, with a few deep longitudinal cracks, whereas that of older trees of dark brown about 1-2 inches thick, rough, with deep longitudinal furrows which provide effective protection against fire.
- Leaves are simple, shining and glabrous. The mature leaves somewhat coriaceous, ovate-oblong, usually about 4-8 in (10-25 cm) long and broadly oval at the base, with

the apex tapering into a long point. New leaves reddish, soon becoming delicate green.

- Flowers yellowish-white, arranged in large terminal or axillary racemose panicles.
- Fruit at full size about 1.3-1.5 cm long and 1 cm in diameter. It is surrounded by segments of the calyx enlarged into 5 rather unequal wings about 5-7.5 cm long. Seed weight varies from 880 to 1060 seeds (with wings) per kg.
- Seeds should be collected from healthy plus trees or well-maintained seed stand. Sal seed loses viability rapidly. Seeds can be stored for 3 or 4 days, but it is always advisable to sow as soon after collection as possible. Sound fresh seeds have high germination capacity.

13.3.3 Phenology

- Flowers appear from late February to April depending on locality and season.
- Ripening of fruits and seeds starts from end of May to early June or early July.
- Seeds ripen from end May to June or early July.

13.3.4 Silvicultural Characters

- Seed weight varies from 880 to 1060 seeds (with wings) per kg.
- Seeds should be collected from healthy plus trees.
- Sal seed loses viability rapidly, therefore, can be stored only for 3 or 4 days but it is always better to sow them immediately after collection.
- Sound fresh seeds have high germination capacity.

13.3.5 Regeneration in *sal* [2]

- Natural regeneration of Sal is very difficult and usually meets failure. However, they can be regenerated through artificial regeneration.
- In clear felled areas, artificial regeneration is carried out by direct sowing. It is particularly done in moist ground immediately after rains.
- Plantation of sal plants is are usually carried out along with other species which favourably assist sal growth and development. Each sal line is alternated with sal associates. Usually a distance of 30 cm is kept between two lines and within the line

seeds are dibbed at 8 cm intervals. After the sowing, the sown area is covered with a light soil layer. Seeds start germinating within 7 to 10 days.

- For sal plantations are raised at 50 years rotation period under clear felling system.
- In some areas, Sal forests are also regenerated through coppicing with an objective to get pole crop. In such conditions, a rotation of 15 years is sufficient for achieving the objective. Thus, the crop is harvested in every 15th year, and stools are left as such in order to arise coppice shoots. One or two such healthy shoots are allowed to grow to pole size. This reduces the cost of regeneration to a great extent and also the supply time of material is also gets reduced. This method is not suitable for places where Sal stumps do not have living root stock and thereby resulting into coppice failure. Such areas are re-stocked by plantation method through nursery raised seedlings.
- **Tending:** Being a species of subtropical regions, Sal plantations receive intense infestation by different weeds and climbers, therefore, it requires intensive tending operations right from seedling till sapling and young stages. Such operations include weeding, cleaning, hoeing, shrub-climber cutting, fencing, and fire protection etc. at different stages of growth and development. Therefore, it is advisable to raise Sal seedlings or saplings along with taungya crops between the lines. The taungya crops usually include cotton, paddy, brinjals, chillies etc. The advantage of raising taungya crops is that the villagers carry out intensive weeding and cleaning for their taungya crops, which automatically ensures weeding for Sal plantations also, thus, saves a significant amount. In the absence of taungya crops, at least five (5) weeding are required in Sal plantations during the first year, and such weeding and cleaning should be carried out regularly up to five (5) year although frequency of such operations are reduced after first year.
- **Injury and Damage:** Young as well as old Sal crops are liable to be damaged by various abiotic and biotic factors. Obnoxious weeds such as *Eupatorium* and *Lantana* pose serious threats to young seedlings. Sal is also sensitive to climbers. Wild animals like elephants, bison, pigs, deer, monkeys and rats cause a lot damage to Sal crops in various stages of growth and development. A large number of bark and wood borers, defoliators, sap suckers, fruit and seed eaters are also observed to have been damaging sal plantations. The most destructive among these is Sal heart

wood borer (*Hoplocerambyx spinicornis*). In additions to these, epidemic attacks by the beetle are also observed in various parts of the country. Sal is also vulnerable to damage by a large number of fungi.

13.3.6 Economic importance [2]

Being a durable wood and also having resistance to attack from white ants, Sal wood is used for a variety of purposes such as:

- construction of bridges,
- manufacture of railway sleepers, doors, boat building and furniture,
- It is good firewood and makes very good charcoal,
- The leaves are made into plates which are in good demand in the market,
- Seed as source of 'sal butter' which is used as a substitute for butter in chocolates, and as cooking agent,

13.4 Silviculture of Shisham

Botanical Name: *Dalbergia sissoo* Roxb.

Vernacular Names: Shishu, Sissu

English Name: Indian Rosewood

Family: Leguminosae

13.4.1 Origin and Distribution

Dalbergia sissoo is widely distributed in many parts of India up to 900m in the sub-Himalayan tract and occasionally ascending to 1500m. It is distributed throughout the sub-Himalayan region from Indus to Assam and in the Himalayan valleys, tarai and Bhabar regions of Uttarakhand. It is found in almost all the states of India. In the sub-Himalayan tract, it occurs along rivers and streams, gregariously growing on alluvial soil [2].

13.4.2 General Description

- *Dalbergia sissoo* (shisham) is one of the most important timber species of India and also provides excellent fuel. The heartwood is brown with darker streaks, very hard, strong and durable. It is a medium to large sized deciduous tree, 10-40 m tall with girth varying from 2-4 m at base. The growth of the bole is as a rule somewhat crooked, and straight logs of any great length are difficult to obtain.

- It is a large deciduous tree with a light crown. Bark is rough with shallow broad longitudinal fissures, exfoliating in irregular woody strips and scales, pale grey or light brown in colour. However, trees from different localities have varied characteristics including growth, form, colour, grain, working and strength properties.
- It has been grown along with many agricultural crops (viz., grasses, agriculture and fruit crops) under various agroforestry systems.
- It is found in a wide range of climatic and edaphic conditions. It grows between 4° C to 50°C temperature and 50 cm to 500 cm rainfall conditons.
- Shisham prefers well drained alluvial soils but growth is poor on waterlogged conditions. The soil pH ranges from 5.0 to 7.7, however, it can tolerate to some extent the saline condition. Stunted growth is observed on heavy clay soils.
- Leaves compound, with 3-5 alternate leaflets and about 15 cm (5.9 in) long. Three or five leaflets arise form one leaf, each roughly heart-shaped with a finely drawn-out short tip. Leaflets are arranged alternately on the leaf stalk, creating a foliar cloud distinct to the shisham.
- Inflorescence is axillary panicles.
- Shisham bears yellowish white flowers which are 7-10 mm long, sessile to pedicellate. Flowers are whitish pink, fragrant and sessile or nearly sessile. Calyx campanulate, corolla pale yellow, standard obovate-orbicular, with a long claw, wings oblong, keel obtuse, stamens 9, monadelphous, ovary long, style incurved.

