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

FR(N) - 202

Principles of Silviculture

FR(N) - 202

Principles of Silviculture

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

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

FRN 202

Principles of Silviculture

UTTARAKHAND OPEN UNIVERSITY

SCHOOL OF EARTH AND ENVIRONMENTAL SCIENCE

University Road, Teenpani Bypass, Behind Transport Nagar, Haldwani - 263 139

Phone No. : (05946) - 286002, 286022, 286001, 286000

Toll Free No. : 1800 180 4025, Fax No. : (05946) - 264232,

e-mail: info@uou.ac.in, Website: http://www.uou.ac.in

Board of Studies

Programme Coordinator

Dr. H.C. Joshi
Associate Professor
Department of Forestry and Environmental Science,
SoEES, Haldwani, Nainital (U.K.)

Editors

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

Dr. Neha Tewari, Dr. Preeti Pant, Dr. Deepti Negi, Dr. Khashti Dasila

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

Units Written by	Unit No.
Adapted from UOU-SLM: FR 01-Principles and Practices of Silviculture (Unit Writer: **Dr. H.C. Joshi,** Associate Professor, Department of Forestry and Environmental Science, SoEES, Uttarakhand Open University, Haldwani	1-9
Dr. Beena Tewari Fulara, Assistant Professor (AC), Department of Forestry and Environmental Science, SoEES, Uttarakhand Open University, Haldwani	10-13

Cover Page Design and Format Editing

Krishna Kumar Tamta and Beena Tewari Fulara
Department of Forestry and Environmental Science, SoEES, Uttarakhand Open University, Haldwani

Title	**:**	Principles of Silviculture FR(N)- 202
ISBN	**:**	XXXX-XXXX
Copyright	**:**	Uttarakhand Open University
Edition	**:**	2025 **(Restricted Distribution)**
Published By	**:**	Uttarakhand Open University, Haldwani, Nainital – 263139
Printed at	**:**	

Table of Content

Unit 1: Introduction to Silvicultural Systems

Unit Structure

1.0 Learning Objectives

After completion of this unit, you will be able to:

- understand the conceptand importance of silviculture;
- understand the definition and concepts of silvicultural systems;
- specific characters and requirement of important sylvicultural systems;
- understand the importance of different silvicultural systems

1.1 Introduction

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.

1.2 Definition of Silviculture

Silviculture may be defined as the art and science of producing and tending a forest. According to Spurr, 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.

1.2.1 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.

1.2.2 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".

1.2.3 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 help 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.

1.3 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. What is silviculture? Define it and explain the concept.
2. How silviculture is related to all branches of forestry? Discuss.
3. Discuss the aims and objectives of silviculture.
4. Discuss the scope of silviculture.
5. Give a brief classification of silvicultural systems in India.

Answers

1. See section 1.2
2. See section 1.2.1
3. See section 1.2.2
4. See section 1.2.3

5. See section 1.3

1.3 Clear felling System

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”.

1.4 The Shelterwood or Uniform System

In this system, the new forest crop is established under the shelter of the old cropand 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’.

1.4.1 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 number 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.

1.4.2 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.

Check your progress

1. What is clear felling system.
2. Briefly explain the concept of shelter-wood system.

Answers

1. See section 1.3
2. See section 1.4

Summary

This unit describes the importanceof different silvicultural systems.Silviculture may be defined as the art and science of producing and tending a forest. According to Spurr, Silviculture may be defined as, “the theory and practice of controlling establishment, composition and growth of the forest”.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.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.

References

1. Toumey, J. W. and Korstain, C.F. Foundations of Silviculture: Upon an Ecological Basis. Second Edition, Revised. NewYork, London: John Wiley & Sons, Inc. Chapman & Hall. Ltd, 1947.

2. 2. Hawley, R.C. Practice of Silviculture. London: John Willey & Sons, Inc. Chapman & Hall, Ltd., 1946.

3. 3. Khanna, L S. Principles and Practice of Silviculture. Dehra Dun : Milton Book Company, 1999.

4. 4. Pinchot, G. A Primer of Forestry: Part II Practical Forestry. s.l. : Washington: Govt. Printing Office, 1909.Preparing and Storing Herbarium Specimens; (2009), Conserve O Gram:1-4.

Unit 2: High Forest systems

Unit Structure

2.0Introduction: Clear felling System

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.**

2.1 Concept and definition

Clear felling system is defined as, **"a method of harvesting forest crop in which all the forest crop is clearly removed from an area resulting into bare areawhich is re-stocked with the same tree species or other as per the objects of owner"**.

2.2 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 outas 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 specieswhich 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 transplantsheavy 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 labourfor 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

2.3Choice of species

Choice of species under clear felling system should be done considering the following points:

- Species should be suitablefor 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.

2.4Characteristics 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 qualityforests / 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 newstand originating on a clear-felled area will be even-aged, irrespective ofwhether the timber before the cutting was irregular or uneven-aged.

2.5 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 seedbeds 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 byrodents 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.

2.6Effect upon Locality Factors

Effect of locality factors differs much during the several periods of thelife of the wood. During early youth, before a complete leafcanopy has been established, the soil is exposed to the effectsof Sun and air currents, both of which act highly injuriouslyon 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 keptout, but there is no impediment to air currents strikingthrough the wood, so that moisture is carried away. In case of shadebearing hardy species with dense crowns,the system yields evidently much better results than in case of light demanding species with thin crowns. The lengthof 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.

Summary

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.

References

1. **Toumey, J. W. and Korstain, C.F.***Foundations of Silviculture: Upon an Ecological Basis.* Second Edition, Revised. NewYork, London : John Wiley & Sons, Inc. Chapman & Hall. Ltd, 1947.

2. **Hawley, R.C.***Practice of Silviculture.* London : John Willey & Sons, Inc. Chapman & Hall, Ltd., 1946.

3. **Khanna, L S.***Principles and Practice of Silviculture.* Dehra Dun : Milton Book Company , 1999.

4. **Pinchot, G.***A Primer of Forestry: Part II Practical Forestry.* s.l. : Washington: Govt. Printing Office, 1909.

Unit 3: High Forest System II

Unit Structure

3.0 Introduction: The Shelterwood or Uniform System

3.1 Concept and definition

In this system, the new forest crop is established under the shelter of the old cropand 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**'.

3.2 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.

3.3 Protection of germination

Generally the protection to young crop is afforded by shelter-woodor 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.

3.4 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 followingthree types:

i) **Preparatory cuttings**

ii) **Seed cuttings**

iii) **Removal cuttings**

3.4.1Preparatory 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.

3.4.2 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.

3.4.3 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 finalcutting. The severity of the removal cuttings and the intervals atwhich one follows the other are governed by the degree to which theyoung 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 ofpoor growth condition. Certain points such as unhealthy foliage color, reduction in height growth or bending of seedlings towards thelight, indicate that it is time to release the shelter. However, theseindicators may not be found uniformly over whole areas at one time but a patch hereor 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 groupmay be cut clear in one place and a few trees thinned out in otherplaces; elsewhere there may be no cutting. After few years, asimilar 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 5years and to cover a period of 2 to 20 years.

3.5 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 rotationis long) over a period of 40 to 60 years, which tends to createa wider range in the ages of the individual trees than the other twomethods. Usually the regeneration period cannot be less than 10or more than 20 years. Even with a long regeneration period thestand still remains essentially evenaged.

3.6Advantages 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), theshelter 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 windthrow 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.

3.7Modifications in shelterwood 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.

3.7.1 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 cuttingswere concentrated in certain strips only in a given time whereas other portions of the stand remainuntouched 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.

3.7.2 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

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

References

1. **Toumey, J. W. and Korstain, C.F.***Foundations of Silviculture: Upon an Ecological Basis.* Second Edition, Revised. NewYork, London : John Wiley & Sons, Inc. Chapman & Hall. Ltd, 1947.

2. **Hawley, R.C.***Practice of Silviculture.* London : John Willey & Sons, Inc. Chapman & Hall, Ltd., 1946.

3. **Khanna, L S.***Principles and Practice of Silviculture.* Dehra Dun : Milton Book Company , 1999.

4. **Pinchot, G.***A Primer of Forestry: Part II Practical Forestry.* s.l. : Washington: Govt. Printing Office, 1909.

Unit 4: High Forest Systems

Unit Structure

4.0 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.

4.1 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

4.2 Selection System

4.2.1 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.

4.2.2 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. Unfortunatelysuch 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.

4.2.3Advantages 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 arecreated 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 wildlifewhich 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.

4.2.4 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 dangeras 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.
1. 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 systemsin which only oldest and/ orthe 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.

References

1. **Hawley, R.C.***Practice of Silviculture.* London : John Willey & Sons, Inc. Chapman & Hall, Ltd., 1946.

2. **Khanna, L S.***Principles and Practice of Silviculture.* Dehra Dun : Milton Book Company , 1999.

3. **Toumey, J. W. and Korstain, C.F.***Foundations of Silviculture: Upon an Ecological Basis.* Second Edition, Revised. NewYork, London : John Wiley & Sons, Inc. Chapman & Hall. Ltd, 1947.

Unit5: Coppice System

Unit Structure

5.0 Introduction

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.

5.1 Learning Objectives

After going through this unit you shall be able to:

- Explain the coppice system
- Elaborate various modifications of coppice system
- Differentiate coppice system
- Elaborate the concept of coppice system and explain various modifications of coppice system

5.3 The Coppice system

5.3.1 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.

5.3.2 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 characteristicsof the stumps

Sprouting ability of trees decreases with age and size. Possible reason is that with maturity tree loses its ability to producepotential 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 byfrost. 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.

5.3.3 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 thesites which are subjected to frostoccurrence 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. Aestheticallythe 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.

5.4The Coppice with Standards System (Stored Coppice)

5.4.1 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 woodi.e. when the underwoodhas arrived at the end of its rotation, it is cut over, and at thesame time those standards are removed which have reachedthe 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 coppicesystem**.

5.4.2 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 sproutstermed 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**.

5.4.3Advantages and disadvantagesof 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 sawtimber

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.

5.5 Choice of silvicultural system

It has been shown in the preceding discussions that different silviculturalsystems have their pros and cons and have variable effects in terms of production ofmajor products, resistance against external dangers andtheir 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 ofthe 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

5.5.1 Suitability or the System to the Selected Species

This is the most important considerationin all caseswhere 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, insuch casesonly high forest systems should be followed. On the other hand, light demanding species with thin crowns arenot suited under ordinary simple high forest system. They shouldbe raised as standards in coppice with standards, or in twostoriedhigh forest systems, or with a coppice underwood, or in mixturewith shade bearing species. Such species are also difficult toraise under shelter-woods. On the other hand, tender shadebearers like Birch and Silver Fir are better adapted to theshelter-wood systems than to the clear felling system.It is also important to note that in a system with two or more crops of differentages on the same area, the over-wood must consist of thin crown and light demanding nature.

5.5.2 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 unfavourableclimate, the first consideration must be the preservationof the factors of the locality otherwise it will lead to steady deterioration of the site. In such cases,clear felling must be avoided and everyeffort should be made to keep the area always stocked with forest stands, in other words, shelter-wood system is appropriate for such conditions.

5.5.3 Protection against external harmful factors or agencies

The object of a good management is to producehealthy 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 cuttingsystem is worst system instead shelter-wood system is preferred.

5.5.4 Quantity and Quality of Produce

Forest stands yield timber, firewood and a variety of minorproducts. Where only the firewood is intended, a system that yields the largestvolume of produce within a short time span, is preferred. Where the objects of management is theproduction of timber, it takes longperiods of timeand 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-agedsystems are desirable under a high rotation for the light demanding species.The former produces principally long and clean timber whereas thelatter timber of more girth.

5.5.6 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 highforest systems than coppice, therefore greater care is needed in high forest system. The shelter-wood systems require more skilled labour thanthe 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

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.

References

1. **Hawley, R.C.***Practice of Silviculture.* London : John Willey & Sons, Inc. Chapman & Hall, Ltd., 1946.

2. **Khanna, L S.***Principles and Practice of Silviculture.* Dehra Dun : Milton Book Company , 1999.

3. **Toumey, J. W. and Korstain, C.F.***Foundations of Silviculture: Upon an Ecological Basis.* Second Edition, Revised. NewYork, London : John Wiley & Sons, Inc. Chapman & Hall. Ltd, 1947.

