# INTRODUCTION

Silviculture has been defined variously authors. According to Toumey and Korstian, 'silviculture is that branch of forestry which deals with the establishment, development, care and reproduction of stands of timber'. Indian Forest and Forest Products Terminology, published by the Forest Research Institute and Colleges, Dehra Dun, defines silviculture as, 'the art and science of cultivating forest crops'. According to Champion and Seth, 'the term silviculture in English commonly refers only to certain aspects of theory and practice of raising forest crops'. Though from the above definitions, there appears to be some diversity in views about the scope of silviculture, yet, in a broad sense, silviculture may be taken to include both silvics and its practical application. According to Indian Forest and Forest Products Terminology, silvics is 'the study of life history and general characteristics of forest trees and crops with particular reference to environmental factors, as the basis for the practice of silviculture'. Thus silvics implies the study of trees and forests as biological units, the laws of their growth and development and the effect of environment on them. It explains the natural laws of their growth and development and their behaviour in a given set of environmental conditions. Though a lost of information on silvics has been collected by experiments, observations and experience of earlier foresters, a lot more information is yet to be collected to explain the unsolved complexities in the lives of trees and crops and the natural laws governing their reproduction, growth and development. The knowledge gathered in silvics is applied to the production and care of forest crops. Thus the practice of silviculture is applied silvics. It deals with the procedure of obtaining natural regeneration under the various silvicultural systems, artificial regeneration of various species, and methods of tending young crops, whether natural or artificial to help them to grow into forests of quality timbers and great economic value. Silviculture is not a purely biological science which has no relation with economics. The foresters raise the forests and tend them for the service of the people, but this is not to be done at a prohibitive cost. If forests are to be grown for the public good, the methods of raising and tending them, developed on the basis of knowledge of silvics, will have to be modified in practice by economic considerations. Silviculture has been rightly described as an art and in this art intuition plays an important part. In our own country as well as in the European countries, there have been foresters who have advocated that, in case of doubt, the trees should be approached for answer. Even today, the local flora is regarded to be the best guide about the suitability of a species for a particular site. This is so because in nature there are so many complex factors at play that it is only the vegetation that can give an indication of the possible solution. But in order to understand the indication of the vegetation or answer of the trees, it is necessary for the forester to be conversant with their language and proficiency in this art comes by close continuous observation and experience.

## Objects of Study of Silviculture

The forests are as old as the universe; naturally they must have been growing and renewing themselves. It is a well known fact that forest preceded civilization in every part of the world. Management of the forests by the Forest Departments is a very recent phenomenon. Even today, there are virgin forests in many parts of our country. The question naturally arises as to what use is the study and practice of silviculture and why should a forester take upon himself the work that the nature had been doing all these years. The answer to this question is purely economic. The object study and practice of silviculture is to produce more useful and valuable forests to meet our multifarious requirements, than nature would do and that too, in a shorter time. The objective with which nature produces vegetation are not identical with that of man. The former produces a 'jungle', the latter a forest. The study of silviculture helps in:

1) Production of species of economic value – In the virgin forests, many of the species are generally neither very valuable nor useful. Therefore, the production of timber of species of economic value per unit area is low. If the forests have to produce timber of industrial and economic importance, it is necessary to study and practice silviculture so that we can produce only the desired species.

2) Production of larger volume per unit area – In the virgin forests, the crop is generally either very dense or very open. Both these extremes are unsuitable for quantitative production. If the crop is very dense, the growth of the individual trees is adversely affected resulting in lesser timber volume production per unit area. On the other hand, if the crop is very open, the number of trees, and

consequently volume, per unit area would be less. Besides this, a large number of trees die out as a result of competition before reaching maturity. In the unmanaged forest, they are not utilized and that volume of timber is lost. The study and practice of silviculture helps in raising sufficient trees per units area right from the beginning to fully utilize the soil and as they grow up, gradually reduce their number so that the requirement of light and food of the remaining trees is met. In this way, while by raising sufficient number of trees, the volume production per unit area is increased, the utilization of the excess trees as the crop grows in age, prevents the loss and consequently further increases that volume.

3) Production of quality timber – In the unmanaged forests, because of intense competition, a large number of trees become crooked, malformed, diseased and defective. This results in the deterioration of the quality of timber produced. If the production of quality timber is to be ensured, knowledge of silviculture will be essential so that the trees can be grown in disease free condition without adverse competition.

4) Reduction of rotation – In the virgin forests because of intense competition in the dense parts, the rate of growth of the individual tree is retarded with the result that it takes longer time to reach the size at which it can be exploited. This increases the cost of production of timber. With the knowledge and practical application of silviculture, the density of the crop can be properly regulated and consequently the rate of growth increased and rotation reduced.

5) Raising forests in blank areas – In nature, a large number of areas, potentially suitable for tree growth, occasionally remain blank due to certain adverse factors inhibiting growth of trees. Silvicultural skills and techniques help in raising forest in such areas.

6) Creation of manmade forests in place of natural forests – There may be areas in natural forests which may not regenerate or reproduce themselves naturally or where natural regeneration may be extremely slow and uncertain. In such areas, it becomes necessary for the forester to take up the work of nature in his hand and raise manmade forests in such areas. Success in this endeavour can be achieved only when he has a good knowledge of the science and art of raising forest crops artificially.

7) Introduction of exotics – The indigenous species may not be able to meet the commercial and/or industrial demands. In such areas, efforts are made to introduce exotics which can grown in that particular locality and can supply the timber required by industries, etc., in time. For example, the demand of paper is increasing very fast. There is no indigenous species which may grow in a variety of sites easily and very fast so that the demand of the paper pulp industry may be met. Therefore, a last growing exotic, Eucalyptus hybrid, had to be introduced. This is possible only when the forester is conversant with the silviculture of the exotics as well as climatic and soil conditions of the localities in which they can be introduced.

**Forestry, its Scope and Classification**

Forestry is defined as the theory and practice of all that constitutes the creation, conservation and scientific management of forests and the utilization of their resources. It is an applied science which is concerned with not only the raising or cultivation of forest crops but their protection, perpetuation, mensuration, management, valuation and finance as well utilization of the forest products for the service of the nation. In favourable localities, this science is applied to get maximum return and so it is called intensive forestry which is defined as the practice of forestry with the object of obtaining the maximum in volume and quality of products per unit are through the application of the best techniques of silviculture and management. When forestry is practiced to achieve more than one purpose, it is called multiple-use forestry which is defined as the practice of forestry for the simultaneous use of a forest are for two or more purposes, often in some measure conflicting, e.g., the production of wood with forest grazing and/or wildlife conservation.

**Based on the objectives, forestry is classified as under**:

**a) Protection forestry** – Protection forestry is the practice of forestry with the primary object of (1) protecting lands whether those upon which the forest is situated or those at a distance from it, against wind and water erosion, (2) conserving water supplies for human consumption, fish culture, etc., (3) reducing hazards from flood damage to human life and property and (4) amelioration of adverse climatic effects.

**b) Commercial forestry** – Commercial forestry is the practice of forestry with the object of producing timber and other forest products as a business enterprise. A specialized aspect of commercial forestry is to meet the requirement of a particular industry and in that case it is called

industrial forestry which is defined as the practice of forestry to sustain a given industrial enterprise, such as a saw mill, pulp mill, chemical plant or a combination of these.

**c) Social forestry** – Social forestry is the practice of forestry on lands outside the conventional forest area for the benefit of the rural and urban communities. Supply of fuel wood to divert cow dung from village hearths to village fields, small timber for rural housing and agricultural implements, fodder for the cattle of the rural population living far away from the forest areas, protection of agriculture by creation of diverse ecosystem and arresting wind and water erosion and creation of recreational forests for the benefit of the rural as well as urban population are the basic economic and cultural needs of the community without which there can be no improvement in the conditions of their living. The application of forestry technology to achieve this social objective is known as social forestry. This is new dimension recently added to the concept of forestry and includes within its scope the following:

1) Farm forestry – Farm forestry is the practice of forestry on farms in the form of raising rows of trees on bunds or boundaries of field and individual trees in private agriculture land as well as creation of wind breaks, which are protective vegetal screens created round a farm or an orchard by raising one at two lines of trees fairly close with shrubs in between.

2) Extension forestry – Extension forestry is the practice of forestry in areas devoid of tree growth and other vegetation and situated in places away from the conventional forest areas with the object of increasing the area under tree growth. It includes within its scope the following:

i) Mixed forestry – Mixed forestry is practice of forestry for raising fodder grass with scattered fodder trees, fruit trees and fuelwood trees on suitable wastelands, panchayat land and village commons.

ii) Shelterbelts – Shelterbelt is defined as a belt of trees and/or shrubs maintained for the purpose of shelter from wind, sun, snow drift, etc. They are generally more extensive than the wind breaks covering areas larger than a single farm and sometimes whole regions on a planned pattern.

iii) Linear strip plantations – These are plantations of fast growing species on linear strips of land on the sides of public roads, canals and railway lines.

3) Reforestation of degraded forests

4) Recreational forestry – Recreational forestry is the practice of forestry with the object of raising flowering trees and shrubs mainly to serve as recreation forests for the urban and rural population. The main object is not to produce timber, grass or leaf fodder but to raise ornamental trees and shrubs in some area to meet the recreational needs of the people. This type of forestry is also known as aesthetic forestry which is defined as the practice of forestry with the object of developing or maintaining a forest of high scenic value.

**RELATION OF SILVICULTURE WITH FORESTRY AND ITS BRANCHES**

Silviculture and Forest Protection

Forest protection is defined as that branch of forestry which is concerned with the activities directed towards the prevention and control of damage to forests by man, animals, fire, insects, disease or other injurious and destructive agencies. A knowledge of the injuries caused to forests by the local human and animal population, both domestic and wild, insects, fungi and other adverse climatic factors and the preventive and remedial measures to counteract them, is essential for effective protection of the forests. Thus while silviculture is concerned with the raising of forest crop, forest protection is concerned with its protection against various sources of damage.

**Silviculture and Forest Mensuration**

Forest mensuration is defined as that branch of forestry which deals with the determination of dimensions, form, volume, age and increment of logs, single trees, stands or whole woods. Thus while silviculture deals with raising of forest crop, forest mensuration deals with measurement of diameter and heights of crop so produced, calculation of its volume, age, etc., for sale and research to decide the best treatment to be given to the crop while it is being raised.

**Silviculture and Forest Utilization**

Forest utilization is defined as the branch of forestry concerned with the harvesting, conversion, disposal and use of the forest produce. Thus while silviculture is concerned with the cultivation of forest crops, forest utilization is concerned with the harvesting and disposal of crops so produced.

**Silviculture and Forest Economics**

Forest economics is defined as those aspects of forestry that deal with the forest as a productive asset, subject to economic laws. Thus while silviculture is concerned with the cultivation of forest crop,

forest economics works out the cost of production including rental of land and compound interest on capital spent in raising the crop, and compares it with the sale proceeds to decide whether raising of the crop is economically profitable or not.  It is also the function of the forest economist to compare the cost of production of a particular crop by different methods and then decide the most profitable method of raising that crop.

**Silviculture and Forest Management**

Forest management has been defined as the practical application of the scientific, technical and economic principles of forestry.  Thus while silviculture deals with the cultivation of forest crop, forest management manages that crop according to the dictates of the forest policy.  Silviculture deals with the techniques and operations which result in the development of a forest.  Forest management prescribes the time and place where the silvicultural techniques and operations should be carried out so that the objects of management are achieved.

The various branches of forestry are so closely related that the considerations of one branch influence the techniques of the other branches.  For example, silvicultural techniques and operations are governed by the consideration of cost and modified to suit the requirement of protection.  Similarly, even the most profitable method of exploitation or harvestings has to be given up if it is not compatible with silvicultural techniques or the protective considerations.

**Silviculture and Forestry**

From the definition of forestry given earlier, it is clear that forestry has a very wide scope and silviculture is only one of its branches.  It has the same relation with forestry as agronomy has with agriculture.  While agronomy and silviculture deal with cultivation of crops, agriculture and forestry deal not only with the cultivation of crops but also with their protection, management, mensuration, marketing, etc.  In short, forestry is an applied science which has many branches.  It may be compared to a wheel.  Silviculture is the hub of the wheel; it is neither the whole wheel nor is it the only essential part.  But, just as a cart wheel composed of several sections is supported on its hub, similarly forestry and its other branches are supported on silviculture without which there would be neither forestry nor its branches.

**THE TREE AND THE FOREST**

THE TREE

Tree is essentially a plant.  Plants may be classified into the following three categories:

i) Herb, ii) Shrub and iii) Tree

i) Herb is defined as plant whose stem is always green and tender and height is usually not more than one metre.  According to the span of life, it is called annual, biennial or perennial.

ii) Shrub is defined as a woody perennial plant differing from a perennial herb in its persistent and woody stem and less definitely from a tree in its low stature and its habit of branching from the bare.  A shrub is usually not more than 6 metres in height. Both these categories of plants supply, if at all, economic minor forest products only.  As they are very small in size, they do not produce timber but shrubs are used as firewood.

iii) Tree is defined as a large woody perennial plant having a single well defined stem (bole or trunk) and a more or less definite crown.  A tree is usually more than 6 metres in height which can, according to species, be upto 127 metres.  For example, height of a Pseudosuga taxifolia tree in British Columbia has been measured to be 127.1 m and that of a Sequoia sempervirens tree in California has been found to be 112.1 m.

In India, the maximum height so far recorded is not more than 75 m.  A scrutiny of the record of heights of trees reveals that the conifers are taller than the broad leaved trees.  For example, while the maximum height of deodar has so far been recorded to be 73.2 m, those of teak and sal have been found to be only 58.5 m and 51.2 m respectively.  From the point of view of girth also, the Sequoia of California and the Eucalyptus of Australia are the biggest because they have attained girths of 3574 cm and 2438 cm respectively.  In India the maximum girth so far recorded is 1646 cm, of a deodar in kulu (Himachal Pradesh).  The maximum girths of teak and sal are even less; these have been recorded to be only 625 cm and 782 cm respectively. Even from the point of view of age, tree has very much more longevity than the shrubs and the herbs.  For example, age of a Sequoia sempervirens of California has been estimated to be more than 4000 years.  In India, the age of a deodar tree, whose section is preserved in the F.R.I. was found to be 704 years.  Of the other Indian species, maximum ages of teak and Dalbergia latifolia have been estimated to be 500 years and 600 years respectively.

All trees provide timber from their stem and thick branches while the thinner branches and hollow portions of stem are used a firewood. The tree can be divided into three parts:

**TREE**

Above the ground
  i) The crown
  ii) The stem

Below the ground
  iii) The root

THE CROWN

The crown is defined as the upper branchy part of a tree above the bole. It is formed by the foliage of the branches springing from the bole.

**Shape and size** – The shape and size of the crowns of trees vary with species and the conditions in which they grow. Phoenix, Cocos and Borassus have crowns of large leaves at the tops of cylindrical unbranched stems. This characteristic distinguishes them from other forest trees which are generally much branched. In chir, deodar and some other conifers, the lower branches are longer while the upper branches are gradually shorter, giving the crown a conical shape. On the other hand, the crowns of Mangifera indica, Azadirachta indica, Tamarindus indica, Madhuca indica, etc., are spherical in shape. In Albizzia stipulata the crown is broad and flat topped while in Abies pindrow it is more or less cylindrical. Except the palms, the crowns of other trees are affected by the situation in which they grow. Normally, the trees growing in the open have large branches and big crowns, while those growing in dense forests have smaller branches and smaller crowns, because the branches on the lower part of the bole die out gradually due to shade and the crowns are limited to the upper part of the bole of the tree. The size of the crown depends upon crown development which is defined as the expansion of crown measured as crown length and crown width.