13.4.3 Phenology [2]

- Leaf fall takes place generally in November-December.
- Tree remains leafless for a very short time from November to January. New leaves appear from end of January and in February, and young flower buds also appear along with these new leaves. The flowering generally starts in March and April.
- Flower buds and flowers appear between February and April. The flowers from flower buds take from 13 to 15 days to come into full bloom and a further 20 to 25 days to develop pods. The flowers take from 13 to 15 days to come into full bloom and a further 20 to 25 days to develop pods.

- Fruiting initiates at the end of May when young pods appear. The pods turn brown and ripen during November-December.
- Seeds are light brown, flat and thin 5 to 9 cm long and 8 to 12 mm wide. They are more or less kidney shaped and glossy.
- There are about 50,000 to 60,000 seeds per kilogram or 18,000 seeds in one kg of dry pods.
- Mature seed that has been properly dried, cleaned and stored should germinate at a rate of 80 to 90%.

13.4.4 Silvicultural Characters [2]

- There are various factors which affect the growth and development of seedlings. These factors include abundance of sunlight, availability growing space, porosity of soil, presence of weeds and plentiful supply of water.
- The sissoo is a strong light-demander, therefore, and needs suitable exposure to sunlight for its best growth and development. In full light the development is always better than under partial shade.
- The effect of growing space on the development of saplings is seen in the manner in which the more vigorous members of a young crop take the lead from the first season and suppress the remainder. There should be sufficient horizontal space for better growth of seedlings and saplings. In order to ensure the best results the thinning should start as soon as the first season ends and should be repeated annually for a few years.
- Similarly porosity of soil has a marked effect on development as it has effects on the water drainage and Shisham does not like water logged conditions. On stiff clay the plants always remain stunted. It has been observed that periodic loosening of the surface soil combined with the eradication of weeds has resulted in better growth and development.
- It is frost-hardy and drought hardy species. The leaves are sometimes affected by severe frost, but the tree is not seriously injured. Seedlings are sensitive to drought, but in its natural state the tree is fairly hardy.

- Sissoo plants are readily browsed by cattle, goats, and camels; where grazing is prevalent, seedlings and saplings are browsed down year after year, and coppice-shoots assume a dense bushy growth.
- The sissoo is not particularly fire-resistant, and the forests suffer greatly where there is much inflammable grass present.

13.4.5 Regeneration Methods [2]

Shisham can be regenerated both by natural regeneration as well as artificial regeneration.

A) **Natural regeneration:** Natural regeneration takes place during the rains when ample water available for germination to take place. After monsoons, the germinating seedling are successful only when they receive continuous water. This water requirement of seedlings growing in riverine tracts is easily met up from the percolation of water from river and is of great significance. As discussed earlier, the other factors which help in establishment of the regeneration are alluvial sandy soil and highly porous soil, sufficient sunlight, low weeds, and sufficient moisture in the surrounding to tide over the dry season.

   Drought is the most important cause of mortality among seedlings. Another common cause of mortality is the damp situations under shade which results in rotting of seedlings. Dense weed-growth entirely prevents the establishment of regeneration. Among the other adverse factors are fire and grazing which has considerable impact on germinating seedlings.

B) **Artificial regeneration:** Artificial regeneration can be bring about either by seeds or by ordinary cuttings or from root cuttings. However, seedlings can be easily raised from seeds. Plantations via root-suckers are very useful and successful in the dry climates. Regeneration by seeds can be done both by direct sowing as well as by transplantation [2].

   Sites suitable for raising Shisham plantation are the ones where sand soil is present so that drainage is adequate. It is advisable to avoid stiff clay soil. One of the important requirement is to have adequate irrigation facilities as it promotes the most rapid growth. Nursery for the purpose may be created near some alluvial land adjacent to rivers or continuous water source. Further, intermittent weeding and loosening of soil is needed for checking unnecessary competition and proper aeration in soil particularly

during the early years of establishment. However, weeding should be started only when seedlings have sent down their taproots, and not during the germination stages, otherwise they are liable to be loosened and washed away by rain or exposed to drought.

Direct sowing of seeds has proved to be successful particularly in large scale plantations. Direct sowing should be carried out in lines so as to facilitate easy weeding. Although transplanting has higher success rates but cost of raising the seedlings and transplanting is higher. However, transplanting is sometimes necessary in order to fill the gaps or carrying out roadside plantations.

In Transplanting, seedlings are first developed in the nursery through seeds. Shisham pods should be sown in drills in seed-beds of light soil thoroughly worked up and lightly covered with earth. The sowing should be carried out well before the rains (March-April in northern India), and the beds should be regularly and copiously watered by hand or by irrigation. Regular weeding and loosening of the soil is necessary. If small transplants are required, the drills should be 9 inches apart. If large transplants of the second year are wanted the lines should run longitudinally along the beds, and should be about 18 inches apart. The seedlings should be thinned out towards the end of the first season; watering should be more sparingly done in the second than in the first season, in order to render the plants hardier. Transplanting with entire stem and roots is successful only with small plants early in the first rains, before the taproot reaches too great a length. Transplanting with pruned stem and roots has invariably given better results, not only as regards the percentage of success, but also as regards the vigour of the plants after transplanting. The stem should be pruned down to a height of about 2 inches from ground level and the taproot to a length of about 6 inches if transplanting is done in the first rains, or about 12 inches, if it is done in the second rains. Plants up to 7 ft. in height or more which have been treated in this way have been transplanted with complete success, vigorous new shoots being produced from the base almost immediately and soon attaining the height which the plants would have reached if they had not been interfered with. Drought is the main factor which may pose difficulty, however, if watering is continuously done until the establishment of plants, then it is useful. If watering can be done in winter planting particularly when the plants are leafless, it gives better results.

Various degrees of spacing have been adopted in sissoo plantations in India. Anything more than 8 ft X 8 ft is generally found to be too wide, resulting in low branching and crooked growth: even this is on the wide side, and 6 ft. X 6 ft. is preferable though more expensive. Spacing 5 ft. apart in lines 10 ft. apart has been found satisfactory, as this facilitates weeding along the lines.

C) **Thinning:** Thinning is one of the most important requirement of shisham plantatins on account of its being a strong light demander. Thinning ensures adequate availability of sunlight to saplings and young growth. It is usually carried out in 6th and 11th year of shisham pure plantation. However, the frequency may be more in case of mixed plantations.