Unit 6: Silviculture of Important Indian Conifers- I

Unit Structure

6.0 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.

6.1 Learning Objectives

The main objectives of this unit are to study the silvicultural characteristics of:

- Silver Fir (*Abies pindrow*)
- Cedar (*Cedrus deodara*)

6.2 Silviculture of *Abies pindrow*

Botanical Name: *Abies pindrow* Royle
Vernacular Names: Raga, Ragu
English Name: Silver Fir
Family: Pinaceae

6.2.1 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].

6.2.2 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.

6.2.3 Phenology

- 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.

6.2.4 Silvicultural Characteristics

- 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.

6.2.5 Regeneration

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.

6.2.6 Silvicultural Systems

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.

6.2.7 Economic Importance

- Suitable for house building in higher altitudes
- Wood white, used for building, planking, boxes
- It is suitable for match manufacture and wood-pulp.

6.3 Silviculture of *Cedrus deodara*

Botanical Name: *Cedrus deodara* Loudon
Vernacular Names: Deodar, Diar
English Name: Himalayan Cedar
Family: Pinaceae

6.3.1 Origin and Distribution

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.

6.3.2 General Description

- 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.

6.3.3 Phenology

- 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.

6.3.4 Silvicultural Characteristics

- 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.

6.3.5 Regeneration

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.

6.3.6 Silvicultural System

Deodar forests or plantations are generally worked upon under selection systems or group selectin systems [2]

6.3.7 Economic Importance

- 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.

References

[1] A. Osmaston, *Forest Flora of Kumaun,* Allhabad: Govt. Printing Press, 1927.

[2] R. Troup, *Silviculture of Indian Trees,* Oxford at the Clarendon Press, 1921.

[3] S. K. S. N. P. G. D. R. B. A. B. G. S. T. U.K. Thapa, *Influence of climate on radial growth of Abies pindrow in Western Nepal Himalaya,* vol. 23.

[4] J. D. A. Stainton, *Forests of Nepal. The Camelot Press Ltd and Southampton, London, UK.,* 1972.

[5] G. o. H.P., *H.P. Forest Manual (Vol. IV) on Technical Matters approved vide H.P. Govt. Letter No. FFE-B-C (1)-7/2013,* 2014..

[6] R. Troup, *Indian Forest Utilization,* Calcutta: Calcuta Goverment Printing Presss, 1907.

Unit 7: Silviculture of Important Indian Conifers II

Unit Structure

7.0 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.

7.1 Learning Objectives

The main objectives of this unit are to acquaint the learners with silvicultural properties of:

- Chirpine
- Chilgoza pine

7.2 Silvicultural of *Pinus roxburghii*

Botanical Name: *Pinus roxburghii* Royle syn. *P. longifolia* Roxb.

Vernacular Names: Chir
English Name: Chirpine
Family: Pinaceae

7.2.1 Origin and Distribution

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.

7.2.2 General Description

- *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

7.2.3 Phenology

- 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.

7.2.4 Silvicultural characteristics

- 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.

7.2.4 Regeneration

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

- 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].

7.2.5 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.

7.2.6 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.

7.3 Silvicultural of *Pinus gerardiana*

Botanical Name: *Pinus gerardiana* Wall.
Vernacular Names: Chilgoza pine
English Name: Himalayan edible pine
Family: Pinaceae

7.3.1 Origin and Distribution

- 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]

7.3.2 General Description

- 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.

7.3.3 Phenology

- 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.

7.3.4 Silvicultural characteristics

- 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.

7.3.4 Regeneration

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:** 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.

7.3.5 Silvicultural System

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].

7.3.6 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.

References

[1] R. Troup, *Silviculture of Indian Trees,* Oxford at the Clarendon Press, 1921.

[2] L. S. R. G. Aditi Sharma, *A Review on Himalayan Pine Species: Ethnopharmacological, Phytochemical and Pharmacological Aspects. Pharmacog J. 10(4):611-9.,* 2018.

[3] H. HFRI, *Pinus gerardiana Wall. (Chilgoza Pine): An Important Conifer of Western Himalaya. Himachal Pradesh Council for Science Technology & Environment [HIMCOSTE], Himalayan Forest Research Institute (HFRI). (Indian Council of Forestry Research & Education), Gov,* https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=13&cad=rja&uact=8&ved=2ahUKEwj9ir3WtaTpAhX6xIsBHYTNBBM4ChAWMAJ6BAgBEAE&url=http%3A%2F%2Fhimcoste.hp.gov.in%2FRnD_Website%2FResearch%2520and%2520development%2520Projects%2FChilgoza%2520Booklet.p, 2018.

[4] P. D. Dogra, *Gymnosperms of India–II. Chilgoza pine (Pinus gerardiana Wall.). Bulletin of the National Botanic Gardon No. 109.,* 1964.

[5] W. B. C. &. J. Little, *Geographic distribution of the pinus of the world, USDA Forest Service,* 1966.

[6] A. Farjon, *Pines: drawings and descriptions of the genus Pinus. Antiquarian Booksellers Association of America Pub, New York, 220.,* 1984.

[7] O. C. R. A. a. C. S. G.S. Shamet Kumar, *Ecology of chilgoza pine (Pinus gerardiana WALL) in dry temperate forests of North West Himalaya. Eco. Env. & Cons. 19 (4) : 2013; pp. (1063-1066),* 2013.

[8] D. K. K. L. R. V. Singh, *Chilgoza pine (Pinus gerardiana) regeneration in Himachal Pradesh. The Indian forester 126-133,* 1973.

[9] J. Tandon, *Revised working plan for the Kinnaur and Kochi forests (upper Sultej valley), Himachal Pradesh. 1961-62 to 1975-76.,* 1963.

[10] V. C. R.N. Sehgal, *Pinus gerardiana the threatened pine of India; life support species, biological diversity and genetic resources news, Commonwealth Science Council.,* 1989.

[11] C. E. C. Beeson, *The ecology and control of forest insects of India and the neighbouring countries, Vasant Press, Dehra Dun, India, 1007,* 1941.

[12] R. Luna, *Plantations forestry in India. International book distributors, Dehradun. 920-922*, 2008.

[13] S. L. G. R. Sharma A, *A Review on Himalayan Pine Species: Ethnopharmacological, Phytochemical and Pharmacological Aspects. Pharmacog J. 10(4):611-9.,* 2018.

Unit 8: Silviculture of some important Indian Broadleaved Trees-I

Unit Structure

8.0 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.

8.1 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.*)

8.2 Silviculture of *Tectona grandis*

Botanical Name: *Tectona grandis* Linn. F.

Vernacular Names: Sagun, Tegu, Tegina, Teku, Thekku

English Name: Sagwan

Family: Verbanaceae

8.2.1 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].

8.2.2 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.*

8.2.3 Phenology

- 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.

8.2.4 Silvicultural Characteristics

- 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 separation 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].

8.2.5 Regeneration methods

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].

8.2.6 Economic importance

- 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.

8.3 Silviculture of *Shorea robusta*

Botanical Name: *Shorea robusta* Gaertn. f.

Vernacular Names: Sal

English Name: Sal

Family: Dipterocarpaceae

8.3.1 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.

8.3.2 General Description

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.

8.3.3 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.

8.3.4 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.

8.3.5 Regeneration in *sal*

- 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.

8.3.6 Economic importance

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,

8.4 Silviculture of *Dalbergia sissoo*

Botanical Name: *Dalbergia sissoo* Roxb.

Vernacular Names: Shishu, Sissu

English Name: Indian Rosewood

Family: Leguminosae

8.4.1 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].

8.4.2 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.

8.4.3 Phenology

- 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%.

8.4.4 Silvicultural Characters

- 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.

8.4.5 Regeneration Methods

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.

8.4.6 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.

8.5 Silviculture of *Alnus nepalensis*

Botanical Name: *Alnus nepalensis* D. Don

Vernacular Names: Uttis, Nepalese alder

English Name: Alder

Family: Betulaceae

8.5.1 Origin and Distribution

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.

8.5.2 General Description

- 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.

8.5.3 Phenology

- The flowering from September to November
- Fruiting in October-November
- Seeds ripen in December-January

8.5.4 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

8.5.5 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.

8.5.6 Economic importance

- 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.

8.6 Silviculture of Eucalyptus

Botanical Name: *Eucalyptus spp.*

Vernacular Names: Lyptis

English Name: Eucalyptus

Family: Myrtaceae

8.6.1 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].

8.6.2 General Description

- *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.

8.6.3 Phenology

- *E. tereticornis* (Syn *E. hybrid*) produce seeds twice a year, once in autumn (October-November) and next in summer (May-June).

8.6.4 Silvicultural Characters

- 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%.

8.6.5 Regeneration Methods

- 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.

8.6.6 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.

References

[1] H. M. Y. J.-S. K. Palanisamy, *Teak (Tectona grandis Linn. f.): A Renowned Commercial Timber Species,* 2009.

[2] R. Troup, *Silviculture of Indian Trees,* Oxford at the Clarendon Press, 1921.

[3] D. H. Kulkarni, *Distribution of teak (Tectona grandis) on the northern slopes of the Satpuras with reference to geology.,* 1951, pp. 112-117.

[4] D. N. Tewari, *A Monograph on Teak (Tectona grandis L. f.),* Dehradun: International Book Distributor, 1992.

[5] K. Gautam, *Regeneration Status of Sal (Shorea robusta) Forests in Nepal.,* Department of Forest Nepal, Kathmandu, 11 pp., 1990.

[6] D. N. Tewari, *A Monograph on Sal (Shorea robusta Gaertn. f.),* Dehradun, India: International Book Distributors, 1995.

Unit 9: Silviculture of some broad leaved trees II

Unit Structure

9.0 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.

9.1 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.*)

9.2 Silviculture of *Terminalia spp*

Botanical Name: *Terminalia spp.*

Vernacular Names: Arjun, arjhan

Ayurvedic Names: Arjuna, Dhananjaya, Kaakubha, Kakubha

English Name: Arjuna

Family: Combretaceae

9.2.1 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].

9.2.2 General Description

- *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.

9.2.3 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].

9.2.4 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.

9.2.5 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

- 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.

9.2.6 Economic importance

- 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.

9.3 Silviculture of Santalum album

Botanical Name: *Santalum album* Linn.

Vernacular Names: Chandan

Hindi Names: Gandada, gandha

English Name: Sandalwood

Family: Santalaceae

9.3.1 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.

9.3.2 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]

9.3.3 Phenology

- *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

9.3.4 Silvicultural Characters

- 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.

9.3.4 Regeneration Methods

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.

9.3.5 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.

9.4 Silviculture of *Azadirachta indica* A.Juss

Botanical Name: *Azadirachta indica* A. Juss.

Vernacular Names: Neem tree

English Name: Margosa tree

Ayurvedic Name: Nimba, Nimbaka, Arishta, Arishtaphala, Pichumarda

Family: Meliaceae

9.4.1 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.

9.4.2 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.

9.4.3 Phenology

- 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.

9.4.4 Silvicultural Characters

- 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

9.4.5 Regeneration Methods

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

- 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.

9.4.6 Economic importance

- 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.

9.5 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)

9.5.1 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].

9.5.2 General Description

- 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.

9.5.3 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]

9.5.4 Regeneration Methods

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: 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.

9.5.5 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.

References

[1] R. Troup, *Silviculture of Indian Trees,* Oxford at the Clarendon Press, 1921.
[2] W. G. Directorate of Forests, *Silviculture of trees and Silviculture Systems,* 2016.
[3] Orwa et al., *Terminalia arjuna,* Agroforestry Database 4.0, 2009.
[4] J. T. S. M. G. J. J. J. P. P. Joy, *Aromatic Plants,* 2016.
[5] M. Huberman, *Bamboo Silviculture,* vol. 13, 1959, pp. 1-11.
[6] G. J. F. B. Manisha Thapliyal, *Bamboo: Flowering, Seed Germination and Storage,* xxxx.