**Mode of branching** – The mode of branching varies with species and sometimes, it is characteristic of the genus or the family. In most of the species, it is absolutely unsystematic. In species with opposite leaves, the branches are also in opposite pairs, though sometimes, this is visible only in the upper branches. Some species, e.g., Bombax ceiba and Pinus wallichiana, with alternate leaves sometimes develop branches in whorls. The angle that the branches make with the stem, is also a specific character. Though in most cases, the branches make an angle of 60o to 70o with the stem, yet in some species, e.g., Populus nigra, Cupressus sempervirens, they make angles upto 20˚ to 30˚. In quite a few species, e.g., old deodar and Dalbergia sonneratioides, the branches are almost horizontal and form terraces of foliage, while in some other, e.g., Anogeissus pendula, Terminalia myriocarpa, leading shoot of young deodar and branchlets and twigs of spruce, they are drooping downwards.

The size and the number of branches also varies with species. While in some species branches are thin and twiggy in others they are thick. Some species have large number of branches while others have only a few. The larger the number of branches and thicker the branches, the more the wood is knotty; this is considered as a defect in timber for several purposes.

**Leaf colour, size and texture** – Normally the mature leaves are green. The shade of colour of the two surfaces of leaf is often different, the lower being often paler than the upper. In addition to the difference in shade, the lower surface of the leaf is sometimes covered with while (e.g., in Quercus incana) or rusty brown tomentum (e.g., in Quercus semicarpifolia). Some species have characteristic attractive colour in their young leaves. For example, young leaves of Quercus incana are pinkish or purplish, those of Acer caesium, Schleichera oleosa bright red, those of mango brown and those of Cassia fistula dark red brown. In some species, leaves undergo a striking change in colour before falling from the tree; such colours are called autumn tints and help the forester in recognizing the species from a distance. For example, before falling the leaves of Lannea coromandelica turn yellow, those of Anogeissus latifolia dark red or bronze, and Sapium sebiferum beautiful red, purpose and orange. But quite a few species, e.g., Elaeocarpus, Bischoffia are characterized by the presence of a few conspicuous red leaves in almost all seasons.

Size of leaf depends upon rainfall and the species. As a rule, the leaves in low rainfall areas are small while they are generally bigger in heavy rainfall areas. In some species, e.g., teak, Dillenia, the leaves are bigger than the usual size of most leaves. Leaves of most conifers are needle shaped and that is why they are called needles.

While the texture of leaves of some species is soft and membranous, it is hard and coriaceous in others. The membranous and soft leaves of species, e.g., Grewia, Ougeinia, Anogeissus, etc., on falling not only decompose rapidly and get mixed up with the soil but hasten the decomposition of the

hard and coriaceous leaves of species, e.g., sal and conifers which otherwise, decompose very slowly and create problem for natural regeneration.

Leaf shedding – All trees shed their old leaves regularly and produce new leaves. The new leaves may be produced while the old leaves are still present on the tree or after they have fallen. On the basis of the presence or absence of old green leaves at the time when the new leaves are produced, the trees and other plants are classified into deciduous and evergreen. **A tree is called deciduous if it normally remains leafless for sometime during the year**. In other words, it produces new flush of leaves In other words, it produces new flush of leaves after all the old leaves have been shed and it has remained leafless for sometime. The leafless period varies with species and situation. For example, sal is leafless for about a weak or ten day while Hymenodictyon excelsum remains leafless for about six months. Even in the same species different trees remain leafless for different periods due to their situation. For example, in areas with abundant and well-distributed rainfall, teak becomes nearly evergreen while in drier areas, it remains leafless for about six months. Santalum album is exception to the above general rules; it becomes deciduous or evergreen according to the habit of its host plant.

**An evergreen is defined as perennial plant which is never entirely without green foliage, the old leaves persisting until a new set has appeared.** The persistence of the old green leaves after the new leaves have been produced, depends upon species and in the same species upon the environment. For example, in chir, the old leaves persist from one year five months to two or three years but in deodar, they persist for five or six years. On lower altitudes, due to higher temperature, chir, which is normally evergreen, become deciduous.

The following are some examples of deciduous and evergreen trees:

**Deciduous** – *Acacia catechu, Adina cordifolia, Ailanthus excelsa, Bombax ceiba, Garuga pinnata, Holoptelia integrifolia, Lannea coromandelica, Melia azaderach, Schleichera oleosa, Terminalia tomentosa.*

**Evergreen** – *Abies pindrow, Cedrus deodara, Cupressus torulosa, Hopea parviflora, Mallotus philippinensis, Mangifera indica, Michelia champaca, Picea smithiana, Pinus wallichiana, Pterospermum acerifolium.*

**THE STEM**

The stem is defined as 'the principal axis of plant from which buds and shoots are developed; in trees, stem, bole and trunk are synonymous' but bole is 'some times used to refer to only lower part of the stem upto a point where the main branches are given off, i.e., as a synonymous for clear or clean bole which is defined as the part of the bole that is free of branches.

The shape and length of the stem varies with species and the situation in which the tree grows. Some species have long and straight stem with relatively few branches, while others have stem which are crooked and/or much branched. Normally the stem is thicker at the base and thinner in the upper portion of the tree. The decrease in diameter of the stem of a tree or of a log from the base upwards, is known as taper. This is due to the pressure of wind which is centred in the lower one third of the crown and is conveyed to the lower parts of the stem, increasing with increasing length. To counteract this pressure, which may snap the tree at the base, the tree reinforces itself towards the base. The situation in which the tree grows affects the shape and length of the stem. The trees growing in the open in plains and or ridges in hills have generally shorter and conspicuously tapering stem as a result of wind pressure. On the other hand, the trees growing in dense forest have relatively longer and more or less cylindrical stem. The production of a long cylindrical bole is a desirable quality in trees because that increases their timber volume. In the earlier stages, thin branches generally cover almost the entire stem of a tree but as the saplings grow into poles and trees, the lower branches fall off resulting in a clean bole. But even in later life, sometimes, due to some adverse factors the clean bole again develops small branches known as **Epicormic branches which are defined as 'branches originating in clusters from dormant or adventitious buds on the trunk of a tree or on older branch when exposed to adverse influence such as excessive light, fire or suppression'.** They are also caused by drought and that is why they are generally found on stag-headed trees.

**Normally trees have one stem but sometimes they are forked and have more than one leader**. From the point of view of timber production, this is not a desirable quality because the portion below the point of forking is either wasted or produces small sized timber and there is always a danger of one of the leaders being broken down in wind storms.

In some species, e.g., Acrocarpus fraxinifolius, Bombax ceiba, Pterocarpus dalbergiodes, Terminalia myriocarpa, etc., buttresses are formed in the basal portion of the stem. **Buttress are out growths formed usually vertically above the lateral roots and thus connect the base of the stem with roots.** They are generally associated with the absence of long taproot due to either shallow soil resulting from the presence of rock a little below the surface or badly aerated and infertile subsoil. Buttress formation, sometimes, extends upto 5 m and therefore the lower portion of the stem becomes useless, unless the buttresses are very small. The felling of buttressed trees present great difficulties as the felling has to be done above buttress formation. In some other species e.g., teak, the lower portion of the stem is characterized by **fluting which is defined as 'irregular involutions and swellings on the bole just above the basal swell'.** As fluting decreases the basal volume considerably, it is considered to be a serious defect. It is attributed to epicormic branches, insect attack, unsuitable site or faulty thinnings; no definite reason is so far known.

**THE ROOT**

The root is that portion of the plant which develops inside the soil and away from light. Unlike stem it does not produce leaves, flowers or fruits. The roots of trees support them firmly to the ground, absorb soil moisture containing mineral salts and send it to stem for onward transmission to the leaves. They, generally, comprise of two kinds of roots, viz., the taproot and the lateral roots. The tap roots is the primary descending root formed by direct prolongation of the radicle of the embryo. In trees, it is the main axis of the large root system and descends vertically below the stem. It is conical in shape, develops towards the permanent moisture in the soil and sometimes, attains considerably length. The lateral roots are the roots that arise from the taproot and spread laterally to support the tree. As the taproot grows, it develops lateral roots which are branched and re-branched and ultimately form rootlets. The ends of the rootlets are covered with fine hairs, called the root hairs. These root hairs spread in the soil particles, and absorb soil moisture to translocate it to stem and leaves where the food is manufactured. The taproot and the lateral roots including their branches upto root hairs, form the root system of the tree. The lateral roots are generally confined to the area covered by the crowns of trees but sometimes they go far beyond. For example, the lateral roots of trees growing on the edge of a forest go far into the cultivated fields and adversely affect the agricultural crops. Even in the forest, they sometimes go beyond the area of the crowns of trees and may form root grafts with the roots of other trees in dense forest. The roots of the seedlings develop very fast and sometimes reach one metre depth in one season in favourable localities. As the roots develop much faster than the shoot in early stages, it is not possible to estimate the length of the root from that of the shoot. Early development of taproot to such a depth where the moisture in the soil is more or less permanent protects the plants against post monsoon and summer drought.

The roots, generally, require a well aerated soil for their development. Therefore, the roots of may species, e.g. sal, are killed by rise in the water table, though those of some species may adjust themselves according to the changed conditions. Similarly, when a layer of silt is deposited on top of the soil, some trees die but some others develop roots from the covered portion of the stem and are not killed. On the basis of the depth of the root system the trees are classified into shallowrooted and deep rooted trees. Shallow rooted trees are those whose root system does not extend far enough into the soil to save them from relatively easy wind throw. The deep rooted trees, on the other hand, are those whose roots go very deep in the soil. **The trees, which develop a long taproot and large lateral roots are not easily uprooted by wind and are called wind firm**.

**Adventitious Roots**

**Adventitious roots are the roots produced from parts of the plants other than the radicle or its subdivision.** In bamboos, the roots are produced from the underground stem called rhizome and are therefore adventitious. These roots are thin and usually undivided. They do not show secondary thickening and are replaced by new roots when the older ones die. The following kinds of adventitious roots are commonly found in trees:

**1) Prop-roots** – Ficus bengalensis produces from its branches adventitious roots which remain suspended in the air till they reach the ground. On reaching the ground, they enter it and get fixed up in the soil. As they support thick branches of the tree, they are called prop-roots.

**2) Stilt roots** – Stilt roots are adventitious roots which emerge from the butt of a tree above ground level, so that the tree appears as if supported on flying buttresses, e.g., mangroves of the genus Rhizophora.

**3) Pneumatophore** – Pneumatophore is a knee shaped or spike like projection of the roots of swamp tree, e.g., Heretiera, Bruguiera, enabling the submerged roots to obtain oxygen.

**Mycorrhiza**

In certain, species, the fine extremities of rootlets behind the root cap, instead of being covered with root hairs are found to be invaded by specific non-pathogenic soil fungi. The invasion results in the formation of composite structures which are neither roots nor fungi. This composite structure or invaded rootlet is called mycorrhiza (plural mycorrhizae). Thus mycorrhiza may be defined as a structure produced from the combination of the modified rootlet with fungal tissue.

Types of mycorrhizae – Mycorrhizae are broadly classified as ectotrophic, endotrophic and ectendotrophic. In the ectotrophic type, fungi usually belong to Basidiomycetes. They form a mantle over the rootlets and the hyphae usually radiate from the mantle. The fungi enter the cortex, thus permitting the hyphae to grow in the intercellular space. In the endotrophic type, the fungi usually belong to Phycomycetes. They are present in the form of individual hyphae on the root surface and penetrate the cells of the cortex. Roots, sometimes, become beaded. In the ectendotrophic type, both kinds of above mentioned infections are combined, i.e., a condition where typical ectotrophic condition is accompanied by intracellular penetration of the hyphae.

Occurrence – Mycorrhiza is found in Pinus, Picea, Abies, Cedrus, Cupressus, Taxus, Populus, Aurocaria, Salix, Podocarpus and Eucalyptus, etc.

**Importance of mycorrhiza in forestry** – Though the exact role of mycorrhiza is still not understood, it is believed to perform the following functions:

i) Absorbs soil moisture by increasing the area of absorbing surface

ii) Helps in the absorption of minerals, e.g., phosphorus, copper, iron, which are in short supply and can not be absorbed by non-mycorrhizal roots and

iii) Fixes nitrogen from raw humus

Because of these functions, mycorrhiza is very beneficial to tree growth and is considered essential for the growth and survival of several species, especially the exotics. A large number of plantations in many countries have failed due to failure to introduce mycorrhiza. With the large scale introduction of exotics in India, it is likely to plant a dominant role in their establishment.

**Introduction of Mycorrhiza** – Though, sometimes, mycorrhiza develops itself in new soils without being introduced by foresters as seen in the successful Eucalyptus plantations in India and chir pine plantations in sal forests of M.P., yet it is advisable to introduce it before planting any exotic. Mycorrhiza may be introduced by the following ways:

i) Mixing soil brought from the natural good quality forests of the species. The soil should be neither dry nor very moist but should contain adequate moisture as well as mycorrhizal roots. It should be brought in sealed polythene bags and applied to the site as early as possible, but not later than 10 days after collection to ensure viability of mycorrhiza.

ii) Interplanting imported seedlings with mycorrhizae in nursery beds

**Lignotubers**

Lignotubers are underground swellings found on most species of Eucalyptus. They are actually modified stems developed from double accessory buds in the axils of cotyledons. They serve the purpose of food storage and regeneration because they bear numerous buds, which become active and produce shoot, if the tree is injured, cut down or burnt.

**Root Nodules**

The roots of a large number of plants and trees have small nodules. They contain bacterial (Rhizobium) in large numbers. The bacteria present in the soil, enters the root through the root hairs in the form of bacterial filament. After entering the root, the filament branches rapidly and reaches inner cortex where it causes active cell division resulting in the formation of nodules. These nodules vary greatly in shape and size. The bacteria living in the root nodule (and not those in the soil) help in fixation of free nitrogen from the air in the form of nitrates. The plants utilize the nitrates and in return, provide the bacteria with carbohydrates. Thus a mutually beneficial relationship, called symbiosis, is established.

Root nodules are found in about 65 species of about 8 families, the commonest being Leguminosae in which they are found in Dalbergia, Bauhinia, Acacia, Albizzia, Erythrina, Tephrosia, Crotolaria, Indigofera and Leucaena. They are, however, not found in Cassia tora. Besides Rhizobium there are some other nitrogen fixing and root nodule forming bacteria also.

**Growth and Development of Trees**

The tree starts its life as a small seedling which grows by increase in length and diameter of its shoot and root. As the shoot grows upwards, it develops branches and foliage. The root grows downward and develops lateral roots and its branches. Thus the seedlings grows not only by increase in the size of its shoot and root but also by the formation of new organs. The increase in size is commonly referred to as growth or increment and the formation of new organs is referred to as development. Thus both growth and development are responsible for the change that takes place in a small seedling growing into a tree.

Various stages of growth and development of a plant are designated as follows:

i) Seedling – Seedling is a plant grown from seed till it attains a height of about one metre, i.e., before it reaches the sapling stage.

ii) Sapling – Sapling is defined as a young tree from the time when it reaches about one metre (3 feet) in height till the lower branches begin to fall. A sapling is characterized by the absence of dead bark and its vigorous height growth.

iii) Pole – Pole is defined as a young tree from the time when the lower branches begin to fall off to the time when the rate of height growth begins to slow down and crown expansion becomes marked.

iv) Tree – Tree is the stage of growth beyond the pole stage when the rate of height growth begins to slow down and crown expansion becomes marked.

As the plant grows, certain changes occur in its morphology. The plant sheds its leaves and produces new leaves every year. It produces flowers and seeds after a certain age and sheds or disperses them on ripening. These changes are important events in the life of plant and in order to know the silviculture of a particular species, it is necessary to study such changes in the members of that species. The science that deals with the study of these changes in plants is known as phenology; it is defined as the science that deals with the time of appearance of characteristic periodic events such as leaf shedding, etc., in the life cycle of organisms in nature especially as those events are influenced by environmental factors. These events do not occur on the same date every year. The variation in time of these periodic events every year can, in most cases, be correlated with changes in the climatic factors but it also depends upon the species. For example, if the weather has unusually warmed up a little before leaf fall or at the time of fruiting, leaf fall is hastened and fruit ripening is quickened. But if that occurs before the normal time of leafing or flowering, these events are delayed. Heavier rainfall in Albizzia procera and sal, but they appear to delay new leafing and flowering. Fruit ripening in Dalbergia sissoo and Mangifera indica does not appear to be affected by the changes in climatic factors.