D) **Injuries, Pest and Diseases:** Shisham plants are injured due to climactic and biological factors. Seedlings and saplings are badly effected by prolonged drought conditions.

- Weeds and tall grasses also effect particularly seedlings as they compete with them for light, nutrients etc.
- Young plants are browsed by herbivores such as deer, cattle, goat, sheep, camel etc.
- There are many insect-pests which harm the shisham plantations. Among the leaf defoliators are *Plecoptera reflexa, Dichomeris eridantis* and *Ascotis selenaria.* Among others are leaf rollers (*Apoderus sissu*), leaf miners (*Leucoptera sphemograpts*) and sap sucking bug (*Droscicha magifera*).
- Among the common fungal diseases are "Wilting" caused by – Fusarium solani particularly in natural forest and, Chlorisis and leaf drop in artificial plantation, and root disease by *Ganoderma lucidum.*

E) **Silvicultural Systems:** Recommended silivicultural system for Shisham is Coppice with standard.

13.4.6 Economic importance

Shisham is one of the important plant which is put to a diversity of uses which are as follows:

- It is among the most useful timber species of India. Wood obtained from the tree has many properties which make it a good timber. It has good strength, elasticity, durability, colour, grain, texture and lucrative surface. This is why shisham is highly valued for high quality furniture, cabinets, decorative veneer, marine and aircraft grade plywood, ornamental turnery, carving, engraving, tool handles and also for constructional and general utility purposes.
- Shisham wood is also has application in the manufacture of certain sports equipment, artificial limbs, and jute/ textile mill accessories.
- The trees provide fuelwood, fodder, green manure and other wood products
- Young branches and foliage is used as an excellent fodder for cattle.
- The tree flowers are used for rearing honey bees and producing honey.
- On account of the species being fast growing, it is suitable for firewood. Wood has a calorific values about 4.9 to 5.2 kcal/g.
- Aqueous extracts from the leaves, stems and roots is used to prepare pesticide properties.
- The pods / seeds of the plant yield tannin or dyestuff.
- Heartwood yields light brown, viscous, no-drying fixed oil suitable as lubricant for heavy machinery.
- There are many medicinal uses of shisham. It includes – treatment of gonorrhea through compound made by boiled leaves; bark and wood extracts are used to lessen vomiting, thirst and burning sensations; among other uses include the treatment of leucoderma, leprosy, boils, ulcers, indigestion and dysentery; oil from the seeds is used to treat skin ailments and people use twigs to clean their teeth
- Branches are also combined with animal dung as a source of fuel.

13.5 Silviculture of Alder

Botanical Name: *Alnus nepalensis* D. Don

Vernacular Names: Uttis, Nepalese alder

English Name: Alder

Family: Betulaceae

13.5.1 Origin and Distribution [2]

The species is native to India, Nepal and Pakistan. It is distributed throughout the Himalayan states in an altitudinal range of 3,000-9,000 ft in both temperate and subtropical regions in the middle hill forests of Uttrakhand, Himachal, Darjeeling hills. It is often found in landslides and in old cultivation, especially near streams. It quickly occupies abandoned previously cultivated lands and forms a pure crop of alder.

13.5.2 General Description [2]

- It is a deciduous large tree that reaches up to 30 m in height and 60 to 90 cm in diameter. In the forest the bark has a dark green colour, and the tree is easily recognized. In open places it is generally silver-grey, resembling that of the birch. The stem is very cylindrical, tall, and grows very rapidly.
- It prefers soils that are moist and well-drained, but not waterlogged. It does poorly on dry, exposed ridge tops. It prefers moist, cool climates with mean annual temperature of 13-26°C and annual rainfall 500 to 2500 mm.
- It is tolerant to drought as well as to frost.
- The leaves are 7–16 cm long, 5–10 cm broad, elliptical, entire or slightly denticulate.
- Fruits are resemble to cone, black, about 1.5 cm long. They are dark brown, 1.5-2 cm long, upright on short stalks, elliptical and with woody scales. The empty catkins persist on the tree.
- The tree grows quickly and is sometimes planted as erosion control on hillsides and for land recovery in shifting cultivation. It tolerates a wide variety of soil types and grows well in very wet areas.
- The tree remains in symbiotic association with Frankia sp. Which helps in nitrogen fixation. Therefore, it does not require rich soil fertility but is suitable for soil improvement and rehabilitation of degraded lands.
- Leaves are simple, alternate, 6-20 cm long, slightly serrate with prominent parallel veins.
- The flowers are unisexual, female and male flowers in separate inflorescences which are known as catkins. Male catkins are 10-25 cm long, drooping and in terminal panicles. Female catkins 1-2 cm long, 3-8 together in axillary racemes.

- Seeds are light brown, circular, flat nut, with membranous wing. More than 2 mm across. Eight kg of catkins contain about one kg of seed which contain approximately 2.3-3.5 million clean seeds.

13.5.3 Phenology

- The flowering from September to November
- Fruiting in October-November
- Seeds ripen in December-January

13.5.4 Silvicultural Characters

- It is a fast growing species needs and, therefore, water should be available in ample amount
- It is self pruning species which results in a good clean bole which is tall and straight.
- One kg of fruit gives 100 gms of cleaned seeds.
- One Kilogram of seeds include 5, 64,000 seeds.
- Seeds are viable for limited time period up to 3 or 4 months

13.5.5 Regeneration Methods

Regeneration is carried out mainly through artificial regeneration. It includes production of seedlings in the nursery and subsequent transplantation in the plantation site. Seeds are broadcasted in shaded nursery beds in March. In general, seeds take 4 to 6 weeks to germinate and after germination seedlings are pricked out and placed in polythene pots in July-August and planted out in the following rains. *Alnus nepalensis* fixes nitrogen in root nodules with *Frankia spp* (An actinomycete). Therefore, the nursery bed/potting mixture should contain soil from mature plantation of *Alnus* to provide necessary inoculants of *Frankia spp.*

Transplanting in the field is done during the first or second rains in standard pits at a spacing of 2m x 2m or 2.5 m x2.5m. Natural seedlings, 15 cm to 23cm in height have been transplanted into plantation entire in July and have been reported to give 75% success. The species should be planted in mixture in alternate lines with slower growing shade bearers.

Direct sowing is an alternative, but it is important to use seeds that are fresh and have high germination. Ample quantities should be used and the seed sown on exposed mineral soils. Good results have been obtained by mixing the seed with soil containing *Frankia*.

- **Tending:** The plantation may be subjected to normal tending operations during the first three years. Being a fast growing species, no tending is required after the third year.
- **Injury/Damage:** This tree is damaged by snow, frost and grazing. It is attacked by a *Lepidopterous* larvae which girdles the young tree. It is also susceptible to attack by stem borers *Batocera horsfieldii* and *B. numitor*. The species is also reported to have been attacked by defoliators.