Unit 10. Categorization of Important species

Unit Structure

10.0. Learning Objectives

After studying this unit you are able to understand about:

- Ecological and functional classification of species
- Conservation based classification
- Conservation status of species
- Criteria for the identification of species

10.1. Introduction

Trees, the main building blocks of forests, are long-living, woody plants that have a major impact on the physical surroundings, variety of life, and ecosystem functions. Knowing how to classify and correctly identify them is essential for understanding forest ecology, managing forest resources, and creating successful conservation plans. This unit specifically looks at how to categorize important tree species in forest ecosystems. We will

examine different classification methods based on their ecological roles, economic importance, growth traits, and silvicultural characteristics. Additionally, we will discuss the main physical and ecological features that help with accurate identification in the field, offering a helpful guide for spotting the key and ecologically important tree species that shape our forests.

10.2. Ecological Roles and Functional Classification

10.2.1. Keystone Species

Keystone species are species that affect their ecosystems that are not commensurate with their abundance. This concept, introduced by Paine in 1969, highlighted species that played an important role in maintaining the structure of an ecological community. In Uttarakhand, some species are considered the main species because of their important role in maintaining the structure, function and biodiversity of the ecosystem. These species often have a disproportionate effect on their environment regarding their abundance. Some examples of Keystone trees in Uttarakhand are:

Tree Species	Local Name	Keystone Role	Key Species Supported
Quercus leucotrichophora	Banj Oak	Moisture retention, forest structure	Mammals, birds, insects
Ficus religiosa	Peepal	Year-round fruiting	Bats, monkeys, birds
Ficus benghalensis	Bargad	Microhabitats, fig provider	Epiphytes, reptiles, birds
Pinus roxburghii	Chir Pine	Soil stabilizer on degraded land	Resin-feeding fauna, birds
Rhododendron arboreum	Buransh	Pollinator support in high altitudes	Bees, sunbirds, butterflies
Betula utilis	Bhojpatra	Alpine slope stability	Alpine insects, mosses, lichens
Juglans regia	Akhrot (Walnut)	Nutrient cycling, food for wildlife	Rodents, birds, insects
Alnus nepalensis	Alder	Nitrogen-fixation, succession in degraded areas	Soil microbes, pioneering species

- Keystone species plays a key role in the ecosystem structure of the region.
- These species supports both terrestrial and arboreal life.
- It help in soil stabilization, particularly on steep slopes, preventing erosion and lan dslides, which is crucial in the mountainous terrain of Uttarakhand.
- The tree plays an important role in nutrient cycling by shedding its leaves, which e nrich the soil. Oak forests help maintain water cycles and carbon sequestration.
- Keystone species contributes significantly to soil health and supports the growth of diverse understory vegetation.

Keystone tree species in Uttarakhand, such as Deodar (*Cedrus deodara*), Banj Oak (*Quer cus leucotrichophora)*, Chir Pine (*Pinus roxburghii*), Peepal (*Ficus religiosa*), and Tamarind (*Tamarindus indica*), play critical roles in shaping the ecosystem. They maintain biodiversi ty, provide habitats, regulate soil and water cycles, and contribute significantly to the local economy and culture.

10.2.2. Foundation Species

Foundation species like *Banj Oak (Quercus leucotrichophora)*, *Deodar Cedar (Cedrus deodara)*, *Chir Pine (Pinus roxburghii)*, *Peepal (Ficus religiosa)*, and *Mango (Mangifera indica)* are crucial for the **stability** and **functionality** of Uttarakhand's ecosystems. They provide **food**, **habitat**, and **nutrients** that support the survival of various species, and help maintain **soil fertility**, **water retention**, and **biodiversity**.

Tree Species	Local Name	Forest Type	Foundation Role
Quercus leucotrichophora	Banj Oak	Mid-altitude broadleaf forests	Controls water flow, erosion, supports biodiversity
Pinus roxburghii	Chir Pine	Subtropical pine forests	Dominates canopy, regenerates degraded areas
Rhododendron arboreum	Buransh	Subalpine broadleaf forests	Regulates microclimate, supports pollinators

Tree Species	Local Name	Forest Type	Foundation Role
Alnus nepalensis	Alder	Riparian and disturbed zones	Nitrogen fixer, pioneer species
Shorea robusta	Sal	Tropical moist deciduous forests	Canopy formation, habitat stability
Betula utilis	Bhojpatra	Alpine forests	Tree-line marker, erosion control
Ficus religiosa	Peepal	Mixed forests and agroforestry	Microhabitat and

10.2.3. Ecosystem Engineers

Ecosystem engineers are organisms that significantly alter their environment, creating, modifying, or maintaining habitats for other species. In the case of **tree species in Uttarakhand**, there are a few examples of species that actively shape the physical environment, creating or modifying habitats that support a variety of other organisms. Here are some examples of **ecosystem engineers** among tree species in Uttarakhand:

Tree Species	Local Name	Role as Ecosystem Engineer	Impact on Ecosystem
Pinus roxburghii	Chir Pine	Alters soil chemistry, influences fire regimes	Changes forest structure, aids regeneration
Alnus nepalensis	Himalayan Alder	Nitrogen-fixing, riverbank stabilizer	Facilitates succession, prevents soil erosion
Ficus benghalensis	Banyan Tree	Creates microhabitats, modifies water flow	Provides habitat, influences local hydrology
Quercus leucotrichophora	Banj Oak	Alters forest composition, improves water retention	Supports plant diversity and forest regeneration
Shorea robusta	Sal	Contributes to nutrient cycling, modifies microclimate	Alters soil fertility, promotes forest health
Betula utilis	Bhojpatra	Erosion control, stabilizes alpine slopes	Maintains alpine ecosystem integrity
Rhododendron	Buransh	Regulates microclimate,	Facilitates regeneration in

Tree Species	Local Name	Role as Ecosystem Engineer	Impact on Ecosystem
arboreum		supports pollinators	subalpine ecosystems
Ficus religiosa	Peepal Tree	Provides shelter, retains water, supports epiphytes	Maintains biodiversity and aids hydrology
Populus ciliata	Poplar	Stabilizes riverbanks, filters water	Prevents erosion, improves water quality
Acacia catechu	Khair	Nitrogen-fixing, provides habitat for wildlife	Improves soil fertility and creates refuge for species

Ecosystem engineers like *Chir Pine (Pinus roxburghii)*, *Peepal (Ficus religiosa)*, *Deodar Cedar (Cedrus deodara)*, *Banj Oak (Quercus leucotrichophora)*, and *Tamarind (Tamarindus indica)* play vital roles in shaping the environment of Uttarakhand's forests. Through their ability to modify **soil**, **water cycles**, and **habitats**, they significantly influence the ecological structure and support biodiversity.

10.2.4. Mutualists

In ecology, **mutualism** refers to a relationship between two species where both benefit from the interaction. In the case of **tree species in Uttarakhand**, several examples of **mutualistic relationships** exist, where trees and other organisms (like animals, fungi, or other plants) interact in ways that benefit both parties. Mutualists engage in interactions that benefit both parties involved. For example, pollinators like bees and butterflies facilitate the reproduction of many plant species, while receiving nectar as a food source. These interactions are vital for the maintenance of biodiversity and ecosystem function. Here are some examples of **mutualists** involving tree species of Uttarakhand:

Tree Species	Local Name	Mutualist Partners	Type of Mutualistic Interaction
Ficus religiosa	Peepal	Fig Wasps	Pollination and reproduction
Ficus benghalensis	Banyan Tree	Fig Wasps	Pollination and reproduction
Quercus	Banj Oak	Mycorrhizal Fungi	Enhanced nutrient and

Tree Species	Local Name	Mutualist Partners	Type of Mutualistic Interaction
leucotrichophora			water uptake
Pinus roxburghii	Chir Pine	Mycorrhizal Fungi	Nutrient absorption and water retention
Acacia catechu	Khair	Nitrogen-fixing Bacteria (Rhizobium)	Nitrogen fixation and soil fertility
Rhododendron arboreum	Buransh	Bees, Sunbirds	Pollination and nectar exchange
Juglans regia	Walnut	Mycorrhizal Fungi	Improved nutrient and water absorption
Salix spp.	Willows	Bees, Butterflies	Pollination and nectar exchange
Shorea robusta	Sal	Mycorrhizal Fungi	Nutrient cycling and moisture retention
Betula utilis	Bhojpatra	Lichens and Mosses	Surface space, moisture, and protection

Mutualistic relationships in Uttarakhand's tree species like *Peepal (Ficus religiosa)*, *Banj Oak (Quercus leucotrichophora)*, *Buransh (Rhododendron arboreum)*, *Tamarind (Tamarindus indica)*, and *Deodar (Cedrus deodara)* demonstrate how trees rely on interactions with **animals** (like birds, bees, and bats) and **fungi** to promote their reproduction, seed dispersal, and nutrient uptake. These interactions help maintain the **health**, **spread**, and **biodiversity** of forests in the region.

10.3. Conservation-Based Classification

10.3.1. Flagship Species

Flagship Species

Flagship species are charismatic organisms

In conservation biology, a **flagship species** is a species chosen to raise support for biodiversity conservation in a given place or social context. Such species were typically chosen because they were attractive and thus more readily engendered support from the public for their conservation.

The concept of a flagship species, typically charismatic vertebrates such as the American buffalo, *Bison bison, has often been used to raise* awareness for conservation in general. The giant panda, *Ailuropoda melanoleuca, is the World Wildlife Fund's emblem for* endangered species.

chosen to represent environmental causes. Their appeal helps garner public support and funding for conservation initiatives. The giant panda is a classic example, serving as a symbol for wildlife conservation efforts in China .

In ecology, **flagship species** are species that are selected to represent an environmental cause or conservation effort, often due to their **charismatic** or **symbolic** nature. These species are typically used to garner attention, raise awareness, and rally support for broader conservation initiatives. In the context of tree species of Uttarakhand, several trees play the role of **flagship species**, symbolizing the region's **biodiversity** and **conservation efforts**. Here are some examples of flagship tree species in Uttarakhand:

Tree Species	Local Name	Role as Flagship Species	Significance
Shorea robusta	Sal	Timber, habitat provider, nutrient cycling	Key species for forest ecosystems and biodiversity
Pinus roxburghii	Chir Pine	Timber, soil stabilizer, firewood	Promotes forest health and local livelihoods
Quercus leucotrichophora	Banj Oak	Habitat provider, soil health, biodiversity	Supports forest regeneration and biodiversity
Ficus religiosa	Peepal Tree	Sacred, habitat provider, air purifier	Cultural symbol, vital for pollinators and local flora
Rhododendron arboreum	Buransh	Ornamental, medicinal, ecosystem health	Promotes eco-tourism, climate adaptation
Betula utilis	Bhojpatra	Cultural, symbolic, habitat for alpine flora and fauna	Critical for alpine zone conservation
Toona ciliata	Toon	Timber, fast-growing, soil enrichment	Sustainable forestry and timber production
Prunus cerasoides	Wild Cherry	Ornamental, early successional species	Promotes forest regeneration and aesthetic value
Alnus nepalensis	Himalayan Alder	Nitrogen fixer, soil stabilizer, habitat for wildlife	Supports reforestation and ecosystem restoration
Tree Species	Local Name	Role as Flagship Species	Significance

Tree Species	Local Name	Role as Flagship Species	Significance
Shorea robusta	Sal	Timber, habitat provider, nutrient cycling	Key species for forest ecosystems and biodiversity
Pinus roxburghii	Chir Pine	Timber, soil stabilizer, firewood	Promotes forest health and local livelihoods
Quercus leucotrichophora	Banj Oak	Habitat provider, soil health, biodiversity	Supports forest regeneration and biodiversity
Ficus religiosa	Peepal Tree	Sacred, habitat provider, air purifier	Cultural symbol, vital for pollinators and local flora
Rhododendron arboreum	Buransh	Ornamental, medicinal, ecosystem health	Promotes eco-tourism, climate adaptation
Betula utilis	Bhojpatra	Cultural, symbolic, habitat for alpine flora and fauna	Critical for alpine zone conservation
Toona ciliata	Toon	Timber, fast-growing, soil enrichment	Sustainable forestry and timber production
Prunus cerasoides	Wild Cherry	Ornamental, early successional species	Promotes forest regeneration and aesthetic value
Alnus nepalensis	Himalayan Alder	Nitrogen fixer, soil stabilizer, habitat for wildlife	Supports reforestation and ecosystem restoration

Flagship tree species like *Deodar Cedar (Cedrus deodara)*, *Banj Oak (Quercus leucotrichophora)*, *Buransh (Rhododendron arboreum)*, *Tamarind (Tamarindus indica)*, and *Chir Pine (Pinus roxburghii)* play a critical role in representing the **natural beauty**, **cultural heritage**, and **conservation efforts** of Uttarakhand. These trees help raise awareness about **forest conservation**, **biodiversity**, and **sustainable land management**, making them symbols for both local and global environmental campaigns.