In addition to these morphological changes, some anatomical changes also take place in the plants annually and these results in the growth. The growth in trees is confined only in certain regions, called the growing points. These consist of meristematic cells which have the capacity to divide and give rise to new cells. The meristematic cells found in the apices of shoot and root are called apical meristems and they are responsible for the growth in height of shoot and length of root. Besides these apical meristems, the trees have primary lateral meristem in the form of cylindrical sheath which is responsible for diameter growth of shoot and root and secondary lateral meristem responsible for the growth of bark. As the plant grows, its physiological activity increases and this requires division of labour; to achieve this, a growing plant develops various kinds of tissues which perform diverse functions. The growth in plants is not uniform throughout the year. Generally, the periods of rapid growth are preceded and followed by periods of slow growth, thereby creating difference between the wood formed during the two periods. This results in the formation of distinct annual rings in some species. The number of annual rings counted on stump, when added with the number of years the tree took to grow to stump height gives the age of the tree at the time of felling. The width of the rings indicates the rate of growth, fast growth being indicated by rings wider than 5 mm. Width of growth rings has considerably effect on the strength properties of wood.

A forester is interested in height and diameter growth of trees as both these affect the volume growth. In addition, he is interested in quality of timber. Therefore, they need a more detailed description.

**Height Growth**

Height growth in trees varies with age, species and in the same species with the quality of site on which they grow. Thus the forester has very little control over the height growth of trees. In terms of age, three distinct stages are usually distinguished, viz., the juvenile or the seedling stage the sapling

and pole stages of young ages, and finally the tree stage past the middle age of the tree. During the juvenile stage, the growth varies from very slow to fast according to species. For example, height growth of Abies pindrow seedlings is very slow. Even in nursery condition, they attain a height of only about 30 cm in 4 years. Deodar seedlings grow slightly faster as they attain this height in about 2½ years. Amongst the Western Himalayan conifers, kail seedlings are faster grown. In the tropical zone sal seedlings are slow fastest grown. In the tropical zone sal seedlings are slow grown and continue to die back for several years. Teak on the other hand, is faster grown in juvenile stages. The rate of growth in juvenile stage is a very important factor in the survival of the seedlings. After the juvenile stage, most of the trees grow fast and attain maximum height for that species and site by the time they reach the middle age; after that the rate of growth falls again and a time comes after which there is no height growth.

## Diameter Growth

Diameter growth of trees is of great importance as it affects the volume of wood produced. It has an added importance for the forester because while he can not influence the height growth of trees, he can influence its diameter growth by silvicultural treatment. The tree grows in diameter right from the juvenile stage of its life; but the growth in diameter upto pole stage is rather slow as the tree concentrates mainly on height growth upto this stage. It is only when the tree has reached the maximum height that it starts increase in diameter with speed. This continues till the tree reaches maturity, when the rate of diameter growth also starts falling.

The diameter growth in trees is affected by a variety of factors such as:

i) Size of the tree – The smaller the tree, the lesser the diameter increment.

ii) Climate – The trees on the warmer sites put on faster diameter increment than those of the same species on colder sites. Rainfall also affects the diameter growth. A warmer season results in higher diameter increment only when there is adequate moisture.

iii) Soil – The diameter growth is influenced by soil quality, soil moisture and nutrient content.

iv) Production of seed – The growth in diameter is retarded in years of heavy seed production because the entire food material is used up in seed production.

v) Injuries – Defoliation by insects, insect attacks and fires have an adverse effect on diameter growth.

vi) Density – In dense forests, the growth in diameter of individual trees is retarded. As soon as the crop is opened up, the diameter growth becomes faster.

As already mentioned, the growth in diameter of the tree is not uniform throughout its height; it is maximum near the base and least at the tip. In the crown portion, the diameter growth is maximum at its base and decreases rapidly towards the tip to give it a conical shape. In the stem portion, the decrease from the base to the top is very gradual with the result that the diameter at the top of the stem is generally about half the diameter at the base. The taper of the tree is characteristic of each species and in the some species it varies with age, density of the stand and site. It is described by the term form. The typical form of a tree can be seen in the open on the best quality sites. Age has a great effect on form; the taper is greatest in young age and reduces gradually towards the old age or maturity. The denser the stand, the greater the tree bole approaches the cylindrical form.

## Growth in Volume

The growth in volume is a function of height, diameter and the form of the tree. Therefore, greater the height and diameter and lesser the taper, the greater the volume of the tree.

## Growth of Trees in Quality

The object of silviculture is not served just by producing trees of large dimensions; if the timber contained in them is not of good quality, it would not only result in lesser merchantable timber but also lesser economic return. Therefore, the aim of silviculture regarding producing trees containing large volume of timber is modified to produce large quantity of timber of high quality. Thus the growth of tree in quality is as great a concern of the forester as the production of larger volume. The quality of timber in trees depends upon size, straightness, taper, knots, other defects and strength. The larger the size of timber, the lesser the wastage and greater the volume. If the tree is straight and not crooked, longer sized timber can be produced with minimum of wastage. The quality of straightness should not be confined to the bole but also to fibres inside, because if the fibres are twisted, the timber would be useless. Taper also affects the quality of timber as it increases wastage. Knots seriously affect the quality of timber. The greater the number of knots, the lower the quality of timber. If the knots are loose, they usually come out on drying leaving a hole in the wood. Similarly, insect and

fungus attacks reduce the quality of timber. Fire also affects the quality of timber. Strength of timber depends upon the rate as well as the uniformity of growth. Very fast rate of growth impairs the strength of timber and reduces the quality. If the rate of growth is sometimes fast and sometimes slow, the timber will not be of uniform quality. The more uniform the growth, the better the quality.

## Reproduction

After attaining maturity or old age, tree dies. Therefore, in order to maintain continuity of its own species and also to multiply its numbers, it has to reproduce itself. Thus reproduction is that vital process by which tree species perpetuate themselves by reproducing new independent members of their own species by some method. Reproduction in nature can be sexual or asexual or vegetative but in trees, only sexual and vegetative reproduction takes place.

### Sexual Reproduction

Sexual reproduction consists in the fusion of two dissimilar sexual units called gametes. In trees, this is achieved by the production of flowers, their pollination, and finally by fertilization resulting in development of seeds.

## Flowering

All trees produce flowers. The age at which the trees start flowering varies with species and their situation. Generally trees produce flowers when the height growth has nearly been completed but there are exceptions also. For example, sissu usually starts flowering at the age of 3 or 4 years and teak occasionally flowers at the age of one or two years. Situation also affects the age of flowering; many trees in open flower at a much earlier age than they do in dense forest. Flowering of trees is affected by internal and external factors. The internal factors relate to certain conditions in the tree itself, e.g., the development of special hormones or florigins and the presence of high concentration of carbohydrates. The external factors relate to environmental factors, the most important of which are temperature and light. Favourable temperature and light conditions accelerate photosynthesis and increase carbohydrate production, resulting in increased flowering. Observations made on teak indicate that flowering is inhibited on the shaded portion of the crown.

In case of trees raised by vegetative methods, flowering is reported to be stimulated by pruning the roots, planting at an angle of 45o or so, strangulation by wire or metal hand and training of branches in horizontal position. As a general rule, however, it may be said that treatment which inhibits growth and prevents or even obstructs the translocation of food material downward promotes early flowering. But this does not appear to apply to trees raised by seed. Sickly trees likely to die soon, sometimes, produce large quantity of flowers and seeds as a last effort to perpetuate their species.

## Time of Flowering

Though most of the trees flower every year, some flower at an interval of years. The time of flowering varies with species and climatic conditions. The time of flowering of some of the important species mentioned below is given in brackets after them: *Acacia catechu* (June to September), *Ailanthus excelsa* (February to March), Azadirachta indica (March to May), Bombax ceiba (January to March), Dalbergia sissoo (March, April), Shorea robusta (February to April),Tectona grandis (June to August or September), Quercus dilatata (April, May). Trees have mostly bisexual flowers but many species have unisexual flowers also. Trees with unisexual flowers may be monoecious, i.e., the male and female flowers may be found on the same individual, or dioecious, i.e., the male and female flowers may be on different individuals. Some species are also polygamous, i.e., they have both unisexual and bisexual flowers.

Examples

Monoecious – Pinus, Abies pindrow

Dioecious – Salix, Mallotus, Taxus, Diospyros, Cedrus deodara, Pistacia

Polygamous – Sterculia, Garuga, Rhus

## Pollination

Pollination of flowers of trees may take place by wind, insects and birds. The following are some examples of the different methods of pollination:

By wind (Anemophily) – Conifers, Betula, Alnus, Juglans

By birds (Zoophily) – Bombax, Butea, Erythrina, Anthocephalus, Oroxylum (the last two are pollinated by bats).

By insects (Entomophily) – Sal, Teak, Sissoo

## Flowering of Bamboo

Flowering of bamboos varies from species to species. While some species of bamboo flower after long periods with no flowering in between, others flower so irregularly that some flowers can be found practically every year. The periodic flowering occurs on practically all the clumps of the species over a considerable area. Thus, flowering in bamboo is of the following two kinds:

i) **Gregarious flowering** – It is the general flowering, within one or a few years, and over considerable areas, of all or most of the individuals of certain species that do not flower annually; in some cases followed by the death of the plant.

ii) **Sporadic flowering** – It is the flowering of one or a few culms in a clump or a few clumps in a locality.

In addition to the above two kinds of flowering, annual flowering is also met with in certain species of bamboos, e.g., Arundinaria wightiana, Bambusa lineata, Ochlandra stridula, etc. It is not followed by the death of bamboo.

**Interval between Pollination of Flowers and Ripening of Seed**

The interval between pollination of flowers and ripening of seed varies from species to species even in the absence of any adverse factors. The following table shows range of interval in a few species:

| l.No. Species | Interval in Months |
|---|---|
| 1. Ailanthus excels | 2 |
| 2. Tectona grandis | 3 |
| 3. Acacia catechu | 4-5 |
| 4. Dalbergia sissoo | 6-7 |
| 5. Cedrus deodara | 12-13 |
| 6. Pinus roxburghii | 24-26 |

**SEED**

After fertilization, the ovary grows and develops into a fruit, while its ovules, after a series of changes, develop into seeds. Thus the seeds are enclosed in the fruit. The plants in which the seeds are enclosed in the fruit, belong to a sub-division called angiosperms. In certain other plants, however, the seeds are not enclosed in the fruit but are directly borne on the open carpel. The plants which have such naked (i.e., not enclosed in fruit) seeds belong to a subdivision known as gymnosperms. In the angiosperms, the fruit as a whole, may fall to the ground on ripening but generally the fruits open up and only the seeds fall to the ground where they may germinate and produce the plants.

**Vegetative Reproduction**

In sexual reproduction, the creation of a new and independent plant is achieved by sowing the seed in the soil. In vegetative production, on the other hand, a new plant is created by some vegetative part of the plant e.g., a portion of the root or shoot (stem or branch), or a combination of both, a bud or even injured roots. Sometimes, however, after a plant has been utilized, its stump produces new plants. There are several methods of vegetative reproduction but in forestry only coppice, root sucker, cuttings (branch, stem or root shoot) and grafting are used.

**THE FOREST**

Definition - **Forest is defined as an area set aside for the production of timber and other forest produce, or maintained under woody vegetation for certain indirect benefits which it provides, e.g., climatic or protective.** This is the general definition of the term and lays emphasis on the direct and indirect benefits that the forests provide. But in **ecology, it is defined as a plant community predominantly of trees and other woody vegetation, usually with a closed canopy.** This definition describes the forest as a kind of vegetation in which trees constitute the predominant part, to distinguish it from vegetation in which grasses or shrubs may be predominant, and are fairly dense so that their crowns touch each other**. In legal terminology, forest is defined as an area of land proclaimed to be forest under a forest law**. This definition describes the forest not as a biological unit but as property having a owner and with rights or certain people. This definition is useful only in law courts, where cases pertaining to offences committed are tried. From the point of view of silviculture, the first two definitions are more important.

The term forest has generally been used so far in India to denote crops raised by the practice of silviculture. But in recent years, an American term 'stand' is also used. American foresters differentiate between 'stand' and 'forest'. According to them, **stand is defined as an aggregation of trees occupying a specific area sufficiently uniform in composition (species), age arrangement**

**and condition to be distinguishable from the forest on adjoining areas. Thus the unit of silviculture is a stand.** Forest, on the other hand, is a collection of stands administered as an integrated unit to obtain the objective of sustained yield.

**Classification of Forests**

Forests can be classified on the basis of

i) Method of regeneration

ii) Age

iii) Composition

iv) Objects of management

v) Ownership and legal status and

vi) Growing stock

**i) Classification based on method of regeneration** –

**Forests can be regenerated either from seed or from vegetative parts; those which are regenerated from seed are called high forests and those regenerated by some vegetative method are called coppice forests.**

**ii) Classification based on age** – Even in plantation raised in a particular year, all the trees are not of the same year because casualities are replaced in the second and third years. Thus forests having all trees of the same age, are usually not found. Therefore forests are classified on the basis of age into even-aged or regular forest and uneven-aged or irregular forest. Even-aged or regular forest is defined as a forest composed of even-aged woods. **The term even-aged used in this definition is applied to a stand consisting of trees of approximately the same age. Differences upto 25% of the rotation age may be allowed in cases where a stand is not harvested for 100 years or more.**

Uneven-aged or irregular forest is defined as a forest composed of trees of markedly different ages. **The term uneven-aged is applied to crops in which individual stems vary widely in age, the range of difference being usually more than 20 years and, in the case of long rotation crops, more than 25% of the rotation.** Such a forest is called selection forest when all or nearly all age gradations or age classes are present.

**iii) Classification based on composition** – A forest may have only one species or more than one species. On the basis of the number of species present, the forest is classified into pure or mixed forest. **Pure forest is defined as a forest composed of almost entirely of one species, usually to the extent of not less than 80%. It is also called pure crop or pure stand.** Mixed forest, on the other hand, **is defined as a forest composed of trees of two or more species intermingled in the same canopy; in practice, and by convention, atleast 20% of the canopy must consist of species other than the principal one.** The species composing the mixture may be distinguished as principal, accessory and auxillary. Principal species is defined as the species first in importance in a mixed stand either by frequency, volume or silvicultural value or the species to which the silviculture of a mixed forest is primarily directed. Accessory species is defined as a useful species of less value than the principal species, which assists in the growth of the latter and influence to a smaller degree the method of treatment. Auxillary species is defined as a species of inferior quality or size, of relatively little silvicultural value or importance, associated with the principal species. It is also referred to as secondary species or subsidiary species.

**iv) Classification based on objects of management** – On the basis of objects of management, forests are classified into production forest, protection forest, farm forest, fuel forest, recreation forest, etc. Production forest is a forest managed primarily for its produce. It is also sometimes referred to as national forest, i.e., a forest which is maintained and managed to meet the needs of the defence, communications, industry, and other general purposes of public importance. Protection forest is defined as an area wholly or partly covered with woody growth, managed primarily to regulate stream flow, prevent erosion, hold shifting sand or to exert any other beneficial influence. Farm forest is a forest raised on farms and its adjoining area either as individual scattered trees or a collection of trees to meet the requirement of fuel and fodder of the farmers and to have a beneficial influence on agriculture. Fuel forest is a forest raised on village wasteland to supply fuel, small timber, fodder, etc., to the village communities living far away from government forest. Recreational forest is a forest which is managed only to meet the recreational needs of the urban and rural population.