13.5.6 Economic importance [2]

- It is a pioneer, nitrogen-fixing (Frankia symbiosis) species and fast growing, therefore, is suitable for soil improvement and rehabilitation of degraded lands and arresting the soil erosion.
- In agroforestry systems, it can be inter-planted with a number of crops
- Wood dries easily and burns well, therefore, is an important source of firewood and charcoal to the nearby villagers.
- It is also used making boxes and in light construction activities.
- The bark of the tree yields tannin and used occasionally for tanning and dyeing purposes.
- The foliage is of low to moderate value as fodder for sheep and goats, however, is not suitable for cattle.

13.6 Silviculture of Eucalyptus

Botanical Name: *Eucalyptus spp.*

Vernacular Names: Lyptis

English Name: Eucalyptus

Family: Myrtaceae

13.6.1 Origin and Distribution

Eucalyptus is an exotic species native to Australia and adjoining Islands. In India, its introduction dates from 1843, when a few trees were planted experimentally in the Nilgiris

mainly with the object of finding some species capable of yielding regular and plentiful supplies of fuel. However, large scale plantation programme throughout the country was carried out in 1960 and beyond. It has also been a popular farm forestry crop [2].

13.6.2 General Description [2]

- *Eucalyptus* has more than 700 species, most of which are found in Australia and some in Tasmania, New Guinea, and other islands. A lot of varieties of eucalyptus have been introduced in India, of which the most widely used was *E. hybrid*. Other species which are grown on large scale plantation programmes were *E. grandis, E. citriodora, E. globulus* and *E. camaldulensis*.
- The *Eucalyptus* plants are evergreen trees. An aromatic fragrance is noticed near *Eucalyptus* plantation which is because of aromatic oil-glands in their leaves.
- The leaves of young trees are opposite, sessile and horizontal, and are often of a different shape from the normal leaves of the adult tree. In adult tree, the leaves are usually alternate, petiolate, and hang vertically.
- The flowers are white or red, and the flower-buds have the calyx-tube covered with a lid or operculum which falls off when the flowers open.
- The fruit is a woody capsule, consisting of the hard calyx-tube and containing numerous small seeds, a considerable proportion of which are usually unfertile.
- It is a tall tree having erect stem.
- Each year there is an increment of living bark that results in the continual expanding girth of the tree. The outermost layer dies each year. In most of the species, the dead layer completely sheds off and thus, exposing a new layer of living bark, and this process continues year after year. These are known as the smooth barks.
- Most species have lanceolate or falcate (curved) and odorous leaves.
- The woody fruits or capsules are roughly cone-shaped and have valves at the end which opens to release the seeds
- Seeds are waxy, rod-shaped, about 1mm in length, and yellow-brown in colour.

13.6.3 Phenology

- *E. tereticornis* (Syn *E. hybrid*) produce seeds twice a year, once in autumn (October-November) and next in summer (May-June).

13.6.4 Silvicultural Characters [2]

- Most of the species have good coppice power, however, the best among these is blue gum {*E. globulus*)
- It is generally wind firm species, however, they are liable to become bent in exposed strong windy situations.
- Most of the species are liable to be badly affected by fire, however, they have better power to recover from fire injury
- Trees start producing large quantities of seeds from the age 5 years. Seeds are very minute and one kilogram of seed contains about 3,50,000 to 3,65,000 seeds.
- Viability of seeds is 6 to 12 months and germination capacity of fresh seeds is as high as 90%.

13.6.5 Regeneration Methods [2]

- It is propagated through artificial regeneration and the most common method is transplantation of nursery raised seedlings in polythene bags. The artificial raising of eucalypts requires a considerable amount of care as the seeds are small and are easily washed away by rain. Further, the young seedlings are sensitive to drought and frost.
- Direct sowings are less commonly employed than transplanting.
- Although most of the planting stock is produced through seeds, but vegetative production from clonal stock by stem cutting of certified superior clones may also be used.
- Seeds are sown in the raised beds in January-March and covered with hay. Beds need to be watered frequently but cautiously by sprinklers or automisers. Germination takes place within 5- 15 days when thatch is removed. Seedlings are pricked out into polythene pots when about 10 cm tall, normally 4-6 weeks after germination. Polythene pots are placed in sunken beds. Lately, however it is advised to use raised beds, made of bamboo or iron frame, to contain the polythene pots. *Eucalyptus* plants attain a size suitable for plantation in about 3 to 4 months' time.
- Transplantion of about 12 inches high seedlings is usually done during the rains. Plantation is carried out with a spacing of 8 ft. X 8 ft. or 10 ft. X 10 ft.

- **Tending operations** are needed in the initial stages till two years from frost and it is achieved by grass covers. Weeding is also required in order to promote the growth of seedling and three weeding are done in the first year.
- **Seedlings or saplings are exposed to Injury** by rain, strong sunlight and hot wind. In termite prone areas, termites pose a major hazard to young seedling in the field. They are also prone to gall formation (an abnormal outgrowths caused mostly by insects). Often the phenomenon of gummosis – exudation of gum on the outside of the stem is observed which a manifestation of injury to cambium is by fire, fungal, termite or borer attack.
- **Silvicultural Systems:** The best method of regeneration is clear felling system. However, simple coppice system is also used for the production of fuel with a rotation adopted of ten to fifteen years.

13.6.6 Economic importance

- These are used for construction, electric transmission poles, a good fuel wood having high calorific value
- The oil is useful in many pharmaceutical preparations, flavouring cough lozenges, mouth gargles, toothpastes, perfumes, repellants against mosquitoes, vermin, germicide etc.
- They provide many desirable characteristics, for use of ornament, timber, firewood and pulpwood
- Eucalyptus oil is made up of approximately 80 per cent eucalyptol (also known as cineole) a potent antiseptic compound and as a natural insecticide
- Eucalyptus leaves are also a source of tannins
- All parts of the plant may be used to make dyes
- The nectar of some species produces high quality mono-floral honey
- Leaves of the plant yield oil which has applications in pharmaceutical industries.

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Unit 14: Silviculture of some broad leaved trees II

Unit Structure

14.0 Introduction

In the previous unit, silviculture of Teak, Sal, Shisham, Alder and *Eucalyptus* was discussed in detail. These species have a great commercial and ecological importance. In this unit, we will discuss silviculture of some more economically important broad leaved species such as Arjun, Chandan, Neeem and Bamboos. Of these first three have importance from the view point of medicinal properties. Chandan is well known for its commercial values and each and every part of it is utilized. Whereas Bamboos are used in

diversity of uses from house building to small scale industries such as basket making, furniture industry etc.