10.3.2. Umbrella Species

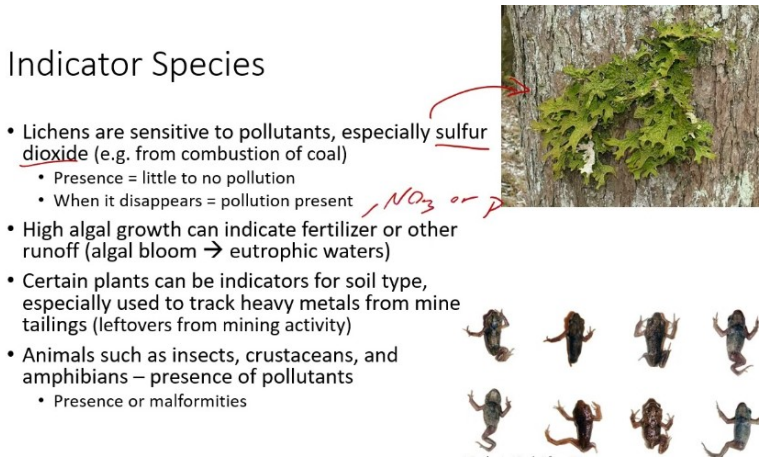
Umbrella species are selected for conservation efforts because protecting them indirectly protects many other species within their habitat. The northern spotted owl is an example;

conserving its habitat also benefits numerous other species that share the same environment .

Tree Species	Local Name	Umbrella Role	Conservation Impact
Shorea robusta	Sal	Habitat and food for mammals, birds, insects	Supports entire forest ecosystem and wildlife
Quercus leucotrichophora	Banj Oak	Habitat provider, improves soil health	Protects mid-altitude biodiversity
Pinus roxburghii	Chir Pine	Shelter and food for various species	Benefits wildlife, prevents soil erosion
Ficus religiosa	Peepal	Provides shelter and food for wildlife	Protects biodiversity, including pollinators
Alnus nepalensis	Himalayan Alder	Improves soil fertility, provides shelter	Protects riparian ecosystems and aquatic species
Rhododendron arboreum	Buransh	Provides food for pollinators, shelter for birds	Maintains health of alpine ecosystems
Betula utilis	Bhojpatra	Stabilizes ecosystem, shelters wildlife	Important for high-altitude ecosystem stability
Prunus cerasoides	Wild Cherry	Provides food for pollinators, shelter for birds	Maintains mid-altitude forest health
Acacia catechu	Khair	Stabilizes soils, supports poll	
Cedrus deodara	Himalayan cedar	Habitat provider, shelter and food	conservation initiatives to protect a wide range of species that share the same ecosystem
Dendrocalamus hamiltonii	Bamboo	soil stabilization and water conswervation	conservation of not only the plant itself but also the broader forest ecosystem
Dalbergia Sissoo	Sissoo		conserve a wide variety of species and the ecological health of riverbank ecosystems

10.3.3. Indicator Species

Indicator species are organisms whose presence, absence, or abundance reflects a specific environmental condition. Lichens, for example, are sensitive to air pollution levels and can serve as bioindicators of air quality.



In **Uttarakhand**, some **indicator tree species** serve as important bioindicators, providing crucial insights into the health of the environment, forest ecosystems, and climate changes. Here are a few examples:

Tree Species	Local Name	Indicator Role	Significance
Pinus roxburghii	Chir Pine	Indicator of fire risks and soil moisture levels	Fire vulnerability, moisture changes
Quercus leucotrichophora	Banj Oak	Indicator of soil health and forest composition	Soil degradation, climate change effects
Shorea robusta	Sal	Indicator of forest health and regeneration	Deforestation, invasive species, regeneration rates
Rhododendron arboreum	Buransh	Indicator of climate change in high-altitude ecosystems	Shifts in altitude due to warming
Alnus nepalensis	Himalayan Alder	Indicator of riparian ecosystem and water quality	Water pollution, soil health
Betula utilis	Bhojpatra	Indicator of pollution and alpine ecosystem health	Alpine degradation, air quality changes
Ficus religiosa	Peepal Tree	Indicator of urban and	Air quality, urban

Tree Species	Local Name	Indicator Role	Significance
		forest ecosystem health	encroachment
Prunus cerasoides	Wild Cherry	Indicator of forest regeneration and pollination	Forest succession and pollinator health
Acacia catechu	Khair	Indicator of dryland soil health and ecosystem integrity	Soil degradation, water scarcity
Carya laciniosa	Shagbark Hickory	Indicator of mixed forest ecosystem integrity	Forest health and biodiversity

Indicator species like *Rhododendron*, *Banj Oak*, *Deodar Cedar*, *Chir Pine*, and *Himalayan Birch* provide early warning signs of ecological shifts, soil health, climate change, and pollution in Uttarakhand's diverse forests. Their health directly correlates with the overall state of the forest ecosystem, making them crucial for environmental monitoring.

10.3.4. Cultural Keystone Species

Cultural keystone species are those of exceptional significance to a particular culture or people. These species influence social systems and culture and are a key feature of a community's identity. The white pine (Pinus strobus) holds cultural importance for the Kitcisakik Algonquin community in Quebec, Canada, influencing their traditions and practices.**Cultural Keystone Species**, meaning they hold significant cultural, religious, and social importance in addition to their ecological value. These species are integral to local traditions, festivals, customs, and even the daily life of the region's people. Here are a few examples:

Tree Species	Local Name	Cultural Significance	Uses
Ficus religiosa	Peepal Tree	Sacred in Hinduism and Buddhism, associated with various deities	Religious offerings, medicinal bark
Shorea robusta	Sal	Sacred groves, associated with local rituals	Timber for construction, resin for medicinal use
Rhododendron	Buransh	State flower of Uttarakhand,	Flower for juice and jams,

Tree Species	Local Name	Cultural Significance	Uses
arboreum		used in traditional beverages	medicinal properties
Betula utilis	Bhojpatra	Sacred tree, bark used for religious texts	Bark for writing, wood for construction and rituals
Pinus roxburghii	Chir Pine	Important for resin collection, cultural significance	Resin for traditional use, timber for construction
Acacia catechu	Khair	Source of *kattha*, used in pan chewing and traditional medicine	Wood for *kattha*, medicinal bark
Ficus benghalensis	Banyan Tree	Symbol of community, protection, and longevity	Shade, medicinal uses
Mangifera indica	Mango	Symbol of prosperity, used in festivals	Fruit for consumption, leaves for decoration
Terminalia arjuna	Arjuna Tree	Sacred, associated with riverbanks and divine protection	Medicinal bark for heart health
Pyrus calleryana	Callery Pear	Symbol of beauty and good fortune	Used in local crafts and decorative arts

Cultural Keystone Species in Uttarakhand like *Buransh* (Rhododendron), *Deodar* (Cedrus deodara), *Peepal* (Ficus religiosa), *Mango* (Mangifera indica), and *Tamarind* (Tamarindus indica) are vital not only for the ecological health of the region but also for the cultural identity and practices of local communities. These trees are involved in religious ceremonies, festivals, cuisine, and traditional medicine, making them deeply woven into the cultural fabric of Uttarakhand.

10.4. Conservation Status and Threat Assessment

The International Union for Conservation of Nature (IUCN) Red List categorizes species based on their risk of extinction. The categories include:

10.4.1. IUCN Red List Categories

In Uttarakhand, some tree species have likely become **locally extinct** due to various factors such as habitat destruction, over-exploitation, climate change, and deforestation.

While it is difficult to get comprehensive and region-specific information about **extinct** tree species, here are **examples** of **tree species** that have been reported as **locally extinct** or are highly threatened in the region, along with their **local names** and **traditional uses**:

1. **Extinct (EX):** No known individuals remaining.

While it is difficult to specifically pinpoint **extinct** tree species from Uttarakhand, many species have **disappeared locally** or have become **endangered** due to human activities. The trees listed below have **historical and cultural significance** in the region and have provided **medicinal, culinary, and economic benefits** for local communities. Conservation efforts are essential to protect the remaining populations of these species and to prevent further degradation of the region's biodiversity.

2. **Extinct in the Wild (EW):** Known only to survive in cultivation or captivity.

When we talk about **"Extinct in the Wild" (EW)** species, it refers to species that no longer exist in their natural habitat and can only be found in cultivation or in the wild under human care (such as in botanical gardens or other protected areas). While there are no specific **tree species** from Uttarakhand that are officially recorded as **Extinct in the Wild (EW)** in globally recognized databases like the **IUCN Red List**, there are species that could be at risk and could potentially fall into this category due to habitat loss, over-exploitation, and climate change

3. **Critically Endangered (CR):** Extremely high risk of extinction in the wild.

Critically Endangered (CR) tree species of **Uttarakhand** are at significant risk due to factors such as **over-exploitation**, **habitat loss**, and **climate change**. Many of these species hold significant **cultural, economic, and ecological value** for the people of Uttarakhand and the broader Himalayan region. **Conservation efforts** such as habitat protection, sustainable use practices, and raising awareness about their value are essential to ensure that these species don't disappear from the wild.

4. **Endangered (EN):** Very high risk of extinction in the wild.

Endangered tree species of Uttarakhand hold **ecological, cultural, and medicinal importance**. Most face threats from **overharvesting**, **illegal logging**, **deforestation**, and **poor regeneration**. Preserving these trees through **sustainable harvesting**, **community-led conservation**, and **habitat protection** is essential to prevent their extinction.

5. **Vulnerable (VU):** High risk of extinction in the wild.

Here is a list of **Vulnerable (VU)** tree species from **Uttarakhand**, along with their **local names** and **traditional uses**. These species are categorized as **Vulnerable** due to declining populations, habitat loss, over-harvesting, and limited natural regeneration.

6. **Near Threatened (NT):** Likely to become endangered in the near future.

Near Threatened (NT) tree species are still found in the wild but are facing **increasing threats**. If not monitored and protected, they may soon move into **endangered** categories. Conservation through **sustainable harvesting**, **community forestry**, and **habitat restoration** is crucial.

7. **Least Concern (LC):** Species evaluated but not currently at risk.

   Least Concern (LC) tree species are vital to the **economy, ecology, and culture** of Uttarakhand. Even though they are not currently at risk, sustainable use and conservation awareness are essential to prevent future decline.

8. **Data Deficient (DD):** Inadequate information to assess risk.

Data Deficient (DD) status indicates that there is insufficient information to assess their risk of extinction.Despite this, these species hold significant ecological, cultural, and economic value in the region.

9. **Not Evaluated (NE):** Not yet assessed.

Not Evaluated (NE) tree species have not been assessed by the International Union for Conservation of Nature (IUCN), and therefore, their conservation status remains unknown.