**v) Classification based on ownership and legal status** – On the basis of ownership, forests are classified into state forest, communal forest and panchayat forest. State forest is a forest owned by

state. Communal forest is a forest owned and generally managed by a community such as a village, town, tribal authority or local government, the members of which share in the produce or proceeds. Panchayat forest is any forest where management is vested in a village panchayat (i.e., a body of men elected by the villagers from among themselves for specific administrative or other purposes pertaining to the village). The state forests are further classified into reserved forest, protected forest and village forest on the basis of their legal status. A reserved forest is an area so constituted under the Indian Forest Act or other forest law. A protected forest is an area subject to limited degree of protection under the provisions of Chapter IV of the Indian Forest Act. A village forest is a state forest assigned to a village community under the provisions of the Indian Forest Act.

**vi) Classification on the basis of growing stock** – On the basis of growing stock, the forests are classified into normal and abnormal forest. Normal forest is defined as a forest which for a given site and given objects of management, is ideally constituted as regards growing stock, age class distribution and increment and from which the annual or periodic removal of produce equal to the increment can be continued indefinitely without endangering future yields. Such a forest by reason of its normalcy in these respects serves as a standard of comparison, for sustained yield management. Abnormal forest is a forest in which, as compared to an acceptable standard, the quantity of material in the growing stock is in deficit or in excess or in which the relative proportions of the age or size classes are defective. From the point of view of silviculture, only the first three bases of classification are important.

**Growth of Forest**

A forest starts its life as an aggregation of seedlings. In the beginning, the number of seedlings over a unit of area is very large but as the forest grows, the number of plants keeps on diminishing. Thus, the most important characteristics of growth of forest is the gradual reduction with age and size, of the number of plants per unit area. The growth of one forest differs from that of the other due to species, age, quality of site and biotic factor, etc.

**Growth in Even-Aged Forests**

Even-aged forest start their life as aggregation of seedlings of nearly the same age as a result of natural or artificial regeneration. While in the seedling crop resulting from natural regeneration, the seedlings are scattered all over the area without any regular spacing, the seedlings of artificially raised crops are generally in lines or rows. In the beginning, the seedlings have ample growing space and in case of conifers, the crowns extend right upto the ground. Before long, due to increase in size, the crowns touch each other. This results in a social struggle or competition for growing space.

**Crown differentiation** – As a result of competition for light and moisture, the inherently stronger trees grow rapidly and their crowns form the uppermost canopy. The less vigorous remain in the intermediate position while the weakest occupy the lowest position. As the trees grow further, competition becomes more intense and crown differentiation becomes more prominent. Due to difference in vigour of trees, all the trees in the upper canopy do not attain the same height and thus some trees are found to be ahead of the others. Thus even the top canopy consists of crowns reaching the highest level and those slightly below them. The trees in the middle position may continue to be there or get relegated to the lowest class due to being overtopped by the neighbours. Some of the trees, in the lowest position may die for want of light and food. Thus the following crown classes are generally met with in an even-aged forest.

**i) Dominant trees** – All trees which form the upper most leaf canopy and have their leading shoots free. These may be subdivided according to the position and relative freedom of their crowns into predominants, i.e., the tallest trees determining the general top level of the canopy and the codominants, i.e., the slightly shorter dominants or to be more precise, 5/6 of the predominants.

**ii) Dominated** – Trees which do not form part of the upper most leaf canopy but the leading shoots of which are not definitely overtopped by the neighbouring trees. Their height is about ¾ of the tallest trees.

**iii) Suppressed** – Trees which reach only about ½ to 5/8 of the height of predominants, with their leading shoots definitely over-topped by their neighbours or at least shaded on all sides by them.

**Crown development** – In addition to developing crown classes as a result of varying heights of trees, the social struggle also affects the shape and size of crown of individual trees. In the earlier stages crowns of seedlings cover a greater part of their stem and in conifers, they start from the ground level. As the seedlings grow, their crowns touch each other and the portion below the point of contact

gradually dies for want of light.  In other words, gradually the length of crown is reduced and it is confined to the upper portion of the tree, making the greater portion of the bole clear of branches.  The competition also affects width of the crowns.  While the crowns of the vigorous individuals are large, those of the dominated and suppressed trees are relatively smaller and constricted.  As the length and width of crowns of individual trees are affected, their crown development is affected.  The shape and size of the crown gives a good indication about the growth of the trees, in the past and present as well as the possibilities of the future.

**Reduction of number of trees with age** – The increasing space required by the trees as they grow in age can only be obtained by reduction in number of trees in the forest per unit area.  Thus in nature, as the forest grows, there is a gradual reduction in number of trees so that the rest of the trees may have enough space inside and outside the ground for their optimum and healthy growth.  As natural reduction in number affects the growth of the survivors in the social struggle, the foresters reduce the number of trees as the forest grows in age so that the growth of the crop is not adversely affected by excessive competition for food and light.

**Crop height and top height** – With the increase in height of individual trees with age, the height of the forest also increases.  The terms, crop height and top height, are used to describe it.  **Crop height is the average height of a regular crop as determined by Lorey's formula**.  The crop height is not of great significance as it varies for the same age and site quality with the intensity of thinning.

**Top height, on the other hand, is the average height of the dominant trees in a stand.  As used in sample plot work and yield tables in India, it refers to the height corresponding to the mean diameter (calculated from basal area) of the 250 biggest diameters per hectare as read from height/diameter curve**.  The top height at it varies with age is generally the basis for determining the site quality of any area.

**Crop diameter** – With the increase in diameter of the individual trees constituting a forest crop, the diameter of the crop also increases.  **The diameter of the forest crop is described by the term, crop diameter which is defined as the diameter corresponding to the mean basal area of a uniform, generally pure crop.**

**Crop volume – The sum of the volumes of the individual trees forming a forest crop is the volume of that crop.**  Yield tables for various species given data for volume per acre of a fully-stocked, regularly thinned, even-aged crops at different ages for different site qualities.  The crop volume is given for the main crop (i.e., the crop left after thinning), final yield (i.e., the main crop and the volume of thinning at that age) and the total yield (i.e., the final yield plus the accumulated yield of thinning at the previous age).

**Crop density** – The volume per unit area of a forest has to be compared with the volume given in the yield table for that site quality and age to determine whether the volume in the forest question, is equal to, more or less than the volume given in the yield table.  This is described by the term **crop density which is defined as the relative completeness of the stocking expressed as a decimal coefficient, taking normal number of trees, basal area or volume as unity.**  The terms over-stocked, full or complete, and incomplete are used to describe crop density, according as it exceeds, equals or is less than 1.0.


## FACTORS OF LOCALITY

Definition

Even a causal observation reveals that the forests occurring in various localities differ from each other in composition and density.  The forests found in the Himalayan region are not similar to those found in South India.  Even in the former, different types of forests are found in different places.  The difference is not confined to species of the dominant trees, their size, and their mixture with other species but it is also found in the composition of the middle storey, undergrowth and ground flora.  This, is due to the fact that the trees and other vegetation constituting a forest, are a living entity.  They grow in the soil and derive food from it.  Local temperature and wind affect their growth.  Rain water provides them with moisture and, therefore, its quantity affects their luxurance.  All living beings, i.e., man, animals, birds, insects, etc., living in or around the forest, have greater influence on its development.  Thus, from the time of germination to the time of felling or death, the trees and other vegetation forming the forest, are influenced by the climate, soil, topography and living beings of that place.  In other words, the type of forest occurring naturally in a place is not an accidental

aggregation of various plants out is the result of the complex influence of the climatic, edaphic, topographic and biotic factors of the locality. Thus the factors of locality may be defined as the effective climatic, edaphic, topographic and biotic conditions of a site, which influence the vegetation of the locality. These factors are also referred to as environment which is defined as all the biotic and abiotic factors of a site. As environment of forest is also referred to as site by foresters or habitat by ecologists, the factors of locality are also sometimes, referred to as site or habitat factors.

**Classification**

Factors of locality are classified into following four broad categories:

1) Climatic factors, 2) Topographic factors, 3) Edaphic factors and 4) Biotic factors

**CLIMATIC FACTORS**

The seeds require moisture, temperature, and air definitely and light to some extent for germination. These elements, which form part of climate of a place, are also required by plants for their growth. Thus climate exerts a great influence on the vegetation of a locality. In our large country, just as there is a great diversity in languages, customs, dresses, similarly there is a great diversity in climate as well. This is reflected in the large number of species and multiplicity of forest types found in our country. Our forests range from the dry thorn scrub of Rajasthan in the west to the wet evergreen forests of Assam and Meghalaya in the east, and from the tropical dry deciduous forests of the south to the alpine forests and scrub of Himalayas in the north. Climate is defined as the average weather conditions prevalent in any locality. Though it is dependent on various meteorological and weather conditions, the most important are solar radiation which gives light and heat both, moisture and wind. Therefore, climatic factors are defined as light, atmospheric temperature, pressure, and humidity, wind and other features of climate – regional, local and seasonal – that influence vegetation. Thus the climatic factors may be classified as under:

1) Solar radiation – a) Light, b) Heat and Temperature, 2) Moisture and 3) Wind

**SOLAR RADIATION**

The energy which is responsible for the growth of vegetation and all life depending on it, on this earth comes directly or indirectly from the sun. Thus, the nature and amount of solar radiation received on the surface of the earth is a factor of great importance. The energy radiated by sun reaches the earth in the form of electromagnetic waves of varying length, ranging nearly from 290 m m to 5300 m m (millimicrons) but the portion of the radiant energy by which objects are made visible due to stimulation of the retina of the eye and therefore, in common parlance, called light, ranges in wavelength from 400 mm to 720 mm. Energy composed of wavelengths shorter than 400 mm is known as ultra violet and that longer than 720 mm is known as infrared. The total energy received from the sun may be classified on percentage basis as under:

Ultra violet  - about 1%

Visible spectrum - about 39%

Infrared  - about 60%

The maximum energy of solar radiation occurs in the green and yellow regions of the visible spectrum (400 mm to 720 mm). Since the heat produced by the radiation is independent, in its effect, of the wavelength, the intensity of the radiation is generally measured by the heat generated by it. The full solar radiation that should reach the earth, does not actually reach it. The atmosphere surrounding the earth partly reflects it back and partly absorbs it also. Similarly the clouds, other solid particles in the atmosphere, and the vegetation absorb as well as reflect back part of it. Even on reaching the earth part of it is absorbed while some part of it is reflected back. It has been estimated that 42% of the incoming radiation is reflected, and this is known as albedo. The solar radiation reaching the earth is further affected by latitude, altitude, season of the year and time of the day. As latitude increases, the intensity of solar radiation decreases. With increase in altitude, the turbid layer of the atmosphere, through which the radiation has to pass, decreases and, therefore, the radiation increases. The most important effect of solar radiation is that it provides both light and heat (temperature); as both are very important, they are being described separately.

**LIGHT**

**Importance of Light**

Light is a very important factor of locality because of its following effects on plants and other vegetation:

**1. Chlorophyll formation** – Light is one of the important and essential factors responsible for chlorophyll formation in plants. Though lower plants, such as, algae, mosses and ferns and some coniferous seedlings can develop it even in darkness, yet the quantity of chlorophyll so formed is less than that formed in light. In the angiosperms, however, light is essential. Light of any wavelength or low intensity is sufficient to form chlorophyll. Without light, plants become pale yellow and have long thin internodes, a condition known as etiolation. Chlorophyll decomposes in bright sunlight, thus formation and decomposition both go on simultaneously when the plant is exposed to light.

**2. Functioning of stomata** – Light is an important factor influencing the daily opening and closing of stomata which, in turn, affects respiration and photosynthesis.

**3. Photosynthesis** – Light is the most important factor of locality for photosynthesis as it can not take place in darkness. Out of the seven colours in the visible part of the spectrum, only red and blue are effective in photosynthesis. The light actually used in photosynthesis is a small fraction of the total light that falls on a leaf. There are two main factors responsible for it. The thickness of the leaf and its chlorophyll content allow only a portion of the light to be absorbed. The rest is either reflected back or transmitted through it. Most of the light energy absorbed is used up in raising the temperature of the leaf and is lost as heat or consumed in transpiration. It has been estimated that light used in photosynthesis is less than 2% of the light energy incident on well-illuminated leaves. As the light actually required for photosynthesis is so low, there is usually sufficient light even in dense forest for this important physiological activity. In very dense forests, however, light intensity may be so low that the photosynthetic gains may not be able to balance the loss due to respiration.

**4. Growth** – Light influences the growth of plants and trees through its effect on photosynthesis. The influence of light varies with its quality, duration and intensity. Quality of light refers to the wavelength of the light spectrum or, in other words, refers to colors. Plants grown in blue light are small but otherwise show normal growth. Red light, on the other hand, results in elongation of cells, giving the appearance of etiolated plants. Violet and ultra violet light bring about dwarfing effect. For example, preponderance of ultra-violet radiation combined with slow absorption of water due to low temperature and desiccating winds is responsible for limiting the heights of plants in alpine region.

Duration of light or the length of exposure to day light also affects the growth of plants. The duration of light or, more correctly, the relative length of day and night to which the plant is exposed is called photoperiod and the response of the plants to photoperiod is called photoperiodism which is defined as reponse in the ontogeny of an organism to relative duration of day and night. Photoperiod varies with altitude and latidue. In higher latitudes, where seasonal differences are marked, photoperiod is particularly important. It affects the growth, breaking of dormancy, germination, leaf fall and flowering. In many species, the duration of growth is related to the lengthbof the day; quite a few species can be grown continuously throughout the year in artificially created conditions of long days. Dormancy of trees can be broken by lengthening the day artificially under favourable temperature conditions. Photo periodism varies with species, e.g., short days may cause dormancy in Populus but not in Juniperus.

**5. Form and quality of trees** – The elongation of the growing axes of trees in the forest occurs mainly between sunset and sunrise because the low intensities of light and infrared radiation tend to stimulate height growth. Height growth is retarded in intense light conditions. Trees growing in shade are usually taller than those of the same age growing in open provided other factors of growth are not restricted. Even the form of trees growing in shade is very dissimilar to that of trees growing in the open. Deficiency of light due to shading effect of upper branches is responsible for the death of lower branches on the stem of trees growing in congested crops, resulting in their having long clear boles. The continued restriction of the crown in the upper part of the tree results in formation of much more cylindrical stem than would otherwise be formed. Thus regulation of light gives forester a powerful weapon to regulate the form of trees and quality of timber produced in the forest.

**6. Species stratification and size and structure of leaves** – The intensity of light in the forest varies from place to place and from time to time between wide limits. While the top canopy has full light, the canopies lower down receive only that much light which escapes the top canopy. Thus the light reaching the forest floor is considerably less. It also depends upon the locality and the density of crop. This results in the stratification of species in different canopies according to the requirement of

light. In natural undisturbed conditions, the vegetation itself gives an indication of light conditions in the forest. For example, Ardesia solanacea is indicative of damp shady places in sal forest.

# TEMPERATURE

Factors Affecting Temperature

As already mentioned, the source of all heat is solar radiation. While the energy received is constant, the temperature of various places on the earth is different because it is affected by the following factors:

**i) Latitude** – Latitude is defined as the distance of a place, north or south of equator, measured as an angle whose apex is at the center of the earth. The ray of the sun strike the earth vertically at the equator and therefore the temperature is highest at equator. As we move to the north or south from the equator, the temperature decreases because the sun's rays become oblique. Thus as the latitude increases, the temperature decreases. In the Indogangetic plain, the normal fall in the mean temperature is estimated to be roughly $0.55^oC$ for increase of each degree in latitude. The effect of latitude on temperature is, however, modified by other factors, e.g., altitude, distance from the sea, wind, etc.

**ii) Altitude** – The altitude of place also affects the temperature. It has been observed that there is a fall of $1^oC$ in mean temperature in the hills for every 270 m rise in altitude upto about 1500 m, after which the fall is more rapid. The marked difference in the mean temperatures of Nainital and Muzaffarnagar in U.P. and Simla (H.P.) and Jullundur (Punjab) situated on the same latitudes, is only due to their varying altitudes.