14.1 Learning Objectives

The main objectives of this unit are to acquaint the learners with silvicultural properties of:

- Arjun (*Terminalia arjuna*)
- Chandan (*Santalum album*)
- Neem (*Azadirachta indica*)
- Bamboo (*Bambusa spp.*)

14.2 Silviculture of *Arjun*

Botanical Name: *Terminalia spp.*

Vernacular Names: Arjun, arjhan

Ayurvedic Names: Arjuna, Dhananjaya, Kaakubha, Kakubha

English Name: Arjuna

Family: Combretaceae

14.2.1 Origin and Distribution

It is native to India and Sri Lanka. It is common in greater part of Indian Peninsula [1]. It occurs in the wild along the banks of rivers and streams throughout the India particularly low lying plains areas, also grown as an avenue tree [1] [2]. The species is a characteristic component of dry tropical riverine forests and tropical moist and dry deciduous forests [2]. It is found planted throughout the country in plains preferably in low-lying areas. The altitudinal range of distribution is up to 1200 m where mean annual rainfall ranges from 750 - 1900 mm and mean annul temperature from 20°C to 30°C [1].

14.2.2 General Description [1] [2]

- *Terminalia arjuna* is an evergreen or nearly evergreen, however, some authors have reported it as deciduous also [2]. It is a large-sized tree attaining 30 m height and upto 2.5 m dbh with an often buttressed trunk. Its superficial, shallow root system spreads radially along stream banks.
- The large, spreading crown produces drooping branches.

- Bark grey or pinkish-green, thick, smooth and exfoliating in thin irregular sheets.
- Leaves simple, opposite to sub-opposite, oblong or elliptic oblong, glabrous, hard, often inequilateral, margin often crenulated.
- Inflorescences are short axillary spikes or small terminal panicles and flowers are small, cup-shaped, regular, sessile, polygamous, white, creamy or greenish-white and strongly honey-scented.
- Fruit obovoid-oblong, dark brown to reddish brown, 2.5 to 5 cm, fibrous woody fruit, indehiscent drupe, glabrous with 5-7 equal thick narrow stiff-wings and striated with numerous upwards-curved veins.

14.2.3 Phenology

- New leaves appear in the hot season (February to April) before leaf fall. Trees sometimes may be leafless for a very short period before flowering [1].
- Flowering begins in April- May whereas the ripening of fruits take place nearly a year after the appearance of the flowers during February to May [2].
- Generally, every third year is a good seed year [2].

14.2.4 Silvicultural Characters

- It grows well on fertile, neutral (pH 6.5 - 7.0) soils, especially loose, moist, alluvial loam with good water supply and drainage.
- Initially it grows at a slow speed, however, in later stages, the growth is fast.
- Weeding and protection from fire and frost is needed for the first two years.
- Pruning is required to remove the weaker shoots when forking takes place due to frost damage.

14.2.5 Regeneration Methods

A) Natural Regeneration: Arjun shows satisfactory natural regeneration by seed as well as coppice. Seeds are dispersed by water. Natural regeneration occurs in loose alluvial soil, along water courses. However, in forests, the species is propagated by artificial regeneration. [2]

B) Artificial Regeneration [2]: Arjun can be regenerated by direct sowing and transplanting of nursery raised seedlings. Direct Sowing: Fruits are sown in dug up lines,

2.3 m to 4.0 m apart, in June-July with the onset of monsoon rains. The pits or trenches used for treatment of seeds can be located in the plantation itself when direct sowing in the field is planned. Germination commences in 4 to 7 days.

Transplanting of seedlings developed in the nursery are planted out in July-August. For the purpose, pre-treated seeds are dibbled in polythene pots in April-May. The pots are watered regularly and weeded as frequently as necessary. After two to three months, the seedlings attains 12.5 cm and 30 cm, respectively. Spacing of transplanted seedlings may be kept 2 m x 2m or 2.5 m x 2.5 m. However, if the plantations is raised for tasar sericulture then the spacing is maintained 1 x 2 m.

C) Tending: Arjun, an initial slow-grower, later grows very fast to attain 2–3 m height in 3 years. Weeding and protection from fire and frost is needed for the first two years. Thinning is required to remove the weaker shoots when forking takes place due to frost damage

D) Injury/Damage [2]

- Young seedlings are sensitive to frost and drought. Literature cites attack by wood borer and defoliator, as also fungal attack.
- Incidence of powdery mildew caused by *Phyllactinia terminalae* and white fibrous rot due to *Polystictus affinis* have been reported.
- Larvae of Apoderus tranquebaricus feed inside rolled leaves, whilst larvae of Gelasma goniaria and Lymantria mathura cause defoliation of the plant. Also the presence of Ceroplastes ceriferus (white wax insects) on the leaves has been reported.
- Seed are damage by *Psittacula krameri* birds has been reported in India.
- Seedlings are susceptible to fire, drought and frost. Frost damage can cause forking of the stem and the development of a bushy habit.
- Heavy shade is also injurious to seedlings resulting in die-back for several years, again leading to a bushy tree.

E) Silvicultural Systems: Selection management systems can be utilized to extract timber, which is 50-60 cm dbh.

14.2.6 Economic importance [3]

- It makes an excellent charcoal and firewood with calorific values of 5030 Kcal/kg and 5128 Kcal/kg for the sapwood and heartwood, respectively.
- It has been widely used in Ayurvedic medicine for the treatment of cancer, dermatological and gynaecological complaints, heart diseases and urinary disorders.
- Timber is locally used for carts, agricultural implements, water troughs, traps, boat building, house building, electric poles, tool-handles and jetty-piles. It also provides satisfactory rayon-grade pulp in mixture with other woods.
- It is widely planted for raising tassar silkworm and livestock fodder in India where leaves are heavily lopped.
- It also yields tannin in its bark (22–24%) and fruit (7–20%), which are used as tanning and dyeing material. The tannage can be used for making fine upper leather and excellent sole leather of light-brown or buff colour with a red tint
- The bark, containing large amount of lime (calcium carbonate), is often burnt to produce lime for chewing with betel. The bark is also used to assist precipitation of mud from turbid water.

14.3 Silviculture of Chandan

Botanical Name: *Santalum album* Linn.

Vernacular Names: Chandan

Hindi Names: Gandada, gandha

English Name: Sandalwood

Family: Santalaceae

14.3.1 Origin and Distribution

Sandalwood tree is indigenous to the mountain districts of South India and some plant historians believe that the tree is indigenous to South East Asia (Timor Islands) and was introduced into India by traders possibly before the Christian Era [4]. According to Troup 1907, the sandalwood tree is indigenous to the Indian Peninsula [1]. In general, it may be distributed best between 600m (2,000 ft) and 1050 m (3,500 ft) though it ascends to over 1200 m (4,000 ft) and descends in places as low as 360m (1,200 ft). It is distributed all

over the country and more than 90% is concentrated in Karnataka and Tamilnadu covering an area of 8300 sq kms. It normally grows in sandy or stony red soils, but can be grown on a wide range of soil types. Its habitat has a temperature range from 0^0C to 38^0C and annual rainfall between 500 to 3000 mm.