Tree Species	Local Name	Conservation Status	Threats
Acacia catechu	Khair	Vulnerable (VU)	Over-exploitation, habitat loss
Aesculus indica	Pangar	Vulnerable (VU), NT	Seed overharvest, habitat loss
Alnus nepalensis	Uttis	Vulnerable (VU), NT, LC	Habitat loss, Pollution, riverbank erosion
Bauhinia variegata	Kachnar	Vulnerable (VU), NT	Over-collection
Betula utilis	Bhojpatra	Endangered (EN) , NT	Over-harvesting of bark, climate change, and shrinking alpine habitats.
Cedrus deodara	Deodar	Vulnerable (VU), NT	Logging, disease
Cupressus torulosa	Cypress	Extinct (ex), EW, CR	Logging and habitat loss in the region
Dalbergia latifolia	Kala Shisham	Endangered (EN)	Illegal logging and habitat degradation
Ficus religiosa	Peepal	Vulnerable (VU), NT, LC	Urban encroachment, Pollution, over exploitation
Fraxinus excelsior	Himalayan Ash	Extinct (ex), EW, CR	Over-exploitation and deforestation
Juglans regia	Akhrot	Endangered (EN)	Deforestation, over-harvesting, poor regeneration in wild.
Litsea glutinosa	Maida Lakdi	Endangered (EN)	Deforestation and overuse for herbal medicine
Madhuca longifolia	Mahua	Vulnerable (VU), NT	Unsustainable harvesting
Mangifera indica	Mango	Least Concern (LC)	Habitat loss, agroforestry decline
Picea smithiana	Spruce	Extinct (ex), EW, CR	Over-harvesting and habitat degradation
Pinus gerardiana	Chilgoza Pine	Extinct (ex), EW, CR	Over-harvesting for its seeds, habitat destruction, and climate

			change.
Pinus roxburghii	Chir Pine	Vulnerable (VU), NT, LC	Fires, overharvesting, over grazing
Pterocarpus marsupium	Bijasal	Endangered (EN)	Over-harvesting, low regeneration, and habitat loss.
Pyrus calleryana	Callery Pear	Not Evaluated (NE)	Habitat destruction
Quercus leucotrichophora	Banj Oak	Vulnerable (VU), NT, LC	Degradation, overuse, Invasive species
Quercus semecarpifolia	Tilonj/Banj Oak	Vulnerable (VU)	Overgrazing, fire
Rhododendron arboreum	Buransh	Extinct (ex), EW, CR, Least Concern (LC), VU	Habitat destruction, climate change
Santalum album	Chandan	Endangered (EN)	Illegal logging and slow growth rate.
Shorea robusta	Sal	Least Concern (LC), VU	Deforestation, overgrazing, illegal logging
Swietenia mahagoni	Mahogany	Extinct (ex), EW, CR	Over-exploitation for timber and deforestation
Symplocos racemosa	Lodh	Endangered (EN)	Habitat degradation and over-extraction for medicinal use.
Taxus wallichiana	Himalayan Yew	Extinct (ex), EW, CR	Over-harvesting for medicinal purposes and habitat loss.
Terminalia arjuna	Arjuna Tree	Least Concern (LC)	Over-exploitation, habitat degradation
Toona ciliata	Toon	Endangered (EN)	Over-exploitation for timber and habitat degradation

10.5 Identification of forest (Local /Regional) tree species

Identification of Important Tree Species: Key Morphological and Ecological Features

Accurate identification of tree species in the field is crucial for ecological studies, forest inventories, and management. This section outlines key morphological and ecological features used for identification:

- **Overall Form and Size (Habit):** The general shape of the tree (e.g., conical, columnar, spreading, rounded) and its mature height and diameter can provide initial clues.
    - **Example:** The tall, straight, conical shape of many coniferous trees like *Pinus* and *Picea* is distinctive.
- **Bark:** The texture, color, and pattern of the bark can be a very reliable identification feature, especially in mature trees. Note variations with age and location on the trunk.
    - **Example:** The smooth, gray bark of *Fagus sylvatica*, the deeply furrowed, dark bark of mature *Quercus robur*, and the reddish, peeling bark of some *Pinus* species are characteristic. In the Himalayan region, the smooth, often peeling bark of some *Betula* species (Birches) is distinctive.
- **Leaves:** Leaf characteristics are often the most readily accessible and informative features for identification. Consider:
    - **Arrangement:** Opposite (e.g., *Acer*, *Fraxinus*), alternate (e.g., *Quercus*, *Betula*), whorled.
    - **Type:** Simple (single blade) or compound (blade divided into leaflets). If compound, note the number and arrangement of leaflets (pinnately, palmately).
    - **Shape:** Ovate, lanceolate, cordate, lobed, needle-like, scale-like.
    - **Margin:** Smooth (entire), toothed (serrate, crenate), lobed.
    - **Venation:** Pinnate (one main vein with smaller veins branching off), palmate (several main veins radiating from a central point), parallel (in monocots).
    - **Size and Color:** Note the overall size and color of the leaves, including any seasonal changes.
    - **Surface Texture:** Smooth, hairy, waxy.
    - **Smell (if crushed):** Some trees have distinctive leaf odors (e.g., *Ailanthus altissima* - Tree of Heaven).
    - **Example (Broadleaf):** The lobed leaves of *Quercus* species, the palmate leaves of *Acer* species, and the heart-shaped leaves of *Tilia cordata* (Small-leaved Lime) are easily recognizable. In the Himalayan region, the

distinctive leaf shapes and sizes of various *Rhododendron* species are key identifiers.

- **Example (Conifer):** Needle-like leaves arranged singly (*Abies* - Fir), in bundles of 2-5 (*Pinus* - Pine), or scale-like (*Thuja* - Arborvitae, *Juniperus* - Juniper) are crucial for conifer identification. The length, shape, and cross-section of needles (e.g., flattened, triangular) are also important.

- **Twigs and Buds:** Especially useful in winter when leaves are absent. Note:
  - **Arrangement of Buds:** Alternate or opposite.
  - **Shape and Size of Buds:** Pointed, rounded, conical, terminal bud present or absent.
  - **Color and Texture of Buds:** Scaly, hairy, resinous.
  - **Lenticels:** Small pores on the twig surface.
  - **Leaf Scars:** Shape and arrangement of scars left after leaves fall.

- **Flowers:** While often seasonal, flowers are critical for accurate taxonomic identification, especially at the genus and species level. Note:
  - **Type:** Solitary or in clusters (inflorescences).
  - **Size, Shape, and Color:** Number of petals, sepals, stamens, and pistils.
  - **Presence or Absence of Petals:** Wind-pollinated trees often have inconspicuous flowers without petals.
- **Fruits and Seeds:** Fruits and seeds are also important reproductive structures used for identification. Note:
  - **Type:** Berry, drupe, pome, capsule, cone (in conifers), nut, achene.
  - **Size, Shape, and Color.**
  - **Seed Morphology:** Winged, hairy, size, shape.
  - **Example (Conifer):** The size, shape, and scale structure of cones are key to identifying different pine, spruce, and fir species.
  - **Example (Broadleaf):** Acorns of *Quercus*, samaras (winged fruits) of *Acer*, and berries of *Sorbus* are distinctive.

- **Scent:** Crushing leaves or twigs can sometimes release characteristic odors that aid in identification (e.g., the citrusy scent of some *Eucalyptus*).
- **Ecological Context:** Habitat, elevation, associated species, and geographic location can provide valuable clues for identification. For example, knowing you are in a high-altitude conifer forest in the Himalayas narrows down the possibilities. The Tanda Range in Uttarakhand will have a specific set of dominant tree species associated with its altitude and climate.

Practical Tips for Tree Identification:

- **Use a Field Guide:** Carry a reliable field guide specific to your region.
- **Observe Multiple Features:** Don't rely on a single characteristic. Look at a combination of bark, leaves, twigs, and fruits (if present).
- **Consider the Season:** Some features (flowers, fruits) are only present at certain times of the year.
- **Look at Multiple Individuals:** There can be variation within a species.
- **Note the Habitat:** Where is the tree growing? What other plants are nearby?
- **Take Good Notes and Photos:** If you are unsure, detailed notes and clear photographs can help with later identification.

10.6. Summary

The categorization and identification of important tree species are fundamental to our understanding and management of forest ecosystems. By classifying trees based on their ecological roles, economic significance, growth characteristics, and silvical traits, we gain insights into forest structure, dynamics, and the complex interactions that sustain them. Accurate identification, relying on a combination of morphological and ecological features, allows us to monitor forest health, assess biodiversity, and implement targeted conservation strategies. In regions like the Tanda Range, Uttarakhand, India, understanding the dominant and ecologically significant tree species, such as Sal, various pines, oaks, rhododendrons, and deodars, is crucial for managing these valuable forest resources and conserving their unique biodiversity in the face of environmental change. The ability to categorize and identify these foundational species empowers us to

appreciate the vital role trees play as the pillars of our forests and to work towards their sustainable management and conservation for future generations.

References:

- Paine, R. T. (1969). *A Note on Trophic Complexity and Community Stability*. The American Naturalist.
- Dayton, P. K. (1972). *Toward an Understanding of Community Resilience and the Potential Effects of Enrichments to the Benthos at McMurdo Sound, Antarctica*. Proceedings of the Colloquium on Conservation Problems.
- Wikipedia contributors. (2024). *Keystone species*. Wikipedia. Retrieved from https://en.wikipedia.org/wiki/Keystone_species
- Wikipedia contributors. (2024). *Foundation species*. Wikipedia. Retrieved from https://en.wikipedia.org/wiki/Foundation_species
- Wikipedia contributors. (2024). *Umbrella species*. Wikipedia. Retrieved from https://en.wikipedia.org/wiki/Umbrella_species
- Wikipedia contributors. (2024). *Flagship species*. Wikipedia. Retrieved from https://en.wikipedia.org/wiki/Flagship_species
- Wikipedia contributors. (2024). *Cultural keystone species*. Wikipedia. Retrieved from https://en.wikipedia.org/wiki/Cultural_keystone_species
- Wikipedia contributors. (2024). *IUCN Red List*. Wikipedia.

Unit 11. Phenology and silvicultural characteristics of important tree species

Unit Structure

11.0. Learning Objectives

After studying this unit you are able to understand about:

- Phonological and silvicultural characteristics of important tree species

11.1. Introduction

Phenology, the study of the timing of recurring biological events, is a critical aspect of understanding tree species' life cycles and their interactions with the environment. The phenological characteristics of tree species encompass the timing and duration of key life cycle events such as leafing, flowering, fruiting, and leaf senescence. These events are influenced by various environmental factors, including temperature, precipitation, and photoperiod.

11.2. Key Phenological Events in Trees

11.2.1. Leafing (Budburst and Leaf Expansion)

The initiation of leaf development, known as budburst, marks the beginning of the growing season. This event is typically synchronized with favorable environmental conditions, such as increased temperatures and adequate moisture. For instance, in Kumaun Himalayan forests, species like *Shorea robusta* and Pinus roxburghii exhibit synchronized leafing during the warm-dry period of the year.

11.2.2. Flowering

The reproductive phase in trees involves the development and opening of flowers. In many species, flowering is timed to coincide with optimal conditions for pollination and subsequent seed development. Studies have shown that in Kumaun Himalayan forests, most tree species have a sharp flowering peak in April, with wet-season flowering being rare.

11.2.3. Fruiting and Seed Dispersal

Following successful pollination, trees produce fruits containing seeds. The timing of fruit maturation and seed dispersal is crucial for the establishment of new individuals. In Kumaun Himalayan forests, species like Shorea robusta and Pinus roxburghii have a single peak of fruit maturation occurring in summer, while other species also exhibit a secondary peak in autumn .

11.2.4. Leaf Senescence (Leaf Drop)

The process of leaf aging and eventual abscission marks the end of the growing season. In deciduous species, leaf drop typically occurs in response to decreasing temperatures and shorter day lengths. In Kumaun Himalayan forests, concentrated leaf drop and simultaneous leafing occur during the warm-dry period of the year, with about half of the species showing multiple leafing .

11.2.5. Environmental Influences on Phenology

Environmental factors play a significant role in shaping the phenological patterns of tree species. Temperature, precipitation, and photoperiod are key drivers that influence the timing and duration of phenophases. For example, in Kumaun Himalayan forests, climatic irregularities and temperature rise have led to shifts in phenological events, such as earlier leaf flushing and extended periods of leaf drop in species like *Myrica esculenta* and *Quercus leucotrichophora*.

11.2.6. Implications for Forest Management and Climate Change

Understanding the phenological characteristics of tree species is essential for effective forest management and conservation strategies. Shifts in phenological events due to climate change can affect species interactions, reproductive success, and ecosystem dynamics. Monitoring phenological patterns provides valuable insights into the impacts of environmental changes on forest ecosystems and can inform adaptive management practices.

11.3. Silvicultural characteristics

Silvicultural characteristics of tree species encompass a range of biological and ecological traits that influence their establishment, growth, management, and regeneration in forest ecosystems. These characteristics are critical for selecting appropriate species for specific silvicultural systems and management objectives.

11.4. Important Silvicultural Characteristics

11.4.1. Shade Tolerance

The ability of a species to grow under varying light conditions. For instance, species like Quercus robur (pedunculate oak) are known for their adaptability to a wide range of site conditions, including different light exposures .