**iii) Distance from the sea** – Sea has a moderating effect on temperature; the farther a place is from the sea, the greater are the diurnal and seasonal ranges of temperatures.

**iv) Winds** – The winds affect the temperature, and if they are from the sea side, their effect is still more marked. In our country, south west monsoon brings rain and reduces the temperature to a great extent.

**v) Mountains** – The direction of the mountain ranges affects temperature through its effect on winds and rainfall. As the windward slopes bear the brunt of the winds and rainfall from monsoonic winds, they have lower temperature than that on the
leeward side. The slopes of the mountain on which sun's rays strike vertically are warmer than those on which they strike obliquely. That is why southern slopes of mountains in northern hemisphere are hotter than the northern slopes.

**vi) Cloudiness** – As clouds screen off the sun, their presence of affects temperature.

**vii) Presence or absence of forest vegetation** – The rays of the sun strike bare sites directly; such place are, therefore, hotter than the places covered with forest vegetation. The crowns of trees obstruct the rays of the sun before they can reach the ground and thus reduce the temperature of the place.

**Importance of Temperature**

The solar radiation warms up the atmosphere and the soil, thereby raising their temperatures. The temperature of the atmosphere affects the activities of shoots of plants while soil temperature influences those of their roots. Through its effect on plants, temperature has a profound influence on forest vegetation.

**Air temperature** – Air temperature influences the plants in the following ways:

i) The solar radiation directly as well as through its influence on air temperature, provides heat to the plant body and helps in satisfactory initiation and continuation of various physiological activities, e.g., transpiration, photosynthesis and respiration. High temperature increases transpiration while low temperature decreases it. Though photosynthesis takes place under a wide range of temperatures varying with species and locality, increases in temperature upto $25^oC$ increases photosynthesis, after which it deceases sharply. The rate of respiration increases as temperature rises from $0^oC$ to $40^oC$ but it decreases in temperature lower than $0^oC$ and higher than $40^oC$. Thus temperature exerts a greater influence on the vital physiological activities of trees.

ii) Air temperature increases microbiological activity on soil surface resulting in decomposition of organic matter and release of nutrients to be available to trees.

iii) Air temperature affects activities of enzymes, which are practically stopped at temperatures above $50^oC$ or below $1^oC$.

iv) Air temperature increases cambial activity in the shoot portion.

v) Through its effect on the vital physiological activities and cambial activity, air temperature affects growth of trees.

vi) Temperature is essential for germination of seeds.

**Soil temperature** – Soil temperature influences trees in the following ways:

i) Soil temperature has a profound influence on absorption of soil moisture which increases markedly with the rise in temperature upto a certain limit. When soil temperature rises above 35°C, there is a decrease in absorption as the permeability of plasma membrane is adversely affected. On the other hand, if there is a fall in soil temperature below 27°C, water absorption is greatly reduced till at 0°C it becomes insignificant. Cold soils are, therefore, physiologically dry.

ii) Soil temperature also affects cambial activity, particularly in temperate climate. Cambial activity in trees starts earlier in warmer soils than in colder soils. Thus growth starts earlier in warmer soils than in colder soils. In short, increase in temperature creates conditions in which trees and other vegetation grow well. This means higher temperature is indicate of multiplicity of vegetation while low temperature that of limited vegetation.

## FROST

Frost means chilling of air below the freezing point. Depending on the mode of occurrence, it is classified into:

i) Radiation frost

ii) Pool frost and

iii) Advective frost

i) **Radiation frost** is defined as the frost occurring on nights with a clear sky, produced by loss of heat by radiation. It is defined as freezing confined to ground level, ice crystals forming on the surface objects, soil or ground vegetation.

ii) **Pool frost** is defined as the accumulation to a considerable depth of heavy cold air flowing down into natural depressions from adjoining areas. This has more deleterious effect on vegetation than ground frost as the freezing effect extends to a considerable height.

iii) Advective frost is defined as a frost produced by cold air brought from elsewhere. Frost pocket, frost hole or frost locality which is defined as an area in which frosts are more frequent and more intense than in the district generally. Frost free season which is defined as the period between the last injurious frost in spring and the first injurious frost in the autumn.

## Frost Injuries

The injuries inflicted by frost may be of the following kinds:

i) Killing of young plants or their parts

ii) Death of plants due to damage to cells

iii) Injuries to the crowns of poles and saplings

iv) Frost cracks

v) Formation of canker

## Frost Hardy and Frost Tender Species

The species which posses power to withstand frost without being damaged are called frost hardy. Frost hardiness varies from species to species and in the same species with age, because some species are affected by frost in earlier stages but can withstand it later. The species which are killed back by frost are called frost tender. A list of some frost hardy and frost tender species is given below:

**Frost hardy** – *Acacia catechu, Hardwickia binata, Madhuca indica, Toona ciliata, Pinus roxburghii.*

**Moderately frost-hardy** – *Adina cordiforlia, Bombax ceiba, Dalbergia latifolia, Gmelina arborea*

**Frost tender** – *Acacia arabica, Azadirachta indica, Tectona grandis, Terminalia arjuna*

## Factors Affecting Frost Resistance

Frost resistance in trees depends on internal (i.e., those relating to the cells in plant body) and external (i.e., those relating to environment) factors described below:

**A) Internal Factors**

i) Size of cell – Plants with smaller cells are usually more frost hardy than those with larger cells.

ii) Water content – The greater the amount of water, the greater the danger of inter-cellular or intracellular ice formation.

iii) Osmotic concentration – The greater the osmotic concentration within the cells, the greater the resistance to frost because, as freezing point of the cell sap would be lower, there would be lesser likelihood of internal ice formation.

iv) Permeability to water – The higher the permeability of the protoplasm to water, the greater is the frost resistance.

v) Water binding colloids – The greater the water binding colloids in cells, the greater the frost resistance because their presence results in (a) reducing the amount of free water that can be frozen, (b) making internal ice formation less likely and (c) reducing the amount of water that can be removed on external ice formation.

**B) External Factors**

i) Temperature – A rapid fall in temperature is much more injurious than its gradual fall even for partially hardy plants because rapid fall increases danger of internal ice formation. Continued freezing for many days causes greater damage with the result that even plants resistant to start with are affected. Frost resistance varies with seasons; plants which can withstand extremely cold conditions during winter, may be killed by slight frost during spring. Increase in temperature even for a short period during winter, decreases frost hardiness. On the other hand, frost hardiness increases if the plants are gradually exposed to increasingly low temperature before the advent of winter.

ii) Light – The lesser the duration of light, the greater the frost hardiness as reduced photoperiod and low temperature result in cessation of growth. Consequently the reserve carbohydrate are converted into sugar resulting in increased frost resistance.

iii) Mineral nutrition – Nitrogen stimulates vegetative growth and therefore reduces frost hardiness. On the other hand, application of potassium and phosphorus generally increases it.

**Hardening Off**

Hardening off is the natural process by which plants become adapted to drought, cold or heat. For preparing seedlings in a nursery for planting out by gradually reducing watering, shade and/or shelter resulting in hardening of plant.

**SNOW**

At higher altitudes, the decrease in temperature results in precipitation taking the form of snow. The amount of snowfall and the period during which it remains on the round depends upon temperature and the amount of winter precipitation. Snow occasionally falls down to 1200 m in north western and central Himalayas but it stays only above 2000 m. In the eastern Himalayas and the south, the altitude to which snow falls, is higher.

**Beneficial Effects of Snow**

i) Snow influences the distribution of deodar, fir and spruce and their best forests are found in places of heavy snowfall. Heavy water snowfall is essential for satisfactory natural regeneration of deodar.

ii) Snow is the source of water in streams and rivers. All perennial rivers and streams have their origin from snow glaciers.

iii) Snow acts as a blanket, prevents further drop in temperature and thus protects seedlings and other vegetation from the damaging effect of excessive cold and frost.

**Injurious Effects of Snow**

i) Snowfall results in the mechanical bending of stems of trees. Snow gets accumulated on the uphill side of the young saplings and poles and causes them to bend outward at the base. This curve is maintained even when the poles develop into trees and can be seen on all mature trees. The bend makes this portion of the tree unfit for utilization. As this portion of the stem has maximum diameter, there is a great loss in volume.

ii) Accumulation of snow on the crowns of trees results in breaking of branches and tops of trees. Kail is most susceptible to snow break and deodar comes next.

iii) Sliding snow not only causes erosion but also uproots trees. Often snow slides wipe out strips of forests along their course. The folds of the hills, in which snow slides regularly, are devoid of vegetation and thus a fair amount of area is without tree growth.

iv) Snow shortens the period of vegetative growth

v) Snow is reported to favour the growth of certain fungi, e.g. Fomes, Trametes

**Effect of Excessively High Temperature**

i) Excessively high temperature is injurious to plant life. There is an optimum and maximum temperature for growth and other physiological activities. Above this optimum temperature, growth is adversely affected but after the maximum is crossed, the life processes may cease and the plant may die. The highest temperature that can be withstood by plants varies from species to species but for most higher plants, the range of lethal temperature lies between 45$^{o}$C to 55$^{o}$C, though they may also

be killed by continuous exposure to temperatures above 40oC. The death resulting from excessively high temperature usually occurs due to coagulation of protoplasmic proteins.

ii) Even if temperature between 35oC to 40oC may not kill the plant, it disturbs the balance between respiration and photosynthesis. The optimum temperature for photosynthesis is lower than that for respiration. When the optimum temperature for photosynthesis is exceeded, the synthesis of food deceases but its breakdown in respiration continues at a high rate. This causes depletion of food resulting in greater susceptibility to attacks of fungi and bacteria.

iii) Excessively high temperature results in deficiency of moisture. Silver fir seedlings are reported to start wilting as soon as temperature reaches 38oC. Sometimes, seedlings die due to heating of soil surface, resulting from excessively high temperature. The sandy soils get heated excessively and this is a common cause of death of seedlings in such soil.

iv) Excessively high temperature results in excessive transpiration and this may result in desiccation of plant tissues. Increased transpiration combined with deficiency of moisture in the soil results in death of plants.

v) Excessive heat, sometimes, results in developing cracks in stem due to excessive shrinking of the outer tissues. This happens particularly in species having thin bark.

**MOISTURE**

Moisture is one of the most important factors influencing vegetation, because water is essential for various physiological activities of plants as well as for soil formation processes.

**A) Importance in Physiological Activities**

1. Water forms about 90 to 95% constituent part of the cell wall and 80% part of the protoplasm which is the physical basis of all life.

2. Water occurs in all the cell vacuoles as cell sap and on it depends the turgidity of the cells, which in turn, governs the growth of plants.

3. It is the only medium for absorption of soil minerals and gases in the plants

4. It is one of the raw materials required for photosynthesis

5. It is required for translocation of manufactured food as well as for all chemical reactions taking place in plant body

6. It is essential for respiration which cannot take place in its absence

7. It is also necessary for transpiration which prevents excessive heating of the plant

8. It is responsible for various movements of plants

9. It is essential for germination and viability of seeds

**B) Importance in Soil Formation Processes**

Water is required for physical as well as chemical weathering, which are the most important soil forming processes. It is also required for translocation of the products of weathering and is, thus, an important factor in soil formation.

**C) Influence on Vegetation**

Because of its great importance in the vital processes of plant life as well as in soil formation, water exerts a profound influence on vegetation. It determines the nature of vegetation that would survive in a particular area. In other words, it determines the species that would grow, their number per unit area, height, diameter and volume growth of trees and other vegetation. It is therefore used as basis for classifying vegetation in broad temperature zones.

**HUMIDITY**

Presence of water vapour makes air humid; humidity refers to that state of air of the atmosphere in which water vapour is present. The amount of water vapour actually present in the atmosphere at a given time at a given temperature is a measure of atmospheric humidity. It is described by the terms absolute humidity, relative humidity and saturation deficit. Humidity affects evaporation and transpiration and consequently the vegetation. Lower the relative humidity, the greater the evaporation from the soil and higher the transpiration from the plants. As humidity affects the availability of moisture to plants, it is a factor of importance particularly in dry and arid areas where only those species can survive, which have well developed contrivances to resist transpiration.

**WIND**

Wind has a great influence not only on the form of trees but also on their distribution. It has favourable as well as harmful effects on trees.

Harmful effects – These may be caused both by direct and indirect action of wind.

Direct Harmful Effect

1. Because of the pressure of the wind, the tree in the open in the plains and on the ridges on the hills are short-statured and have pronounced taper in their boles.
2. Trees often get bent if wind blows only in one direction
3. Trees are often uprooted or their stem or branches get damaged. The trees which withstand strong winds without being over thrown or broken are called wind firm. But the trees which are uprooted are referred to as wind fall or wind throw. In case only the stem is snapped from some place or the branches are damaged, it is referred to as wind break
4. The branches on the windward side get, often killed and they remain only on the leeward side. This adversely affects the growth on one side
5. The bole of the tree, often, becomes elliptic with larger diameter in the direction of the prevailing wind
6. As a result of strong winds, timber often gets ruptured

Indirect Harmful Effects

1. Wind fans up forest fire thereby increasing fire damage
2. Wind affects the trees through its influence on humidity. Dry winds lower theamount of atmospheric water vapour by mixing it with dry air and thereby increase transpiration
3. Winds also increase evaporation from the soil
4. In dry areas, wind causes wind erosion. It removes the top fertile soil or deposit sand on fertile fields, thereby deteriorating the soil in both cases
5. Along sea coast wind-bronze salt spray, often results in considerable injurious effect on sensitive plants
6. Strong cyclonic winds to immense damage not only to trees but also to other property and agricultural crops

**Favourable Effects**

1. Wind brings fresh supplies of carbon dioxide to the foliage of trees and thus
helps in photosynthesis
2. Wind helps in pollination of anemophilous flowers
3. Wind helps in dispersal of seed of many forest trees, e.g., Holoptelia, Bombax, Hymenodictyon, Toona, etc.

**BIOCLIMATE**

The various climatic factors influence the vegetation collectively but not individually and separately. Thus the vegetation of a place is the result of various climatic factors acting together. While affecting vegetation collectively, these factors modify the influence of each other to certain extent. Therefore, each climatic factor has to be modified or adjusted in such a way that it may describe the influence of the collective complex climatic factors on plant life. The climate defined by these modified or adjusted climatic factors is called bioclimate. For example, total rainfall of a place will have a certain effect on vegetation. But the effect of total rainfall is modified by the number of rainy days. A certain amount of total rainfall with larger number of rainy days will result in a different vegetation than the same total rainfall and small number of rainy days is further modified by the amount of evaporation taking place in that locality. Therefore, in order to describe the correct effect of rainfall as a climatic factor, the total rainfall will have to be modified by the number of rainy days and evaporation.

**Topographic Factors**

Topography is the description of the physical features of a place. It describes configuration of the ground, its altitude, slope, aspects, etc. These physical features affect the local climate, soil formation processes, soil moisture, soil nutrients, etc., and since all these have a profound influence on vegetation, topography affects the vegetation indirectly. Thus topographic factors may be defined as factors pertaining to the configuration of land surface viz., altitude, slope, aspect and exposure. These factors have a great influence on vegetation through their influence on climatic and edaphic factors which have a direct bearing on vegetation of a place.

Topographic factors may be classified into:
i) Configuration of land surface, ii) Altitude, iii) Slope and iv) Aspect and exposure.

**i) Configuration of land surface**- It affects the vegetation through its effect on temperature, wind movement etc. In hilly and valley countries, valleys are generally shaded. Due to high hills sunlight

reaches the valleys late hence they are colder in winter. In summer though shade prevents rise in temperature early in morning yet heat radiated from nearby hills makes them extremely hot after sometime and this radiation continues till late night. Hence valleys have far greater variation diurnal and seasonal temperature

Wind movement is also affected by valley and hilly areas, the blowing of strong noisy wind up and down the valley, locally called as 'Dadu' is such common feature. Monsoonic winds are often affected by this configuration of land.