14.3.2 General Description

- Generally speaking, the climate within its habitat is comparatively cool, with a moderate rainfall, much sunshine, and long periods of dry weather [1]
- Sandalwood is a small evergreen tree growing to 18 m in height (40 to 50 ft) and 2.4 m in girth (3 or 4 ft), with slender drooping branches [4].
- It has slender drooping branchlets with opposite leaves, sometimes alternate, occasionally ternate, ovate or ovate-lanceolate, 3.5-4 cm long, sometimes larger in fertile localities, glabrous and shining above, glaucous beneath. [4]
- Bark is reddish brown or dark brown, red inside, smooth in young trees, rough with deep vertical cracks in old trees. Wood is hard, very close-grained, oily, sapwood white, scentless, heartwood yellowish brown and strongly scented.
- The flowers are purplish brown, unscented, in axillary, terminal cymose panicles. The fruit is a purplish black globose succulent drupe 0·3-0·5 in. in diameter, with a. brown endocarp which is moderately hard but brittle and easily broken.
- The seed has a copious white albumen and a straight embryo. It retains its vitality for some time if kept dry. Good seed-years occur almost every year. Seeds are available in two seasons, April to May and September to October; both the seeds perform alike with respect to germination [1].
- Germination is epigeous.
- Root parasitism is one of the important feature of sandalwood. The fact is that the sandalwood tree is a root-parasite and was first of all established in 1871 by Mr. John Scott, a Curator of the Royal Botanic Gardens, Calcutta. Some of the best hosts of the tree are *Acacia concinna, A. intsia, Albizzia lebbek, Bambusa arundinacea, Dalbergia sissoo, Eucalyptus globulus* etc. [1]

14.3.3 Phenology [1]

- *Santalum* is an evergreen tree usually have a flush of new leaves in May also after the monsoon in October.
- It flowers and fruits twice a year during March-April and September –October. Trees start flowering from 3 years of age.
- the fruits ripen in May and June.
- About 6000 seeds make one kilogram

14.3.4 Silvicultural Characters [1]

- In the initial stage of development, the tree needs light whereas the later stages it can grow well even in shade.
- It has a good coppice capacity in its young stage where it loses the capacity as it approaches old stage.
- Frost is unknown in the natural habitat of the sandal, however, prolonged drought conditions may kill the plant
- Cattle, goats and deer browse the leaves especially in dry season
- The tree is extremely sensitive to fire, and may be killed outright or badly injured and rendered unsound
- The tree requires good drainage, and does not stand water-logged ground.

14.3.4 Regeneration Methods [1]

Sandalwood can be regenerated both by natural means as well as artificial means.

A) Natural regeneration: Natural regeneration mainly takes place under the protection of bushes, hedgerows and scrub. In open areas, germination does not occur because the seedlings are require protection from excessive drought and from browsing animals. Seedlings die in large numbers if exposed to excessive drought or to a hot sun. Soil moisture is an important factor affecting the growth of seedling which is evident from the fact that sandal often reproduces itself along the banks of streams. Damping off of seedlings owing to an excessive amount of dense wet herbaceous undergrowth sometimes affects negatively to the growth of seedlings.

Lantana acts as a good host to the tree in its early stages, however, excessive dense growth of it kills the seedlings. Further, the species being fire sensitive, the presence of Lantana exposes the risk of fire.

B) Artificial regeneration: A number of trial to cultivate Sandal artificially were carried out since 1870, but all of them met with failure after a growth of 10 years or even more, after which the plants became unhealthy and died off by degrees. This was probably because that time the importance of host plant was not realized and absence of host in the nearby locations resulted into failure. In the later stages, when people realized the importance of host plant, the artificial regeneration became successful. For the purpose, generally, the seeds are obtained from plants over 20 years old. Fresh seeds obtained from fruiting in October. Seeds are dried and sown on seed beds. Gibberellic acid is used to bring down the dormancy period and to induce quick and uniform germination. After germination, seeds are put in polybags of size 15 cm x 25 cm. A host plant is sown in the polybag when the seedling reaches 15 cm in height [4].

C) Injuries: Natural seedlings suffer much in their earlier stages from the attacks of rats, while hares also seek them out readily; as the plants grow larger, deer, goats, and cattle browse them eagerly if they are not protected by bushes.

14.3.5 Economic importance

- It is used for carving and other fancy work, and largely distilled for its fragrant oil, which is used in perfumery and medicine. For distillation purposes the heartwood of the stem, branches and roots are used, every part of the tree which contains heartwood as small as one inches in diameter can be utilized.
- Sandalwood oil was used traditionally to treat skin disease, acne, dysentery, gonorrhea and number of other ailments. It is used in aromatherapy to be effective in treating dry skin, general skin irritation and acne. It is also effective in the treatment of bronchitis, dry persistent coughs, laryngitis as well as sore throats [1].
- Sandalwood Oil is a natural fixative for all the top class perfumes. Some of the major industries depending on sandalwood oil are Attar industry, Perfumery Soaps and toiletries chewing scented tobacco Pan Masala Pharmaceutical applications. The production of Attars has occurred in India for centuries, it is a blend of sandalwood oil and flower oil, such as rose petal, jasmine, kewda etc. The quality of attar depends on

the concentration of flower effervescence with in sandalwood oil. Numerous types of attar products are made in India and it forms an important constituent for the manufacture of incense sticks and Scented tobacco, Pan Masala, Zarada, Gutka etc.

14.4 Silviculture of Neem

Botanical Name: *Azadirachta indica* A.Juss.

Vernacular Names: Neem tree

English Name: Margosa tree

Ayurvedic Name: Nimba, Nimbaka, Arishta, Arishtaphala, Pichumarda

Family: Meliaceae

14.4.1 Origin and Distribution

It is a native to Burma and distributed in subtropical and tropical regions of our country. It is commonly found in the open scrub forests of Shiwalik hills. It thrives in majority of soil types and does not do badly even on clay [1]. It is found in wild and in cultivation throughout the subtropical and tropical climates.

14.4.2 General Description

- Neem is a moderate to large sized evergreen tree with pinnate leaves which are crowded near the end of the branchlet; leaflets sub-opposite, obliquely lanceolate, acuminate and serrate [1] [2].
- bark is moderately thick, furrowed longitudinally and obliquely, dark grey, reddish brown inside
- heartwood is red, hard and durable
- Flowers white, fragrant, shorter than the leaves. [2]
- Fruit is ellipsoidal drupe, yellow when ripe and single celled, single seeded or sometimes even two-seeded. Tree produces seeds profusely from an early age of about 5 years [1].
- Germination is of epigeous kind.