11.4.2. Coppicing Ability

Some species can regenerate from stump shoots, a trait known as coppicing. *Shorea robusta* (sal) is a strong coppicer, capable of producing new shoots from stumps up to 20–30 cm in diameter.

11.4.3. Seed Production and Dispersal

Species vary in their seed production and dispersal mechanisms. For example, *Shorea robusta* produces light-winged seeds dispersed by wind, which is crucial for natural regeneration.

11.4.4. Growth Rate and Productivity

The rate at which a species grows and its overall productivity are vital for timber production. *Cedrus deodara* (deodar) is a slow-growing species with a mean annual increment of 5–8 m^3/ha/year .

11.4.5. Soil and Site Requirements

Species have specific soil and site preferences. *Quercus robur* thrives in well-aerated, deep, moist, fertile soils with a pH of 4.5–7.0 .

11.4.6. Resistance to Pests, Diseases, and Environmental Stressors

Species vary in their susceptibility to pests, diseases, and environmental stressors. *Shorea robusta* is noted for its fire resistance, making it suitable for areas prone to wildfires.

11.4.7. Regeneration Methods

Species exhibit different regeneration strategies. Cedrus deodara primarily regenerates through seed, and its slow growth necessitates careful management to ensure successful regeneration.

11.4.8. Wood Properties

The physical and mechanical properties of wood, such as density and strength, influence its suitability for various uses. Cedrus deodara wood is light and soft, with a specific gravity of 0.57, making it suitable for construction and fuel.

Table 1: Phenological and silvicultural characteristics of important Indian tree species of Uttarakhand.

Species (Common Name)	Scientific Name	Phenology	Silvicultural Characteristics
Banj Oak	*Quercus leucotrichophora*	Leaf fall: Feb–Mar; Leaf flush: Mar–Apr; Flowering: Mar–May; Fruiting: Sep–Nov	Moderate shade-tolerant when young; good coppicing ability; managed under shelterwood system; mid-Himalayan elevations (1200–2500m)
Chir Pine	*Pinus roxburghii*	Pollination: Mar–Apr; Cone ripening: Apr–May; Seed dispersal: May–June	Light-demanding; managed under shelterwood compartment system; good natural regeneration on open slopes; altitudes of 600–2000m
Deodar	*Cedrus deodara*	Cone maturity: Oct–Nov; Seed dispersal: Nov–Dec	Shade-tolerant when young; managed under selection or irregular shelterwood; thrives in cool, moist conditions at 1500–3000m
Sal	*Shorea robusta*	Leaf fall: Feb–Apr; Leaf flush: Apr–May; Flowering: Apr–May; Fruiting: Jun–Jul	Light-demanding; fire-sensitive; managed under shelterwood or selection systems; poor regeneration under heavy canopy
Sagon (Teak)	*Tectona grandis*	Deciduous; Leaf fall: Nov–Jan; Flowering: Jun–Aug; Fruiting: Aug–Nov	Light-demanding; prefers deep, well-drained soils; managed under clear felling or coppice with reserve systems
Toon	*Toona ciliata*	Deciduous; Leaf fall: Dec–Jan; Flowering: Mar–Apr; Fruiting: May–Jun	Light-demanding; sensitive to frost; fast-growing; suitable for agroforestry
Bel	*Aegle marmelos*	Leaf fall: Jan–Mar; Flowering: May–Jun; Fruiting: Mar–Apr	Drought-resistant; grows in poor soils; used in dryland agroforestry
Neem	*Azadirachta indica*	Leaf fall: Mar–May; Flowering: Apr–May; Fruiting: Jun–Aug	Hardy, drought-tolerant; grows on degraded soils; light-demanding
Poplar	*Populus*	Deciduous; Leaf	Light-demanding; fast-growing;

	deltoides	fall: Nov; Flowering: Feb–Mar; Fruiting: Mar–Apr	requires deep, moist alluvial soils; used in agroforestry
Eucalyptus	*Eucalyptus spp.*	Evergreen; Flowering: varies (often biannually); Fruiting: 11–12 months after flowering	Fast-growing; drought-tolerant; often managed in short-rotation plantations
Chandan (Sandalwood)	*Santalum album*	Flowering: after 7 years; Fruiting: almost year-round	Hemiparasitic; needs host plant; slow-growing; high-value timber; managed under agroforestry
Rohini	*Mallotus philippensis*	Leaf fall: Jan–Mar; Flowering: Mar–Apr; Fruiting: May–Jun	Grows in moist deciduous forests; used in reforestation; shade-tolerant
Shisham	*Dalbergia sissoo*	Leaf fall: Feb–Apr; Leaf flush: Apr–May; Flowering: Apr–May; Fruiting: May–Jun	Light-demanding; grows well on alluvial soils; nitrogen-fixing; valuable timber
Peepal	*Ficus religiosa*	Semi-evergreen; Leaf shedding: Mar; Leaf flush: Apr; Fruiting: multiple times a year	Tolerates a wide range of soils; grows well in urban conditions; culturally significant
Bargad (Banyan)	*Ficus benghalensis*	Leaf fall: Mar–May; Leaf flush: May; Fruiting: biannually	Large spreading tree; supports aerial roots; requires space; grows in a variety of soils
Buransh	*Rhododendron arboreum*	Leafy throughout year; Flowering: Feb–Apr; Fruiting: May–Jul	Prefers cool, temperate climate; found in Himalayan forests (1500–3000m); shade-tolerant
Chinar	*Platanus orientalis*	Deciduous; Leaf fall: Nov–Dec; Flowering: Mar–Apr; Fruiting: Apr–Jun	Grows in moist, well-drained soils; ornamental and shade tree; thrives in Kashmir and temperate zones
Surai (Cypress)	*Cupressus torulosa*	Evergreen; Flowering: Feb–Mar; Fruiting: Nov–Dec	Light-demanding; drought-tolerant; used in plantations and ornamental planting; grows in temperate and subtropical zones

Summary:

Understanding the silvicultural characteristics of tree species is essential for effective forest management. These traits guide decisions on species selection, silvicultural systems, and management practices to achieve desired outcomes such as timber production, biodiversity conservation, and ecosystem restoration

References:

- Troup, R.S. (1921). *The Silviculture of Indian Trees*. Oxford University Press.
- Champion, H.G. & Seth, S.K. (1968). *A Revised Survey of the Forest Types of India*.
- Forestry literature from ICFRE, FRI Dehradun, FAO databases, and various regional forest working plans.
- Ralhan, P. K., Khanna, R. K., Singh, S. P., & Singh, J. S. (1985). Phenological characteristics of the tree layer of Kumaun Himalayan forests. Vegetatio, 60(2), 91–101. Link
- Mittal, A., Tewari, A., Singh, N., & Sharma, S. (2016). Patterns of phenological characteristics of important tree species of Kumaun Himalaya. Current World Environment, 16(1), 15–22. Link
- Kikim, A., & Yadava, P. S. (2001). Phenology of tree species in subtropical forests of Manipur in north eastern India. Indian Journal of Forestry, 24(1), 1–6. Link
- Einarson, M. D., & Link, S. O. (1976). Theophrastus and the study of plant phenology. Economic Botany, 30(2), 184–188. Link

Unit 12. Germination

Unit Structure

12.0. Learning Objectives

After studying this unit you are able to understand about:

- Phonological and silvicultural characteristics of important tree species

12.1. Germination

Germination is the process by which a seed develops into a new plant. While sexual reproduction through seed germination is the most common method, plants also employ various asexual or vegetative means to propagate and ensure survival. Understanding these diverse mechanisms is crucial for agriculture, horticulture, and conservation efforts.

12.2. Sexual Reproduction: Seed Germination

Seed germination involves the growth of a seed into a new plant. This process typically requires specific environmental conditions such as appropriate temperature, moisture, and sometimes light. Seeds may possess dormancy mechanisms that delay germination until favorable conditions are met.

12.2.1. Stages of Seed Germination

Imbibition: Uptake of water by the dry seed.

Activation: Enzyme activation, respiration starts.

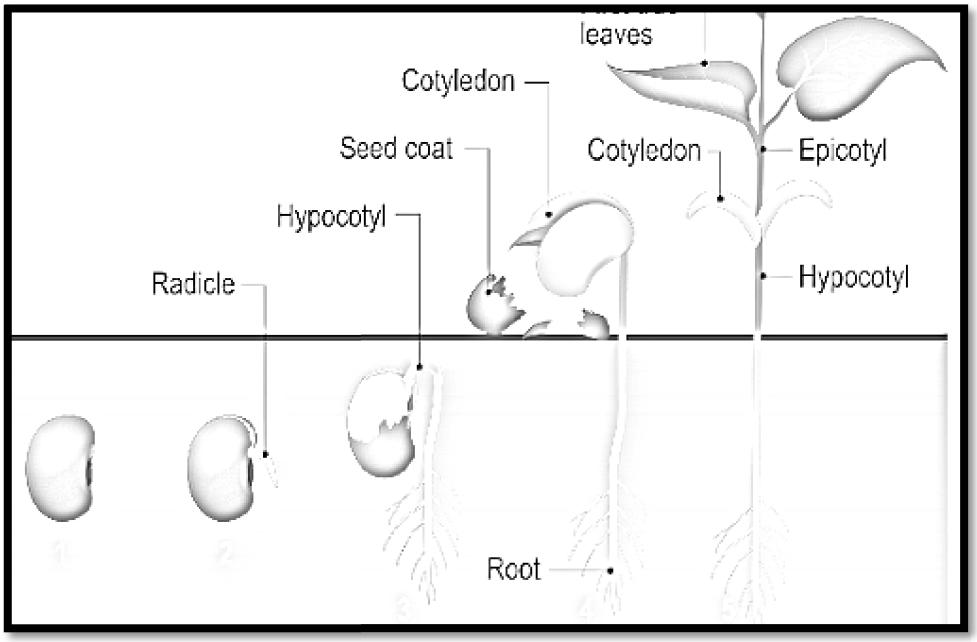
Radicle emergence: The embryonic root breaks through the seed coat.

Shoot development: The plumule grows upwards to form the shoot.

12.2.2. Types of Seed Germination

Epigeal Germination: In this type, the cotyledons (seed leaves) emerge above the soil surface. An example is the common bean (Phaseolus vulgaris), where the hypocotyl elongates, pushing the cotyledons upward (Saxena & Bhatnagar, 2016)

Hypogeal Germination: Here, the cotyledons remain below the soil surface. The epicotyl elongates, pushing the shoot above ground. An example is the pea (Pisum sativum), where the cotyledons stay underground, providing nutrients to the developing plant ([Taiz et al., 2015).



12.2.3. Dormancy and Breaking Dormancy

Some seeds exhibit dormancy, a state of metabolic inactivity that prevents germination even under favorable conditions. Breaking dormancy can involve:

Scarification: Mechanical or chemical methods to break or weaken the seed coat, facilitating water absorption. For instance, Tylosema esculentum seeds have hard coats

that can be scarified using sandpaper or hot water to enhance germination. Physical or chemical abrasion of hard seed coats (e.g., Albizia lebbeck) [Bewley et al., 2013)

Stratification: Exposure to cold temperatures for a specific period, mimicking winter conditions.

Light or Darkness: Some seeds require exposure to light or darkness to trigger germination.

Table 1: List of species germinated through seed in Uttarakhand.

Botanical Name	Common Name	Forest Division	Location	Notes
Pinus roxburghii	Chir Pine	Nainital	Bhwali, Dakshin Gola	Wind-dispersed seeds; requires specific conditions for germination.
Quercus leucotrichophora	Banjh Oak	Almora	Dwarahat, Kotura	Acorns mature in December; naturally regenerates via seeds.
Populus ciliata	Himalayan Poplar	Nainital	Nagar Palika	Dioecious; seeds are produced in capsules and require moist conditions for germination.
Prunus cerasoides	Wild Himalayan Cherry	Almora	Bisar Vanya Jeev Vihar	Produces seeds in fruits; requires specific conditions for germination.
Myrica esculenta	Kaphal	Almora	Bisar Vanya Jeev Vihar	Seeds are produced in fruits and require specific conditions for germination.
Cedrus deodara	Deodar Cedar	Almora	Dwarson	Propagated through seeds; requires specific conditions for germination.
Alnus nepalensis	Uttis	Almora	Dwarahat	Seeds are produced in cones; requires specific conditions for germination.
Fraxinus micrantha	Himalayan Ash	Nainital	Kosi	Seeds are produced in samaras; requires specific conditions for

				germination.
Quercus floribunda	Tilonj	Nainital	Uttari Gola	Acorns mature in December; naturally regenerates via seeds.
Quercus lanuginosa	Latua Banj	Almora	Bisar Vanya Jeev Vihar	Acorns mature in December; naturally regenerates via seeds.