**ii) Altitude-** It affects solar radiation, temperature, rainfall which in turn have great effect on vegetation.

In higher altitude air is clear and rare hence solar radiation has to pass through lesser turbid atmosphere. The intensity of solar radiation increases with increase in altitude.

Temperature decreases with increase in altitude as air gets rarer and incapable of absorbing and retaining heat. Up to 1500m there is fall of $1°C$ in mean temperature with rise of 270m in the hills but after 1500 m the fall is rapid. The temperature requirement of each species differs, above and below that range the species get replaced by another.

Rainfall mechanism is governed by presence of mountain range it is a very effective barrier for the monsoon. However even on a mountain range the zone of maximum precipitation is usually much below the top due to reduction of water vapour content in clouds before reaching top.

iii) Slope – It affects runoff and drainage and thus has a profound influence on moisture regime of soil. Slope modifies intensity of solar radiation and thus affects temperature & moisture of surface soils. As the top soil of the hills keeps on getting washed with rain water, the humus content of these soils is low as compared to that of soils in the valleys or plains where the washed soil with humus gets deposited.

iv) Aspect & Exposure - Aspect is defined as 'the direction towards which a slope faces'. Exposure on the hand is defined as 'the relation of a site to weather conditions, especially sun and wind'. These both determine amount of insolation received by a hill slope

Similarly proximity of sea makes climate of coastal areas different from that of places in the hinterland.

Even though the climatic factors such as light, temperature, rainfall, humidity and wind define the general climate of a region, certain variations are often met with in localized places due to the effect of the topography, soil climate, or the vegetation itself.  The difference in the growing conditions in that particular place affects vegetation locally although the general vegetation type may change or not.  Thus, microclimate is defined as the climate of small areas, which for some reason, differs significantly from the general climate of the area, more particularly, the climate outside that cover. The effect of topography on solar radiation, temperature, rainfall, humidity and wind has already been described.  The effect of forest cover on these important factors is described below:

**Solar radiation** – Forest cover reduces the intensity of solar radiation reaching the forest floor in an inverse proportion with its density, i.e., the denser the cover, the lower the intensity of solar radiation reaching the forest floor.  As the amount of light affects temperature, atmospheric humidity, soil moisture regime, it has a great influence on the nature and density of vegetation and regeneration of various species.  As the requirement of light of seedlings of various species is different, canopy has to be manipulated to admit sufficient quantity of light to induce regeneration to come up.  Chaturvedi found a direct relationship between incident light and the density of bamboo clumps.  He found that when over wood was clear felled and maximum light admitted on the forest floor, largest number of new clumps were obtained.

**Temperature** – Forest cover makes the temperature, both of the air and soil, more equable than it is in the open.  This is due to the fact that forest cover acts as a screen and prevents sunrays from heating the air and the soil inside the forest to the same extent as it does in the open.  During the night, this screen prevents the loss of heat by radiation.  The result is that mean maximum temperature of the air inside the forest is lower and the mean minimum temperature higher.  The effect on temperature inside the forest varies with species.  For instance, studies in new forest revealed that the temperature under a cover of Casuarina equisetifolia was the lowest during the summer and highest during winter. On the other hand, temperature under cover of Pinus roxburghii was highest during summer and lowest during winter.

Rainfall – Though influence of forest in increasing the total rainfall of a place has been disputed, there is no doubt that forests exercise considerable influence in increasing the number of rainy days over limited regions. Studies made in Nilgiris before and after afforestation have indicated that the presence of forest increases the number of rainy days during that period of the year when monsoon is not active.

Dew – Observations made at new forest have revealed that there is no dewfall immediately below the crowns of trees in a forest, though there is some dewfall in the openings in the canopy.

Humidity – It has been estimated by Seth that a sal forest of 37 years age and containing 778 trees per hectare transpires about 1200 mm of water annually. Thus, forests have a favourable effect of humidity. Warren observed that while humidity of treeless Ranchi plateau dropped to 5 in hot dry summer, humidity of Chaibassa in the neighbourhood of Singhbhum forests never dropped below 50. Forests increase humidity not only of the adjoining areas but also inside themselves.

Evaporation – As forests reduce solar radiation reaching the forest floor and consequently temperature and wind velocity inside, they reduce evaporation of moisture from the forest floor. Reduction in evaporation depends upon the type of forest, its age, density as well as the moisture regime of the soil. However, it has been estimated that evaporation from forest floor may be 10 to 80% of that in the open.

Wind – A strip of trees and shrubs reduces wind velocity considerably. The reduction in wind velocity, the height and distance to which it is affected, is dependent on the height of trees and their density. That is why wind breaks are established around orchards and shelterbelts are raised in areas experiencing wind erosion or desiccating effect of cold winds. In case of a forest, the influence of height of trees and their density on wind velocity is further affected by the length and breadth of the forest. It has been estimated that inside the forest, the reduction of wind velocity may be from 20 to 60% of that in the open. However, the efficiency of forest in decreasing wind velocity on the leeward side of the forest is considerably less as compared to that of a shelterbelt.

**Importance of Microclimate**

Microclimate is of great importance in the practice of Silviculture. If proper attention is not given to this important factor, silvicultural operations, such as natural or artificial regeneration, may fail completely due to the local adverse or limiting factors responsible for the microclimate. The following examples will illustrate the importance of microclimate:

1) As already stated, microclimate of different aspects of hills in the temperate zone of Himalayas is different and that is why on the two sides of a ridge two different species occur towards the upper limit of deodar altitudinal zone. This is due to the fact that northern aspect at that altitude is too cold for deodar. If deodar is planted on the northern aspect at that altitude in utter disregard of the microclimate, the attempt is bound to fail. Even in deodar zone, warmer aspects are occupied largely by Kail. Attempts to replace Kail by Deodar in such places are never successful as the microclimate of these aspects is not suited to deodar.

2) In the upper reaches of subtropical zone, northern aspects become too cold for Chir which is replaced by Kail in nature. Sowings of Chir in such places are not likely to be successful.

3) In Dehra Dun valley, pool frost is a common occurrence. If, in utter disregard of this factor, clear felling followed by sowing or planting may be done to raise a new crop, it is bound to fail.

4) If, in the introduction of an exotic, climate and microclimate of its natural habitat are not taken into consideration and it is introduced in areas with different climate, it is not likely to succeed.

**EDAPHIC FACTORS**

Edaphic factors are defined as ecological influences characteristic of the soil brought about by its physical and chemical characteristics. Thus, edaphic factors are factors which relate to the soil in which the trees grow and which, therefore, forms environment of roots.

**Definition of Soil**

Soil has been defined variously by geologists and pedalogists. The Indian Forest and Forest Products Terminology following pedalogist's view, defined soil as the upper most weathered layer of the earth's crust and recognized the following two subdivisions:

i) Surface soil - The more or less completely weathered surface layer, rich in soluble material and containing a relatively higher proportion of organic matter and fine earth; also called top soil. The zone of aeration and intense root and micro-biological activity.

ii) Sub-soil – The layer immediately below the surface soil which is incompletely weathered and contains much less of soluble ingredients, organic matter and fine earth. This definition, though correct, is not comprehensive because forests, sometimes, grow on rocks. The following two definitions are suitable from the point of view of foresters:

i) Forest soil is defined as a portion of earth's surface which serves as a medium for the sustenance of forest vegetation; it consists of minerals and organic matter, permeated by varying amounts of water and air and inhabited by organism; it exhibits peculiar characteristics impressed by the physical and chemical action of tree roots and forest debris – Wilde.

ii) Soil is defined as a dynamic layer of surface material which is constantly changing and developing under processes of adjustment to conditions of climate, parent material, topography and vegetation – Champion and Seth.

## SOIL FORMATION

The factors responsible for soil formation and development are climate, biological agencies including vegetation and animals, parent rock, topography and time. The first two of these factors are referred to as active factors because it is through their action that soil formation takes place. As the last three do not take any active part in soil formation, they are referred to as passive factors. Actually, it is only when the active factors, having been modified by topography, act on the parent material for considerable length of time that the soil is formed. The active factors results in the formation of soil through their effect on a geological process known as weathering which is defined as all physical and chemical changes produced in rocks, at or near the earths surface, by atmospheric agents and which result in more or less complete disintegration and decomposition. The weathering process is of two kinds, viz., physical and chemical weathering.

Physical weathering – Physical weathering is the physical disintegration or breaking up of rocks resulting in exposure of their larger surface for other forces to act. It is mainly the result of climatic factors. Temperature changes result in unequal expansion and contraction and, therefore, in breaking up the rock. As there is a great diurnal variation in temperature in most parts of India, this is a very important factor. In higher hills, water, lying in the crevices of rocks, is frozen at night and therefore expands in volume resulting in disintegration of rocks. Moving water erodes them and ultimately breaks them. Moving glaciers also result in fragmentation of rocks. Strong winds with sand particles in them, keep on sculpturing the rocks.

## Physical Properties of Soil

Physical properties of soil have a profound influence on tree growth because of their effect on the supply of moisture, nutrients and air. They affect the supply of moisture directly by affecting its movement, storage and availability and nutrient supply and air through their effect on water. The physical properties of soil relate to its texture, structure, porosity, etc.

## 1. Soil Texture

Soil texture is defined as the relative proportion of the various size groups of individual soil particles; the individual size groups are referred to as soil separates. The following soil groups are recognized:

Clay – particles smaller than 0.002 mm
Silt – particles between 0.002 mm and 0.02 mm
Find sand – particles between 0.02 mm and 0.2 mm
Coarse sand – particles between 0.2 mm and 2.0 mm

Depending on the proportion of soil separates, soils are classified into different soil classes. A soil class is defined as a group of soils having same range in particle size and physical properties based on texture. For practical purposes, soil classes can be grouped as follows:

Coarse–textured soils, viz., sand and sandy loams
Medium–textured soils, viz., loams and silt loams and
Fine–textured soils, viz., clays and clayed loams
Coarse-textured soil is also called light soil. Similarly, the fine-textured soil is called heavy soil.

## Importance of Soil Texture

i) Moisture relations – The percentage of finer particles governs the quantity of moisture that can be held by the soil and the amount that would be available to plants. Coarse-textured soil are easily drained and apt to be dry while, on the other hand, fine-textured soils are poorly drained and hold much water on the large surface area.

ii) Nutrient supplies – The percentage of finder particles governs nutrient status of the soil. The fine-textured soils are high in nutrient status, sandy soils, on the other hand, are low in fertility. The sandy soils support either pioneers or hardy species with low moisture and nutrient requirement, examples being sissoo and chir respectively.

iii) Aeration – Texture of the soil regulates pore space and consequently the aeration of the soil. Coarse-textured soils are better aerated than clayey soils.

iv) Root development – Texture of the soil affects root development.

**2) Soil Structure**

Soil structure is defined as the arrangement of individual soil particles into aggregates of definite size and shape. Thus, while texture refers to the actual size of soil particles, structure refers to the mode of grouping of these particles into aggregates. Soil aggregate is defined as a single mass or cluster of many soil particles held together, such as clod, prism, crumb or granule.

On the basis of structure, the soils are described as follows:

i) Single-grained – It is a structureless condition of the soil, each grain being independent, as in dune sand.

ii) Massive – It is a structureless compacted condition of the soil, showing no distinct arrangement of soil particles. It is common in podsols and ill-drained soils. It is often the result of overgrazing or agricultural misuse of land.

iii) Crumby – A soil is called crumby when it has crumbs. A crumb is a small aggregate of irregular shape and 3 mm or less in diameter, formed by the cohesion of a number of soil particles. The condition in which the soil particles form water stable crumbs largely by the physical and physico-chemical action of soil organic matter is called crumb structure.

iv) Granular –It is a type of soil structure in which the soil aggregates are more or less sub-angular or rounded in shape and of size upto 6 mm in diameter. It is commonly found in mull humus layers in brown earths.

v) Blocky or nutty – A soil is called blocky or nutty when it has a nut structure which is defined as a soil structure in which soil aggregates are compact, more or less rounded in shape and 6 mm to 25 mm in diameter.

vi) Cloddy – A soil is called cloddy when it has irregularly shaped aggregated of medium to hard consistency and more than 25 mm in diameter.

**Importance of Soil Structure**

i) Structure is the most important physical property of soil as it affects soil moisture and soil air relations

ii) It is an indication of nutrient status and activity of microorganisms in the soil

iii) If affects soil erosion. Crumb is least liable to erosion while single-grained structure is most liable to erosion

3) Soil Porosity

Soil porosity is defined as the extent to which the gross volume of the soil is unoccupied by solid particles. The space unoccupied by soil particles is also known as pore space. Soil porosity is of two kinds:

i) Capillary porosity – It is the portion in a soil which is not filled by water when the soil is wet but well drained.

ii) Non-capillary porosity – It is the air space in a soil at field moisture capacity.

**Chemical Properties of soil**

Soil is the chemical laboratory of nature in which various chemical decomposition and synthesis reactions keep on taking place.

**1. Cation exchange capacity**

It is defined as total capacity of the soil for holding cations and is expressed in erms of milli-equivalents per 100gms of oven dry soil.

Clay and humus in soil form organic and inorganic colloids. though it has both positive and negative charge , yet negative charge s much more greater in magnitude. It has therefore thecapacity to absorb cations from soil solution. The absorbed cations are Ca, Mg, K, Na and H.

Importance of CEC

1) It is storehouse of mineral nutrients which cannot be leached away easily and are available to plants.

2) CEC determines rates at which fertilizers to be applied to nursery and plantation soils. ex- In fine textured soils where CEC is high, large amount of fertilizers can be applied as they will be absorbed however cannot be done in coarse textured soils due to low absorption capacity.

3) Absorbed cations improve soil structure by Flocculation

4) Acidity or basicity of soil depends on CEC

**2. Soil Acidity (p$^H$)**

It is the negative logarithm of the reciprocal of H ion concentration.

It is imp to select species for a particular locality.

It affects availability of nutrients, increase results in increase of Ca, Mg , Mo and K availability.

It has profound effect on bacterial activity and rate of decomposition of organic matter

It determines the degree of maturity of soil and stages of development in plant succession

3. Silica-sesquioxide ratio

Increase in sesquioxides results in decrease of CEC and moisture retenvity of soil.

**NATURAL REGENERATION**

The trees and forest crops depreciate in value and die with age. But the forester does not want the tree crops to grow to a size that their value may depreciate. He therefore utilizes the trees when they have gained maximum value. Having utilized the trees when they have gained maximum value. Having utilized the trees it is his duly to see that the crop is regenerated with trees of the desired and economically valuable species so that he gets maximum return on a sustained basis in perpetuity. As already stated, to regenerate means to renew a forest crop by natural or artificial means. Thus, regeneration is defined as the renewal of a forest crop by natural or artificial means. It also refers to the crop so obtained. Reproduction is a synonym for regeneration but it is more usually applied to a forest crop obtained by natural method, viz., self-sown seed, coppice or root suckers, etc.

**Methods of Regeneration**

From the above definition, it is apparent that there are two main methods of regenerating forest crops but in practice, a combination of the two methods is also sometimes adopted. Thus, the methods of regeneration of forest crops are

i) Natural regeneration

ii) Artificial regeneration and

iii) Natural regeneration supplemented by artificial regeneration

**Natural Regeneration**

Natural regeneration is defined as 'the renewal of a forest crop by self-sown seed or by coppice or root suckers. It also refers to the crop so obtained. Thus, the natural regeneration may be obtained from the following two main sources:

i) From seed and

ii) From vegetative parts

When regeneration obtained from seed forms a crop, it is called a seedling crop which is defined as 'a crop consisting of seedlings neither planted nor of coppice or root sucker origin but originating in situ from natural regeneration'. When this seedling crop grows into a forest, it is called a high forest. When regeneration obtained by coppice forms a crop, it is called coppice crop and when it develops into a forest, it is called coppice forest to differentiate it from the high forest. Root suckers are, however, not used for large scale regeneration operation.