14.4.3 Phenology [1] [2]

- it is always evergreen, however, only in dry localities, it become leafless for a brief period. Usually, the new leaves appear before the older fall off, usually in March-April

- Flowers are white and the panicles of small flowers appear in March to May.
- Ripening of fruits take place during June to August
- Viability of seeds is only for short duration.
- Number of seeds per kg varies between 3000 and 5000.

14.4.4 Silvicultural Characters [1]

- Neem is a light demander species
- It is a frost tender species especially during seedling or sapling stages
- It has a great coppicing power and also produces by root suckers particularly in dry localities
- Sheep and goat do not like it, however, camel can cause damage through browsing
- In porcupine dominant areas, it is damaged by them by gnawing off the bark round the stem at its base

14.4.5 Regeneration Methods [1] [2]

Neem can be regenerated through natural as well as artificial methods. These are described as follows:

A) **Natural Regeneration:** Natural regeneration occurs through seeds. Seeds are produced profusely by neem tree right from the age of five years. Mature Neem trees produce seeds in abundant quantity and are mainly dispersed by birds. Natural regeneration is plentiful under the protection of thorny bushes, hedges or fence. Under suitable conditions, the germination takes place in two or three weeks. The germinated seedlings, however, required protection from damaging agencies. It is ensured through establishing a row of bushes around the regeneration.

B) **Artificial regeneration:** It is carried out through transplantation of seedlings raised in nurseries. However, direct sowing of seeds in the plantation site has also been proved successful. For this purpose, seeds are collected in June last or July first week. Only complete matured seeds in the trees are collected. Since the seeds are viable for only for a very short time, therefore, they should be sown as soon as possible. It is desirable to cover the seeds with soil in order to protect the seeds and germinating radical from destruction by insects.

Germination percentage of fresh seeds is found to be from 70 to 95% in 7 to 21 days. In nursery, seeds are sown 1 cm deep and at a spacing of 2.5 to 5 cm apart. Line sowing if preferred with spacing between lines of 15 to 20 cm. Seedlings of 7 to 10 cm tall are produced in 2-3 months. The seedlings are generally retained in nursery for further 1 or 2 years. The seedlings so produced are suitable for transplantation which is carried out in the rainy season. For this purpose seedlings of 10 to 12 cm. in height are suitable. If larger seedlings are required, than they are raised for some more years in the nursery and then transplanted [1].

C) Injury/damage [2]

- It is wind-firm but frost and fire tender species.
- Seedlings die back in dry season.
- Seedlings or plants are susceptible to browsing.
- The plant is also prone to damage by certain insects and fungi.

14.4.6 Economic importance [1] [2]

- The tree has many uses. The red or brown wood is aromatic, durable and takes good polish. It is used for furniture, carts, axles, yokes etc.
- The bark has medicinal value.
- The leaves are used in herbal medicine and insect repellent.
- The twigs are commonly used as chew sticks or tooth brushes.
- The most useful and valuable part is the seed which contain deep yellow fatty oil known as margosa oil of commerce. The main active principle of this oil is 'nimbidin', which has many therapeutic uses.
- Heartwood is used for house-building, furniture, and many other purposes;
- The bark, gum, leaves, and flowers are all used in medicine, while the seeds yield an oil used in medicine and for burning.

14.5 Silviculture of *Bamboos*

There are many species of bamboos found in India. Some of the important species are *Bambusa arundinacea, Arundinaria falcata*. Bamboos belong to the grass family Poaceae (Graminae)

14.5.1 Origin and Distribution

Bamboos are an important component of wet evergreen, moist deciduous and dry deciduous forests in the tropical parts of southeastern Asia, principally in the India (Andamans), in Burma, Cambodia, Ceylon, Indonesia, Laos, Malaya, New Guinea, Pakistan, Philippines, Thailand and Viet-Nam [5] [1].

14.5.2 General Description [1] [5]

- Bamboos are tall tree like but are woody perennial grasses and therefore, belong to the family Poaceae (Graminae).
- Most of the bamboos have a habit of growing gregariously (grow in groups). Pure bamboo forests are found singly or in compact or open clumps, but usually bamboo forms the understory of the evergreen, semi-evergreen, moist deciduous and dry deciduous forests of tropical areas. In most cases this understory consists of a single bamboo species and only rarely are more than one species found together [1].
- Most of the bamboos culms are hollow with walls which vary much in thickness according to species. In some cases, as in *Dendrocalarmus strictus* in dry Idealities, the cavities are small or even absent, thus, resulting in solid culms. The culms are divided at certain interval (nodes) by solid transverse septa.
- Bamboo has three parts – (1) leafy aerial part (culm), (2) rhizome and (3) roots. The rhizome (a part of the stem) and the roots are underground parts. Adventitious roots develop from the nodes of the rhizome and occasionally from the nodes of the culm. It is the bud in rhizome which develops into culms. Since the culm has no terminal bud, therefore, there is no terminal growth, however, the culms grow in height due to elongation of the internodes. Daily increase in length of each internode is on an average 2.5cm. Generally 5-6 internode grow at a time. Each internode is covered with a sheath.
- The flowering of a bamboo is a unique phenomenon known as ‘gregarious flowering’ in which all populations of a particular species of bamboo flower all at once and is of very rare occurrence throughout the plant kingdom. It place in three stages- preliminary sporadic flowering, gregarious flowering and final sporadic flowering, with varying intervals between these stages. It may occur over small areas or over hundreds of square miles. It has been observed to begin in one locality and to spread in a definite

direction, requiring several years to extend over the entire flowering area. Flowering occurs usually in December and January [5] [1]. Most of the bamboos flower once every 60 to 130 years depending on the species. So far there is on explanation of the long flowering intervals [1]. However, not all bamboos exhibit the same flowering characteristics or patterns. Depending on the species, a bamboo can exhibit either gregarious flowering, or sporadic flowering. For most species of bamboo, this can happen at intervals anywhere between 60 to 130 years. This flowering cycle is genetically pre-programmed into each species. The bamboo flowers and produces seeds when it reaches the stage of full maturity and after flowering the older one generally die. During the gregarious flowering, the bamboo expends tremendous amount of energy in producing flowers and seeds. The mass flowering stresses the bamboo to such an extent that it dies. Since the bamboo seeds are a source of food to rat, therefore, gregarious flowering of bamboos is often followed by increase in rat population. Sporadic flowering is when bamboo flowers sporadically or intermittently. Unlike gregarious flowering, sporadic flowering does not happen on a mass scale and the bamboo seldom dies after flowering. It typically occurs on an individual or a group of plants from a localized area [1].