12.3. Asexual (Vegetative) Reproduction

Asexual reproduction allows plants to produce offspring genetically identical to the parent, ensuring rapid propagation and survival.

12.3.1. Methods of Vegetative Propagation

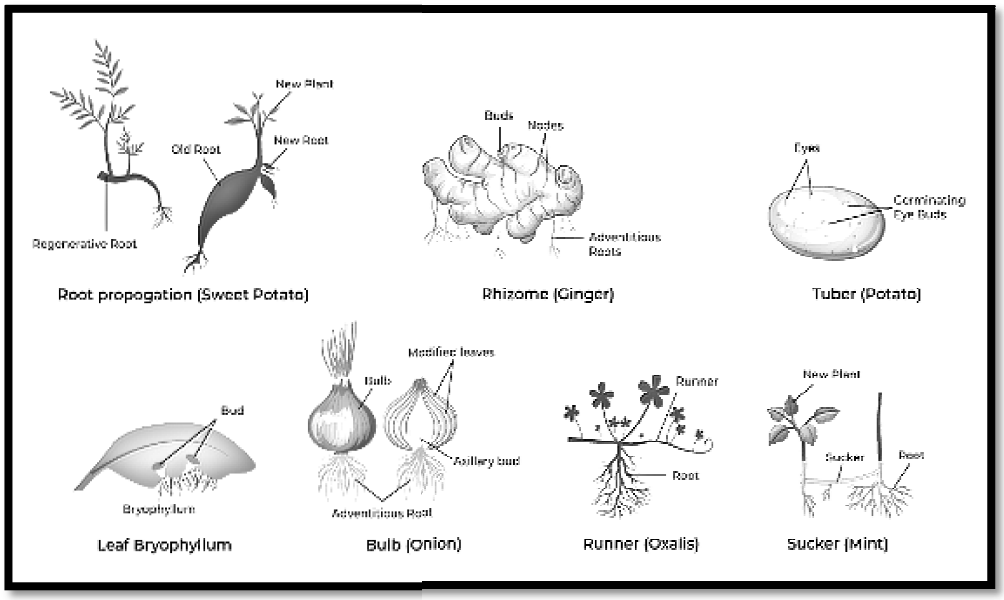
A) Natural Vegetative Structures

a) Tubers: Swollen underground stems.Example: Solanum tuberosum (potato) [Hartmann et al., 2011)

b) Rhizomes: Horizontal underground stems.Example: Zingiber officinale (ginger)

c) Bulbs: Fleshy storage leaves around a bud. Example: Allium cepa (onion)

d) Stolons/Runners: Above-ground horizontal stems. Example: Fragaria × ananassa (strawberry)



B) Artificial Vegetative Propagation

a) Cuttings: Segments of stems, leaves, or roots are planted to grow new plants. For example, rose cuttings can develop roots and grow into new plants. A cutting may be a piece of stem, a leaf or part of a leaf, a piece of root, or root stock, or even a scale of bulb. Classification of cuttings: Cuttings are usually classified in to 3 groups according to the particular part of the plant used as cutting.

1. Stem cuttings
2. Root cuttings
3. Leaf cuttings

a) Stem cutting: The stem cutting is the most common and easy method for propagation of forest tree species. Tree species differ in their rooting ability and accordingly can be classified into

1. Very easy to root (Salix sp., Morus alba, Bambusa vulgaris)
2. Easy to root (Ficus spp., Pongamia pinnata, Eucalyptus spp.)
3. Moderately difficult to root (Dalbergia latifolia, Grevillea spp., Pteridofolio)
4. Difficult to root (Tectona grandis, Emblica officinalis)
5. Very difficult to root (Hardwickia binnata, Albizia procera, Terminalia spp.)

b) Shoot cuttings, also referred to as stem cuttings, are the most common type. A segment of stem branches can be rooted to produce full plant. The size of the cutting varies: it could be a few centimeters (Eucalyptus, Casuarina) to 1-2 meter poles (Cassia, Siamea, Gliricidia, Sepium). The presence of buds on the cutting is very essential for cutting propagation, because it supplies many factors responsible for rooting. Evenly the presence of leaves greatly affects rooting in the cuttings. Based on the presence or absence of leaves, the cuttings can be categorized as leafless cutting (Hardwood cuttings) and leafy cutting. These cuttings can be broadly placed into four categories depending on the time of year they are collected and based on the degree of maturity and lignification of wood used in making cuttings.

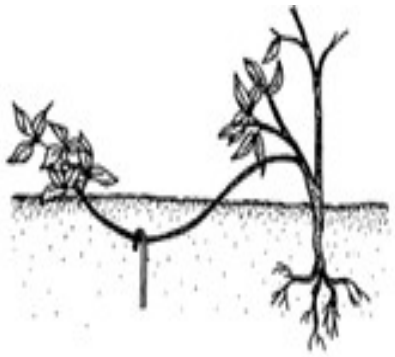
1. Hard wood stem cuttings

2. Semi hard wood stems cuttings

3. Soft wood stem cuttings Herbaceous stem cuttings

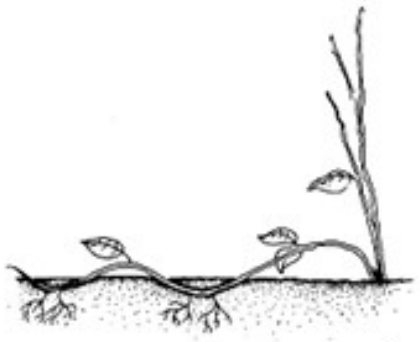
c) Leaf Cutting: Though not used extensively in forestry applications, this cutting method warrants a brief mentioning. This form of propagation utilizes the leaf to promote new plant growth. A root and shoot will form and develop, from the leaf cutting, into a new plant. The original leaf cutting does not remain as part of the new formed plant. In leaf cuttings the plants are formed generally via two mechanisms: first, from pre-formed embryos present on the margin of leaves (Bryophyllum and ornamental plants) and second through induction of secondary meristem. Propagation by leaf cutting has limited utility. Only a small group of species can be multiplied by the method.

B) Layering: A stem is bent to the ground and covered with soil; roots develop at the buried section, and the new plant is separated once established. Examples include jasmine and grapevine.



Simple layering

A. Simple layering: It is used on species that produce many shoots annually. In this method, a branch is bent to the ground and some portion of it is covered by soil leaving the terminal end of the branch exposed. Root initiation takes place at the bent and buried portion. After allowing sufficient time for root formation, the rooted stem is separated from the mother plant. To increase the removal of root bark, girdling, wiring etc. can be done to the buried part. All these treatments favour accumulation of carbohydrates by blocking downward the transport of food material.

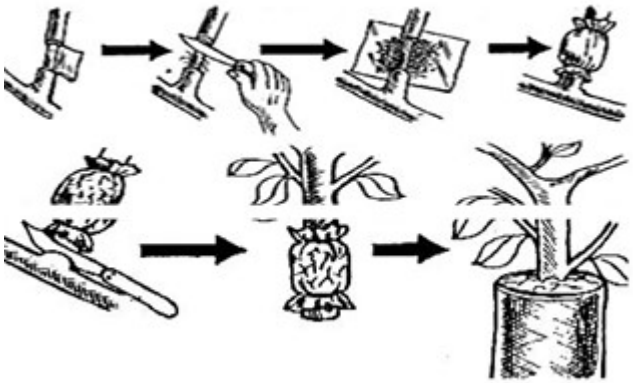


Serpentine or Compound Layering

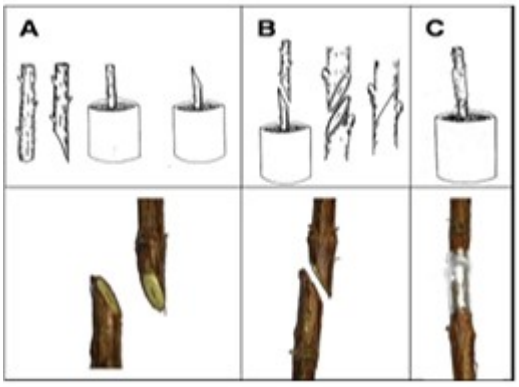
B. Serpentine or Compound Layering:

Serpentine or Compound layering is essentially the same as the simple layering except that the branch is alternatively covered and exposed along its length. The branch for compound layering must be long and flexible so that it can be layered at different places along its length. It means the long flexible branch is buried at more than one point, giving it the appearance of a snake. In this, more than one plants are obtained from a single branch.

C. Air Layering: This type of layering is more useful in forestry than other methods. Inthis mothod the bark is completely removed from a small area of the branch, and the exposed area is covered with moist moss and again covered with polythene. After some days, the roots develop and at this stage the branch can be removed and planted as a separate plant. The exposed area of the branch can be treated with auxin for better results. In air layering roots form on an aerial shoot. The rooting medium is tied to the shoot for getting root initiation. Sphagnum moss is the best rooting medium for air layering as it holds large quantities of water till root initiation and through the root initiation and through the root development.



Grafting: Grafting is the process of attaching a shoot (or less frequently a bud) from the individual you want to clone to the root system and lower stem, collectively called the root stock, of another tree. It produces a genetic mosaic, where most of the stem and crown of a tree or shrub are one genotype, and the root system and lower stem are another. This can come in handy for combining different roots and shoots with desirable properties. It is the only available method of cloning older trees of many species. Typically a dormant scion (shoot cutting with terminal bud) is harvested from the upper crown of the tree to be cloned (the ramet) in mid to late winter, then attached to the top of the cut stem of a seedling of approximately the same diameter. It is important that the xylem, phloem and



cambium of the rootstock and scion are in contact. Initially, wound callus is formed by both the rootstock and scion. The two then grow together and develop continuous vascular tissue. Root stock and scion need to be genetically compatible; otherwise a proper union will not develop and the tree will eventually die. Breeding programs have produced lines of rootstock that have high levels of compatability for other genotypes for some species such as Douglas fir (Pseudotsuga menziesii). Grafting is commonly used to establish genetically superior trees in seed orchards (mature scion material is used so graft will flower sooner) and to propagate unique trees for horticultural purposes (e.g., weeping varieties, infertile flowering cherries).

C) Division: The parent plant is divided into sections, each capable of growing into a new plant. This method is common in plants like lilies and ferns.

D) Micropropagation: Also known as tissue culture, this technique involves growing plants from small tissue samples under sterile laboratory conditions. It's used for rapid multiplication of plants like orchids and bananas.

C) Specialized Reproductive Structures

Some plants produce specialized structures for reproduction:

Spores: Non-seed reproductive bodies that can develop into new individuals. Spore germination is common in lower plants like ferns, mosses, and fungi. These are haploid propagules that develop directly into a new gametophyte. Spores require moisture and shade to germinate (Gifford & Foster, 1989)

Bulbs and Tubers: Underground storage organs that can develop into new plants. Examples include onions (bulbs) and potatoes (tubers).

Rhizomes and Stolons: Horizontal stems that grow underground (rhizomes) or above ground (stolons), producing new plants at nodes. Examples are ginger (rhizomes) and strawberries (stolons).

4. Germination from Spores

Summary

Plants exhibit diverse and adaptive reproductive strategies, ranging from seed-based germination to complex vegetative methods. Each method has its ecological significance and practical application, influencing agriculture, horticulture, and environmental management. Continued research into germination physiology enhances our ability to manage plant resources sustainably.

References

Bewley, J. D., Bradford, K., Hilhorst, H., & Nonogaki, H. (2013). Seeds: Physiology of Development, Germination and Dormancy. Springer.

Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. (2015). Plant Physiology and Development. Sinauer Associates.

Hartmann, H. T., Kester, D. E., Davies Jr., F. T., & Geneve, R. L. (2011). Plant Propagation: Principles and Practices. Prentice Hall.