**Natural Regeneration from Seed**

Natural regeneration from seed depends upon

1) Seed production 2) Seed dispersal 3) Germination and 4) Establishment

**1) Seed Production**

The most important prerequisite of natural regeneration from seed is the production of adequate quantities of fertile seed by the trees of the area or immediate neighbourhood. The production of seed depends upon species, age of trees, size of crown, climate and other external factors. All species do not seed annually and abundantly. For instance, while teak, babul, khair, shisham seed every year, deodar, fir, spruce seed at an interval of years. The quantity of seed produced by annual seeders also varies within wide limits and so seed years are described as good, moderate or poor depending on whether the quantity of seed produced is abundant, moderate or less. Interval between moderate and good seed years of a few important species is given below

Species                    Moderate seed years   Good seed years

| | | |
|---|---|---|
| Shorea robusta | 2 | 3 – 5 |
| Terminalis tomentosa | 2 | 3 – 4 |
| Pinus wallichiana | 2 | 2 – 3 |
| Pinus roxburghii | 3 | 4 – 5 |
| Cupressus torulosa | 3 | 7 – 8 |
| Cedrus deodara | 3 | 4 – 5 |
| Picea smithiana | 3 | 5 – 6 |
| Abies pindrow | 6 | 10 |

The age of trees also affects the production of adequate quantities of fertile seed. The seeds produced by immature trees as well as over mature trees are, sometimes, infertile. Abundant quantities of fertile seeds are produced by the trees after the height growth has culminated because during the period of height growth, carbohydrate produced is utilized in it. Thus, abundant quantities of fertile seeds are produced from middle-aged trees.

The size of the crown of trees also affects seed production. As a general rule, the bigger the crown, the larger the production of seed. Therefore, while selecting seed bearers for natural regeneration, middle-aged mature trees with well developed crowns should be selected.

Climate also affects the seed production. As a general rule, warmer climate favours larger seed production. Therefore, in the hills the trees growing towards the lower limit of the altitudinal zone of their species produce more seeds than those growing towards the upper limit. Hot dry years are generally followed by heavy seed years on account of increase in photosynthesis. Heavy rain storms at the time of pollen dissemination reduce chances of good seed production. Similarly, late frost adversely followed affects seeding.

The other external factors which affect seed production are fire injury, insect attack and girdling. Injury by fire and insect attack stimulate seed production. Similarly, girdling is by heavy seeding.

**2) Seed Dispersal**

The seed produced by the trees is dispersed by the agency of wind, water, gravity, birds and animals. Some examples of seed dispersal by various agencies are given below:

By wind – Conifers, Acer, Betula, Rhododendron, Populus, Alnus, Salix, most Dipterocarps, Terminalias, Dalbergia, Acacia catechu, Adina, Bombax, Holoptelia, most Apocynacea and Asclepiadaceae, Casuarina, Cedrela, Chloroxylon, Pterocarpus marsupium, etc.

By water – Trewia, most mangrove species, Dalbergia, teak, etc.

By gravity – Oaks, Juglans regia, Aesculus, etc.

By birds – *Prunus, Mulberry, Broussonetia, Trema, Diospyros melanoxylon*, etc.

By animals – *Acacia Arabica, Prosopis juliflora, Ziziphus, Anthocephalus*, etc.

As the seeds of all conifers in hills are dispersed by wind, special care has to be taken to see that the seed bearers are retained on ridges and on the upper portion of hill slopes so that they can cover maximum area.

**3) Germination**

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

a) Internal factors b) External factors

a) Internal factors – The internal factors are the factors pertaining to the seed itself. The following internal factors affect germination:

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

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

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

iv) After ripening – Even if the embryo is fully developed, seeds, sometimes, do not germinate because the embryo is not chemically ready for germination. Such seeds germinate only when they

have undergone a process of after-ripening.  Delayed germination of Juniperus macropoda is due to after-ripening.

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

Conifers – Abies pindrow (17 seed/gm), Cedrus deodara (9 seeds/gm), Cupressus torulosa (240 seeds/gm), Picea smithiana (63 seeds/gm), Pinus roxburghii (9 seeds/gm), Pinus wallichiana (16 seeds/gm).

Broad-leaved – Acacia arabica (8 seeds/gm), Acacia catechu (39 seeds/gm), Acrocarpus fraxinifolius (32 seeds/gm), Adina cordifolia (11288 seeds/gm), Aesculus indica (40 seeds/kg), Ailanthus excelsa (9.5 seeds/gm), Ailanthus grandis (1235seeds/kg), Albizzia lebbek (7400 seeds/kg), Albizzia procera (23 seeds/gm), Bischofia javanica (92 seeds/gm), Bombax ceiba (26 seeds/gm), Casuarina equisetifolia (758 seeds/gm), Dalbergia sissoo (53 seeds/gm), Dendrocalamus strictus (30 seeds/gm), Eucalyptus hybrid (2700 seeds/gm), Fraxinus micrantha (7 seeds/gm), Gmelina arborea (1764 seeds/kg), Hymenodictyon excelsum (170 seeds/gm), Juglans regia (110 seeds/kg), Kydia calycina (32 seeds/gm), Morus alba (455 seeds/gm), Pterocarpus marsupium (1623 seeds/kg), Quercus incana (529 seeds/gm), Quercus semecarpifolia (140 seeds/kg), Shorea robusta (529 seeds/kg), Tectona grandis (1760 fruits/kg), Terminalia tomentosa (529 seeds/kg), Toona ciliata (247 seeds/gm).

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

**(vii) Germinative capacity and germinative energy-**

All the seeds that fall to the ground do not germinate.  As the percentage of seeds that germinate, affects natural regeneration, it is important to know the germinative capacity and germinative energy of the seeds of the species.  Germinative capacity is defined as 'the percentage, by number, of seeds in a given sample that actually germinate, irrespective of time'.  Germinative energy is defined as 'the percentage, by number, of seeds in a given sample that have germinated upto the time when the rate of germination (number of seeds germinating per day) reaches its peak (Holmes)'.  The germinative capacity of some of the species is given below:

| Germinative capacity | Species |
|---|---|
| 1-5 | Alnus nitida, Anogeisssus latifolia; |
| 5-10 | Buxus wallichiana, Grewia tiliaefolia; |
| 10-20 | Abies pindrow, Anthocephalus cadamba, Kydia calycina; |
| 20-30 | Boswellia serrata, Cassia fistula, Duabanga sonneratiodes, Picea smithiana; |
| 30-50 | Bombax ceiba, Tectona grandis, Cupressus torulosa' |
| 50-70 | Acacia Arabica, Betula alnodies, Dendrocalamus strictus, Terminalia tomentosa, Toona ciliate, Melia azedarach, Pinus wallichiana, Cedrus deodara; |
| 70-90 | Acer campbellii, Butea monosperma, Ougeinia oojeinensis, Pinus roxburghii,  Acacia catechu, Albizzia procera, Juglans regia, Shorea robusta; |
| 90-100 | Albizzia lebbek, Anacardium occidentale, Artocarpus chaplasha, Bauhinia variegate, Cassia siamea, Dalbergia sissoo. |

1. Germinative capacity – (a) The percentage, by number, of seeds in a given sample that actually germinate within twice the energy period (Baldwin).  (b) The total number of seeds that germinate in a germinator, plus the number of sound seeds remaining at the end of the test, expressed as a percentage of the total sample (Holmes).

2. Germinative energy-The percentage, by number, of seeds germinating within a given period, e.g., seven or fourteen days, under optimum conditions (Baldwin modif).

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

of the number of the seeds in a sample that develop into seedlings at the end of the first growing season'. The following table shows the germinative capacity and plant percentage of a few species to give an idea of their relationship:

| Species | Germinative capacity | Plant percent |
| --- | --- | --- |
| Acacia Arabica | 50 | 26 |
| Shoea robusta | 80 | 66 |
| Tectona grandis | 50 | 25 |
| Terminalia tomentosa | 70 | 29 |
| Gmelina arborea | 85 | 30 |
| Dalbergia sissoo | 90 | 78 |
| Pinus roxburghii | 80 | 37 |
| Pinus wallichinana | 66 | 63 |
| Cedrus deodara | 65 | 58 |
| Abies pindrow | 13 | 6 |

(b) External factors – External factors are the factors of environment which affect germination. These are:

(i) Moisture – An adequate quantity of moisture is very essential for germination. Moisture activates the dormant embryo and by softening the seed coat helps it to come out. Moisture is also necessary for dissolving the food material collected in the cotyledons and for translocating it in solution to the radicle and the plumule. Diffusion of oxygen for respiration also takes place in aqueous solution.

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

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

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

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

Seedling year – Seedling year is defined as a year 'in which a given species produces abundant first year seedlings.' It is 'also used to designate a year, in terms of the amount of natural seedling regeneration produced by a particular species, as good, fair, poor or very poor.' As the is usually a considerable seedling mortality as a result of adverse climatic and soil factors as well as weed growth, a good seed year is not necessarily a good seedling year and therefore it is necessary to differentiate between the two. A good seedling year requires a rare coincidence of good flowering, good seeding, favourable climatic and edaphic factors and absence of adverse weed competition.

**(4) Seedling establishment** – Even if the germination is good it does not mean that the natural regeneration would be good because a large number of seedlings die at the end of rains or as a result of frost during winter or drought during summer. In addition, there may be other factors such as weeds, grazing, burning, which may kill them. These adverse factors pose a threat to seedlings not only in the first year but also for several years depending upon their rate of growth. Thus, good natural regeneration can be achieved only when the seedlings are established. Establishment is defined as the 'development of a new crop, naturally or assisted, to a stage when the young regeneration, natural or artificial, is considered safe from normal adverse influences such as frost,

drought or weeds and no longer needs special protection or tending operations other than cleaning, thinning and pruning.' The following factors affect establishment of seedlings:

(i) Development of roots – For some time after germination, the seedlings depend upon the food reserves of the cotyledons but soon they have to depend on their own resources. For this, it is essential that the seedling may develop a long tap root soon so that it reaches a depth where there is permanent moisture in the soil. If the development of roots does not reach that depth in the first growing season, the seedling may be killed by drought after the rains or in the summer season. Thus, in the species in which the development of root is fast, the seedling mortality is less.

(ii) Soil Conditions – As the tiny seedling has to depend upon the soil for its food, moisture and air, its establishment depends upon favourable soil conditions. The soil should have adequate moisture. Excess of moisture or its deficiency are both injurious for plant growth. Deficiency of nutrients has adverse effect on the development of seedlings. The presence of a thick layer of undecomposed organic matter inhibits establishment because while, on the one hand, its presence is an indication of deficiency of nutrients in the soil, on the other hand, it presents physical obstruction to the roots in reaching the mineral soil. The seedlings whose roots do not reach the mineral soil and remain only in the undecomposed organic matter, die after the rains due to moisture deficiency. Soil aeration also plays an important role in seedling establishment. Soil aeration affects seedling establishment in two ways, viz.,

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

 (ii) as a result of imbalance in the constituents of the soil air as is seen in case of sal whose seedlings start dying as soon as carbon dioxide/oxygen ratio reaches 2.8.

(iii) Light - Light is a very important factor in seedling establishment but its requirement varies from species to species and even in the same species according to climatic conditions and age. For example, in moister localities teak seedlings must have sufficient light from the very beginning but in dry hot localitites, a sudden influx of light on young seedlings may cause their death. In fact, in such localities, teak seedlings, in their infancy, actually require protection against sun. The requirement of light increases with age. The younger seedlings require comparatively lesser light b ut as they grow in age, the require more light.

(iv) Other climatic factors - Extremely high or extremely low temperature are both harmful for seedling establishment. In extremely high temperature, seedlings are killed due to insolation while in extremely low temperature they are killed by frost. For seedling establishment, only adequate rainfall is not essential but its proper seasonal distribution is also essential. Otherwise, the long dry season after the monsoonic rains, kills most of the seedlings.

(v) Condition of grass, and other competing weed growth-The effect of grass and other competing weed growth depends upon the nature of weed growth and the climatic conditions. The competing weed growth may be grass alone, a mixture of grass and shrubs or shrubs alone. The density of the weed growth has a great influence on establishment. A dense growth of grass is very harmful particularly when it forms dense mat-like roots and causes water logging. For instance, very few species, including teak can survive in the dense growth of Imperata. Similarly, dense growth of shrubs, particularly low shrubs, is very harmful as they cut off light. For example, dense growth of Strobilanthes and Petalidium is very harmful for teak regeneration Clerodendron for sal regeneration and Parrotia for deodar regeneration. A light growth of grass and shrubs generally present good conditions for seedling establishment. In the dry and arid areas, a certain amount of weed growth is helpful in conserving moisture and affording a certain amount of shade to the seedlings but in moister localities, weeds, particularly dense weeds, are very harmful. The effect of grasses, shrubs and other weed growth on seedling establishment also varies with their species. While some species of grasses and shrubs are not harmful, others are. Thus, the species of grasses, shrubs, etc., indicate conditions favourable and unfavourable for natural regeneration of a particular tree species. For example, while Viola canescens is an indicator for favourable conditions for natural regeneration of deodar and kail, Impatiens, Strobilanthes, Spirea sorbifolia, Dipsacus, Parrotia (inKashmir) are indicators of unfavourable conditions. Similarly, while Flemingia spp. and Narenga porphyrocoma indicate favourable conditions for sal natural regeneration, Imperata arundinacea, Saccharum procerum indicate unfavourable conditions for it.

(iv)  Grazing, browsing and burning – Light grazing and browsing is not harmful to seedling establishment but uncontrolled grazing and browsing completely destroy regeneration.  Similarly, light or controlled burning is not harmful.  On the other hand, it reduces the density of shrub growth and destroys the undecomposed organic matter, and thus favours rapid growth in seedlings.  Uncontrolled burning is, however, very injurious.  The resistance to and the power of recovery from grazing the fire injuries vary with species and with age.

(vii) Drip – Drip from the large leaves of species such as sal, teak is very harmful for seedling establishment because it removes soil from the roots of the tiny seedlings in splash erosion thereby exposing the roots resulting in the death of plants.  The splashed soil covers the shoot of the tiny seedling and besides preventing it to perform photosynthesis, also kills it by rotting of shoot.

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

**DYING BACK OF SEEDLINGS**

 In some species, the shoot portion of seedlings keeps on dying year after year while the root remains alive.  This phenomenon, which is known as dying back, results in keeping back the progress of the seedlings to towards establishment because every year the shoot dies back to produce whippy new shoots little or no bigger than the last year's shoot from the ground level.  This continues for as many as 20 years or more with the result that the seedling does not develop a permanent shoot.  As the root stock keeps on developing, it produces in some year with rare coincidence of absence of all adverse factors, a shoot that does not die and thereafter the shoot makes steady progress.  This phenomenon is seen in sal, Pterocarpus santalinus, Terminalia tomentosa, Bombax ceiba and Boswellia serrata.  It is caused by adverse climatic and edaphic factors as well as adverse weed competition.


DYING BACK OF SAL SEEDLINGS

 After a good seed year and with the timely commencement of rains, sal seed germinate readily and thousands of seedlings are seen covering the forest floor.  But soon after they start dying back.  Some die during the rainy season, some towards the end of rainy season, some in the ensuing dry season, some during the winter and yet some others during the summer.  The dying  back starts with the formation of blotches on the leaves followed by their drying  and the drying of the shoot.  The dying back may result in the death of the whole shoot generally but some times only a part of the shoot dies.  Next year, one or two new small whippy shoots are produced.  These shoots meet the same fate and the root stock sends forth new shoots again.  Thus, while the root stock keeps on developing, the shoot remains small, thought it increases slowly in height.  The process comes to an end when in a chance year as a result of absence of all adverse factors, the root stock sends a shoot whose height is about 50 cm and leaves relatively larger.  After this the seedling does not die regularly and gradually makes progress.  In this way, it, sometimes, takes about 40 years to establish.