- Among species which show a marked tendency towards gregarious flowering at long intervals of time are *Bambusa arundinacea*, *B. polymorpha*, *Melocanna bambusoides* and *Teinostachyum helferi*. Those which often flower sporadically and may also flower gregariously are *Dendrocalamus strictus*, *D. Hamiltonii*, *D. longispathus*, and *Arundinaria falcata* [1].
- The majority of bamboos thrive in a wide range of climate (8°C to 36°C). Some species, however, grow at high altitudes, as in the case of some *Arundinaria* and *Thamnocalamus spp.* species up to 10,000 feet (3,050 meters) in Himalaya, India
- The inflorescence, which is made up of spikelets with varying number in different species.
- The fruit is a caryopsis.

14.5.3 Phenology

- The new culms are produced from the rhizomes mainly in rainy season.

- Most of the bamboo species flower once every 60 to 130 years depending on the species, however, sporadic flowering is also found.
- Fruits ripen from February to April, or in some localities to as late as June. Seeds germinate quickly, but can be preserved for three months to two years [5].
- Germination, in majority of the bamboo species is epigeal [6]

14.5.4 Regeneration Methods [1]

A) Natural Regeneration

- Natural regeneration in bamboos takes place from seeds fallen on the ground following sporadic or gregarious flowering. The rhizome buds also throw up culms as annual shoots. The process continues till the clumps produce gregarious flowering and die.
- Under natural conditions the seed germinates at the commencement of the rainy season and the ground in the neighborhood of the seedling clumps become carpeted with the young seedlings. These spring up and survive in greatest abundance on bare ground, and particularly newly exposed soil. Although bamboo seedlings have great power of recovery after being burnt, protection from fire encourages their growth to a remarkable degree.

B) Artificial Regeneration: Artificial regeneration can be carried out by seed, by stem or rhizome cuttings or by layering. The commonest method of propagation is by cutting is termed as planting offsets. Culm of one year old are cut through with a slanting cut about 3 to 4 ft from the ground and the rhizomes to which they are attached are dug up with the root intact and cut off to a length sufficient to include a well-developed bud. These offsets are planted out sufficiently deep to cover the first two or three nodes, which are usually found close to the base of culms. The transplanting of the offsets should be carried out immediately before the beginning of rainy season.

C) Injury / Damages: Grazing is the greatest enemy of natural reproduction. However, bamboo seedlings has great power of recovery from damage.

D) Silvicultural System [1]**:** Bamboo forests are generally worked on culm selection system cum- thinning on a cutting cycle of 3-4 years. General rules are as follows:

- Immature culms less than one year old are not to be cut

- In a clump containing 12 culms or more, at least 6 mature culms over one year old should be retained;
- Culms should not be cut below the second node, but in any case not higher than 30 cm from the ground level;
- No felling should be done during the growing season;
- Soil should be heaped around the developing clump to allow and ease shoot production, which takes place mainly in the periphery of the clump;
- No cutting should be done in the year of flowering; flowered clumps should be clear-felled after they have shed their seeds.

14.5.5 Economic importance

- Bamboo is known as poor man's timber. It produces the maximum biomass per unit area and time among the forest plants. It is a popular farm forestry species as it is capable of generating quick income. About 130 bamboo species occur in India of which more than 50% are found in Eastern India.
- Bamboo is used as food, fodder, fuel, fencing, paper pulp, housing, cottage industries etc.

Summary

- Arjuna (*Terminalia arjuna*) is native to India and Sri Lanka and is found up to 1200 m. It is a large-sized evergreen or deciduous tree. Natural regeneration occurs by seeds whereas artificial regeneration is generally carried out by transplantation of seedlings raised in the nursery, however, direct seed sowing method can also be used. Weeding and protection from fire and frost is needed for the first two years. Thinning is required to remove the weaker shoots when forking takes place due to frost damage. Young seedlings are sensitive to frost and drought. Incidence of powdery mildew caused by *Phyllactinia terminalae* and white fibrous rot due to *Polystictus affinis* have been reported. Larvae of Apoderus tranquebaricus feed inside rolled leaves, whilst larvae of Gelasma goniaria and Lymantria mathura cause defoliation of the plant. Also the presence of Ceroplastes ceriferus (white wax insects) on the leaves has been reported. Seed are damage by *Psittacula krameri* birds has been reported in India. Seedlings are susceptible to fire, drought and frost. Frost damage can cause forking of

the stem and the development of a bushy habit. Heavy shade is also injurious to seedlings resulting in die-back for several years, again leading to a bushy tree. It is managed under selection system. Economically the species is put to a diversity of use such as fuel, medicinal, timber, fodder, Tannin or dyestuff and other uses.

- Chandan **(***Santalum album*) also known as sandalwood tree is indigenous to the Indian Peninsula. It is a small evergreen glabrous tree with slender drooping branchlets. Root parasitism is one of the important feature of sandalwood. For successful regeneration, presence of suitable host plant is a pre-requisite. Some of the good hosts are *Acacia sp., Albizzia lebbek, Bambusa arundinacea, Dalbergia sissoo, Eucalyptus globulus* etc. Economically the plant is very useful. It is used for carving and other fancy work, and largely distilled for its fragrant oil, which is used in perfumery and medicine. Sandalwood oil was used traditionally to treat skin disease, acne, dysentery, gonorrhea & number of other ailments. Sandalwood Oil is a natural fixative for all the top class perfumes.
- Neem *(Azadirachta indica)* a native to Burma and distributed in subtropical and tropical regions of our country. Neem is a light demander, frost tender especially in seedling or sapling stages. It has a great coppicing power and also produces root suckers particularly in dry localities. Sheep and goat do not like it, however, camel can cause damage through browsing. The other enemies are porcupine which can damage it by gnawing off the bark round the stem at its base. Neem can be regenerated through natural as well as artificial methods. It has diversity uses such as, timber, fuel, medicinal uses of leaves and seeds oil.
- Bamboos are one of the important group of species which belong to grass family Poaceae. Some of the important species found in India are *Bambusa arundinacea, Arundinaria falcata*. Bamboos are an important component of wet evergreen, moist deciduous and dry deciduous forests in the tropical parts of southeastern Asia. The flowering of a bamboo is a unique phenomenon and very rare occurrence in the plant kingdom and happens once every 60 to 130 years depending on the species. It is called as 'Gregarious flowering'. It takes place usually in three stages: (1) preliminary sporadic flowering, (2) gregarious flowering, and (3) final sporadic flowering of the remaining clumps. Regeneration can be done through both natural as well as artificial means. Grazing is the greatest enemy of natural reproduction. However, bamboo

seedlings has great power of recovery from damage. Bamboo is known as poor man's timber on account of its uses. Bamboo is used as food, fodder, fuel, fencing, paper pulp, housing, cottage industries etc.

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