George, E. F., Hall, M. A., & De Klerk, G. J. (2008). Plant Propagation by Tissue Culture. Springer.

Gifford, E. M., & Foster, A. S. (1989). Morphology and Evolution of Vascular Plants. Freeman.

Unit 13. Silvicultural Systems

Unit Structure

13.0. Learning Objectives

On completing this unit, you should be able to understand:

- Define silvicultural systems and understand their role in forest management.
- Classify silvicultural systems into even-aged and uneven-aged categories.
- Describe the characteristics, advantages, and limitations of each system.

13.1. Introduction

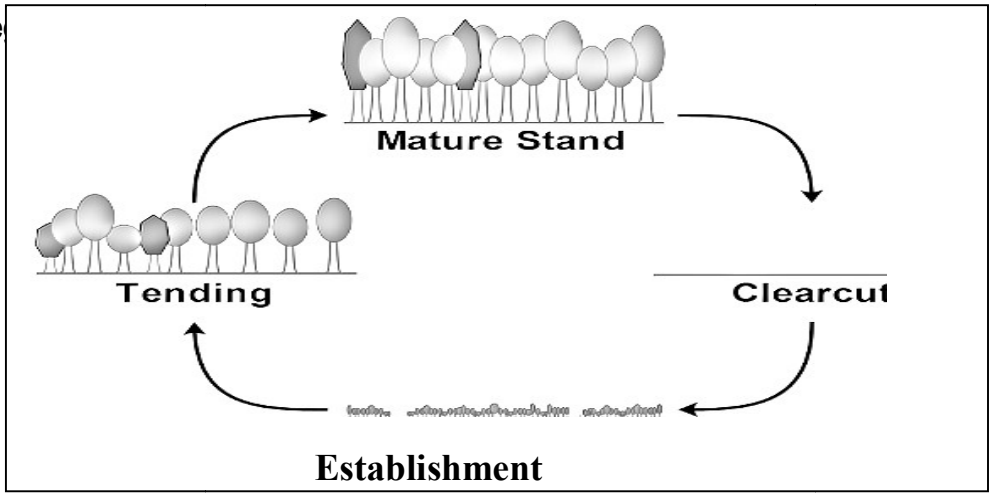
Silviculture is the science and art of managing forest establishment, composition, structure, and growth to meet diverse objectives such as timber production, biodiversity conservation, and ecosystem services. Central to silviculture are the systems employed to regenerate and manage forests, categorized primarily into even-aged and uneven-aged systems.

13.2. Even-Aged Silvicultural Systems

In even-aged systems, all trees in a stand are of the same age class, typically resulting from a single regeneration event. These systems are suitable for species that require full sunlight for regeneration.

13.2.1. Clear-Felling System

The clear-felling system involves the complete removal of all trees in a designated area in a single operation. This method is often followed by artificial or natural regeneration. It is particularly effective for species that are intolerant to shade and require full sunlight for re



Types of Clear-Felling Systems:

Block Clear-Felling: Entire blocks of forest are felled, allowing for uniform regeneration.

Patch Clear-Felling: Smaller patches are cleared, which can help in maintaining biodiversity and reducing the risk of large-scale soil erosion.

Strip Clear-Felling: Narrow strips are cleared, often in a directional pattern, to facilitate natural regeneration and reduce wind damage.

Alternate Strip Clear-Felling: Alternating strips are cleared, leaving uncut strips to provide seed sources and shelter for regeneration.

Each type has its advantages and is selected based on site conditions, species requirements, and management objectives.

13.2.2. Shelterwood System

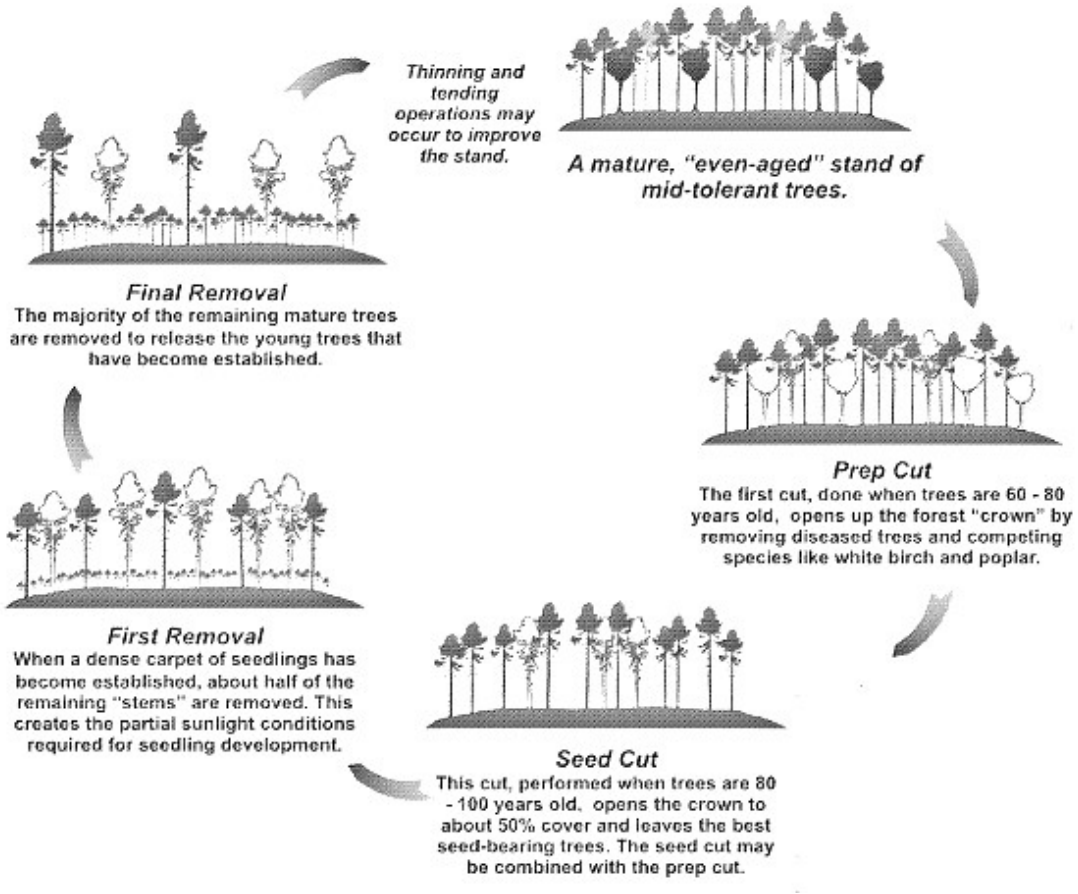
The shelterwood system involves the gradual removal of mature trees in a series of cuts to create favorable conditions for regeneration under partial shade. This system is suitable for species that are intermediate in their shade tolerance.

Stages of Shelterwood System:

Preparatory Cut: Remove undesirable trees to prepare the stand for regeneration.

Establishment Cut: Create conditions for seedling establishment by removing some overstory trees.

Removal Cut: Remove the remaining overstory trees to allow full light to reach the new generation.



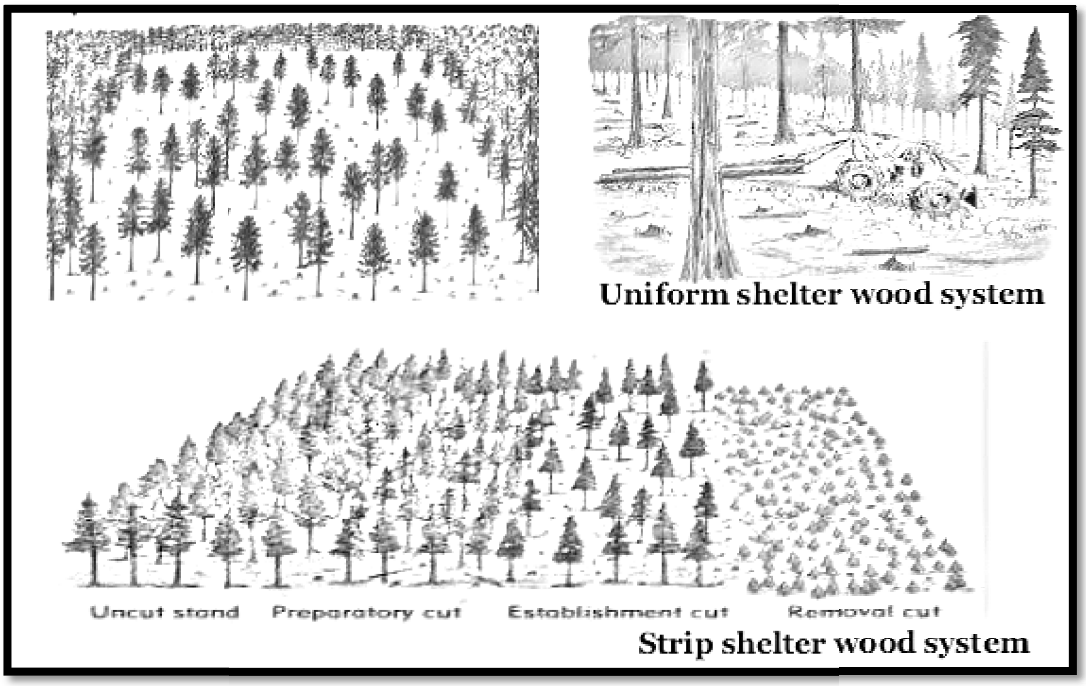
Types of Shelterwood Systems:

Uniform Shelterwood: A uniform canopy is maintained across the stand.

Group Shelterwood: Small groups of trees are removed to create openings for regeneration.

Strip Shelterwood: Strips of trees are removed in a systematic pattern.

Irregular Shelterwood: Uneven removal of trees creates a more heterogeneous structure.



13.3. Uneven-Aged Silvicultural Systems

Uneven-aged systems aim to maintain a continuous forest cover with trees of multiple age classes. This approach is suitable for species that are shade-tolerant and require continuous canopy cover.

a. Selection System

The selection system involves the selective removal of individual trees or small groups of trees to maintain a continuous canopy and promote regeneration. This system is often used in forests where maintaining biodiversity and habitat is a priority.

Types of Selection Systems:

Single-Tree Selection: Individual trees are selected and removed.

Group Selection: Small groups of trees are removed to create openings for regeneration.

This system helps in maintaining a diverse age structure and is commonly applied in temperate forests.

13.4. Coppice System

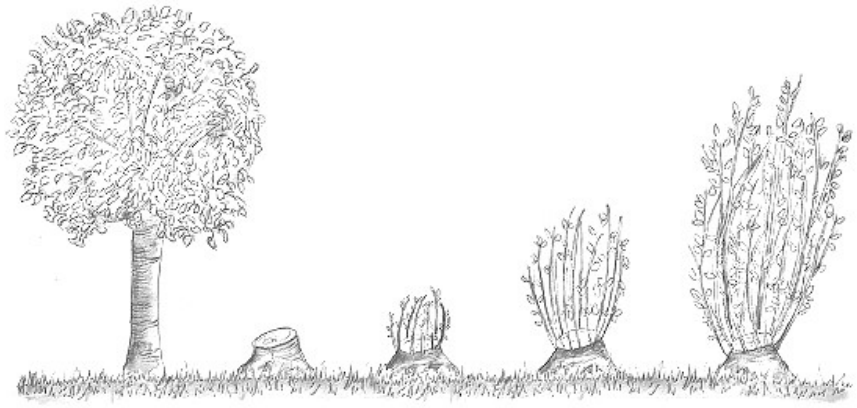
The coppice system involves the cutting back of trees to ground level to stimulate the growth of new shoots from the stump or roots. This system is effective for species that have the ability to regenerate vegetatively.

Types of Coppice Systems:

Simple Coppice: Trees are cut back to ground level at regular intervals.

Coppice with Standards: Some trees are allowed to grow to maturity while others are coppiced.

Coppicing is often used for species like willow and hazel, which are used for products like poles and firewood.



Summary

The choice of silvicultural system depends on various factors, including the species to be managed, site conditions, and the objectives of forest management. Each system has its advantages and is selected to meet specific goals such as timber production, biodiversity conservation, or ecosystem restoration. Understanding the characteristics and applications of different silvicultural systems is essential for effective forest management.

References:

Forest Research. (n.d.). Silviculture. Retrieved from [https://