 **CAUSES OF DYING BACK OF SAL SEEDLINGS**

 The factors responsible for dying back of sal seedlings are:

(i) Dense overhead canopy and inadequate light reaching the forest floor.  Even though sal does not require complete overhead light, yet it does require diffused light which is not possible under a dense overhead canopy.  Under inadequate light conditions, leaves become small and develop blotches; photosynthesis is retarded and it has an adverse effect on root development.

(ii) Dense weed growth – Dense weed growth not only affects light but also causes root competition and both these have adverse effect on the growth of the seedlings and their establishment.  Even if the shrubs are replaced by dense growth of grass, it is injurious for the seedlings.  For sal seedlings, the ideal undergrowth is a fifty fifty mixture of light grass and shrubs.

(iii) Undecomposed lef litter – The leaves of sal are coarse and they do not decompose easily with the result that there is often a thick layer of undecomposed leaves which presents physical obstruction to the roots in reaching the mineral soil.

(iv) Accumulation of carbon dioxide – Towards the end of rains, there is an accumulation of carbon dioxide in the soils of sal forests as a result of respiration by roots and decomposition of organic matter.  When the carbon dioxide/oxygen ratio reaches 2.8, the sal seedlings start dying back.

(v) Frost – A fairly large number of seedlings die during winter as a result of frost.

(vi) Drip – As a result of destruction of the middle storey, drip from the leaves of the top canopy causes splash resulting in the death of seedlings by exposure of roots, retardation of photosynthesis by leaves covered with splashed mud or rooting of tender shoot.

(vii) Drought – Sal seedlings require adequate moisture but between two consecutive rainy seasons, it has to face a long dry period.  Though winter rains relieve the hardship, yet large number of seedlings die as a result of post monsoon as well as a summer drought.

(vii) Grazing and browsing – In places where there is heavy grazing, some seedlings die as a result of trampling as well as due to their being eaten up with grass.  An excess population of cheetal and sambhar has also a serious adverse effect on the growth of seedlings.  During the summer when all other vegetation is leafless or has dry hard leaves, sal seedlings produce attractive, coloured and juicy leaves and therefore they are heavily browsed.

## SEEDLING ESTABLISHMENT PERIOD

 The seedling establishment period is defined as the period which elapses between the initiation of natural regeneration and the time when it is considered safe from adverse influences such as frost, drought or weeds.  This would naturally vary with species and in the same species with locality.

 After the seedlings have established, the seedling or sapling crop has to be protected against all kinds of damages and it has to be tended so that the plants of the desired species may be protected against adverse competition from not only the unwanted species but also the inferior individuals of the desired species.  In short, the development of a forest of the desired species from seed under natural conditions depends upon the following conditions:

(i) Adequate and well distributed seed supply, i.e., there  should be not only adequate seed but that seed should be well disseminated over the whole regeneration area.

(ii) Favourable conditions for the germination of seeds.

(iii) Favourable conditions for the development and establishment of seedlings.

(iv) Favourable conditions of under growth, ground cover and overhead canopies so that the seedlings receive not only adequate light but are also free from root competition.

(v) Protection against all kinds of injuries.

(vi) Tending during most part of the life span of crop.

(vii) Control over mixture.

All these conditions have to be attended to in different ways while developing a new crop of desired species under various silvicultural system.  The method of obtaining natural regeneration and developing it into a high forest under various silvicultural systems will be discussed separately later. But it is important to note here that in order to achieve successful natural regeneration of any species, the knowledge of the conditions in which it regenerates freely and abundantly in nature and in which it does not regenerate is an essential prerequisite.  The branch of science which gives this knowledge is called ecology which is defined as 'the study of plants and/or animals in relation to their environment, i.e., all the biotic and abiotic factors of a site.'  Therefore in order to achieve successful natural regeneration of any species, it is necessary to create those conditions in the various silvicultural systems in which, according to ecology, it regenerates freely in nature.  The importance of the knowledge of ecology is abundantly clear from the following two examples:

(1) In the riverain areas, the first tree species to come are khair and sissu but they do not regenerate under their own canopy.

(ii) Sal and chir regenerate freely in nature but once they form pure crops, under certain conditions, their regeration becomes a problem.

If the causes of failure of regeneration in both these cases are analysed it would be seen that the regeneration of these species require relatively drier condition than that which exists under their canopies.  Khair and sissu come up in infertile sandy soil with complete overhead light and great diurnal range of temperature.  But once these species form a forest crop, the conditions of the forest floor are changed considerably.  The moisture retentivity and the fertility of the soil improves, complete overhead light is no longer available on the forest floor and the diurnal range of temperature is also not as wide as before.  It means that if khair and sissoo have to be regenerated naturally, the conditions of site have to be reversed to the first stage of succession.  Chir regenerates in nature in areas where grazing is common and fire occurs regularly periodically or annually.  Similarly, in very moist areas, sal regenerates in crops with broken canopy and subjected to periodic or annual fire.  But once these species form extensive pure crops, scientific management exercises a check on both these

factors with the result that the conditions in these forests become too moist for these species to regenerate freely and abundantly. Evergreen shrubs come up in large numbers to make conditions still more difficult for the regeneration to come. Thus, the generation of these species becomes a victim of the conditions created by vigorous protection against fire and grazing. If natural regeneration is to be achieved, retrogression in the site conditions has to be brought about, which is, sometimes, not possible.

## NATURAL REGENERATION FROM VEGETATIVE PARTS

Normally trees species regenerate by seed but some species have the power to regenerate themselves by vegetative parts, viz., root, stem, branch, etc. Reproduction obtained from these parts is called vegetative reproduction which is defined as 'asexual reproduction in plants from some part of the plant body, e.g., of trees by coppice or root sucker or from root, stem or branch cuttings'.

## ADVANTAGES OF VEGETATIVE REPRODUCTION

The power to produce new plants by vegetative reproduction gives the species following advantages:

(i) One plant produces several plants;

(ii) This is also possible when the plant is not capable of producing seed;

(iii) The plants obtained from vegetative reproduction grow faster than the seedlings and cost less;

(iv) The capacity can be used for genetical improvement of the species either by layering a branch of a plus tree or using its bud for budding or its flowering shoot for grafting on an inferior tree of the species. A plus tree is defined as a tree which is genetically superior, i.e., a tree which is superior to other trees in its habitat from the point of view of its size, length, shape, and cylindricalness of stem, height, diameter and volume increment, timber quality, resistance to disease, and other specific qualities, viz., high resin yielding capacity etc.

## METHODS OF VEGETATIVE REPRODUCTION

Vegetative reproduction can be obtained by any of the following methods:

(i) Coppice – Coppice is that method of vegetative reproduction in which the tree, plants or the seedlings of a species when cut from near the ground level, produce coppice shoots. Coppice shoot is defined as 'a shoot arising from an adventitious bud at the base of a woody plant that has been cut near the ground or burnt back'.

(ii) Root sucker – Root sucker is that method of vegetative reproduction in which a root of a plant is partially or wholly cut to produce a shoot called root sucker.

(iii) Cutting – Cutting is that method of vegetative reproduction in which a portion of the stem, branch or root is placed in the soil or other medium, in order that it may develop into a plant. Depending on the part of the plant used, cuttings may be classified into stem cutting, branch cutting, root cutting and root and shoot cutting which is defined as 'a young plant with pruned tap-root and severed stem used for planting'.

(iv) Layering – Inducing development of roots on branches while they are still attached to the trees is called layering. Layering may be done in soil or in air and so layering is of two kinds, viz., soil layering and air layering. Soil layering is that method of vegetative reproduction in which an undetached branch with bark or after removing a ring of bark 1 cm wide is partially buried in the soil to enable it to strike root, when it is cut from the parent plant to be planted elsewhere. Air layering, on the other hand, is that method of vegetative reproduction in which bark is removed from part of the circumference of a thin branch, and the wound is covered with some soil and moss and tightly wrapped round with polythene sheet. When the roots are formed the branch is gradually severed from below the rooted portion and planted in pots to be planted in field later.

(v) Grafting – Grafting is a method of vegetative reproduction in which a portion called scion, of one plant is applied to stock, usually rooted, which is another plant, with the object of securing vegetative union between the two, when the scion is detached from the parent plant and the shoot of the other plant is severed, to produce a new plant to be planted out. There are several methods of grafting but cleft grafting has been found to be more useful for genetical improvement work in forestry.

For cleft grafting, flowering shoots of plus trees are cut and kept about 40 to 45 cm long. These are scions. If the scions are to be transported to long distances, their cut ends are dipped in melted wax and then taken out. Thus, the cut end gets a coating of wax and therefore it does not dry and is not liable to be attacked by insects or fungi. In spite of this precaution, attempt is made to transport the scions to the grafting place latest within 24 hours. On reaching the grafting site, the scion is kept

about 30 to 40 cm long and the rest is cut off. The cut end is then given the shape of a wedge 5 cm long and then the scion is made to stand in a bucket with some water.

The stock is selected from those 2 or 3 year old nursery plants whose girth at about 20 to 25 cm height from the ground may be about 1 to 2 cm. At this height the stock is cut and is cleft with a sharp knife for a distance equal to the wedge of the scion. Then the scion whose girth at the top of the wedge is equal to the girth of the stock is fitted upright in the clefted stock with the wedge inside it. Then this portion is tied firmly with sutli in such a way that the bark is not damaged. The sutli is tied from the lower side upwards in such a way that neither the cleft portion of the stock nor the wedged portion of the scion should be visible and that the scion can not be pulled out. Then a polythene strip is wrapped over the joint and tied with sutli again so that rain water can not enter the joint. After about 1 ro 2 months, the joint is opened to see if the scion and stock have joined. If not, it is tied again. The most important precaution in this work is to see that the diameter of the scion above the wedge and that of stock are equal so that the cambium layers of the two join well. Such cleft-grafted plants start producing genetically superior seed in 3 or 4 years. On the basis of an experiment conducted on teak in Dehradun, April and May have been found to be the best months of cleft grafting.

(vi) Budding – Budding is that method of vegetative reproduction in which a bud with some portion of the bark of a genetically superior plant is grafted on an inferior plant so that it may produce shoot when the old shoot of the stock is cut off. Bud is grafted on the stock in the form of a patch after removing the bark of the stock in that portion or by making an incision in the bark of the stock in the form of T and then fixing the scion inside it. The scion is tied on the stock keeping the bud uncovered. The scion is first tied with sutli and then with polythene strip and sutli as in the case of cleft grafting. April and May have been found to be the best months for budding on teak in Dehradun.

Out of the methods described above, coppice, root sucker and cuttings are used for regeneration work, while layering, grafting and budding are used for genetical improvement work in forestry. Of the methods used in regeneration of forests, coppice and root suckers are used for natural regeneration work while cuttings are used for artificial regeneration work. Therefore, the methods of obtaining natural regeneration by coppice and root sucker only have been described in this chapter.

## NATURAL REGENERATION BY COPPICE

Natural regeneration by coppice can be obtained either by:

(1) Seedling coppice; or (2) Stool coppice.

(1) **Seedling coppice** is defined as the 'coppice shoots arising from the base of seedlings that have been cut r burnt back'. This method of obtaining natural regeneration is used for cutting back woody shoots and established reproduction which is not making any progress so that they may produce vigorous shoots and soon develop into saplings and later into poles. It is generally used in case of sal and teak. The advance growth of sal in the form of whipply shoots, woody shoots and, some-times, even the established regeneration often does not progress due to adverse environmental conditions and keep on stagnating for year. If this stagnating advance growth is cut back and given proper light conditions, it progresses fast and soon develops into a sapling and pole crop. This method of obtaining natural regeneration of sal is used in several sal divisions in U.P. (e.g., Dehradun), M.P., Bihar and Orissa, Similarly, this method is used for obtaining natural regeneration to teak in many division of M.P.

(2) **Stool coppice** is the coppice arising from the stool or a living stump. In this method, regeneration is obtained from the shoots arising from the adventitious buds of the stump of felled tree. The coppice shoots generally arise either from near the base of the stump or from its top. Of the two, those arising from near the base are better because they get established easily. The shoots arising from near the top of the stump are liable to be damaged by he rotting of the upper portion of the stump as well as by wind, etc.

## FACTORS AFFECTING NATURAL REGENERATION BY COPPICE

The following factors affect natural regeneration by coppice:

(1) Species – All species do not coppice and even in the species that coppice, the power varies with species. On the basis of their power to coppice, species are classified into following four categories, some examples of each being given against them:

(i) Coppice strongly – *Acacia catechu, Albizzia spp., Anogeissus spp., Azadirachta indica, Broussonetia papyrifera, Butea monosperma, Cassia fistula, Cleistanthus collinus, Dalbergia spp., Diospyros tomentosa, Emblica officinalis, Eucalyptus globules, Garuga pinnata, Melia azedarach,*

*Morus alba, Ougeinia oojeinensis, Prosopis juliflora, Robinia pseudacacia, Salix spp., Sapium sebiferum, shorea robusta, Syzygium cumini, Tectona grandis, etc.*

(ii) Coppice fairly – Aesculus indica, Chloroxylon swietinia, Hrdwickia binata, Juglans regia, Pterocarpus marsupium, Quercus incana, Quercus lanuginose, Quercus semecarpifolia, Terminalia belerica, Terminalia tomentosa, etc.

(iii) Coppice badly – Adina cordifolia, Bombax ceiba, Casuarina equisetifolia, Madhuca latifolia, Populus ciliate, etc.

(iv) Do not coppice – Abies pindrow, Cedrus deodara, Picea smithiana, Pinus roxburghii, Pinus wallichinana, etc.

In some species, e.g., Acacia Arabica, Boswellia serrata, Quercus dilatata, etc., coppicing power varies, sometimes, with locality to locality.

(2) Age of tree – The older the tree, the lesser is the coppicing power because old bark prevents the emergence of dormant buds. Youngers saplings and poles, as a rule, coppice readily and profusely.

(3) Season of coppicing – The best season for coppicing is a little before growth starts in spring because delay results in reducing the growing period. This season has another advantage that at this time there is large reserve of food material in the roots and all of it is utilized in the growth of coppice shoots. The greater the delay after the growth season has started, the more depleted will be the food reserves and consequently the growth of the coppice shoot will be affected. But in places where there may be danger of late frost in spring, coppicing should be done after the danger is over. If the coppice coupe has to be burn after felling, burning should be done as early as possible and definitely before coppice shoots have started sprouting, otherwise they will be burnt.

(4) Height of stump and method of cutting it – The effect of height of stump varies with species. For example, some bad or indifferent coppicers, e.g., Casuarina equisetifolia, Hardwickia binata, Manilkara hexandra, produce better coppice shoots when the stumps are higher. Usually, lower the stump, the better it is for the coppice because they are not liable to be damaged by wind or animals. Such coppice shoots also develop independent roots and rooting of the stump does not affect them. On the other hand, coppicing low is expensive and there is usually a danger of the stump splitting or drying up from top and in such cases, coppice may be adversely affected. Low coppicing is also, sometimes, inadivisable if the stump is affected by root rot as in case of dry sal and teak coppice areas. If the stump is cut flush with the ground level, there is no place for the buds to sprout. On the other hand, the higher the stump, the greater the possibility of the shoots being damaged. Thus, the stumps should be neither too low nor too high, a height of about 15 to 25 cm being very suitable.

The method of cutting or trimming the stump also affects the coppice. In the past, it was insisted that the stump should be made conical with the highest point in the centre so that the water drains off. In this method, besides expense, there the water drains off. In this method, besides expense, there was always a danger of the stump being damaged. Therefore, now the stump is given some slope in one direction. It should be clean cut without damaging the bark or splitting the wood.

(5) Rotation – Since most of the trees coppice best during the early age, coppice rotation should be short. Long rotation encourages seedling regeneration and for that reason, coppice rotation is generally shorter than the age at which trees produce good viable seeds.

(6) Silvicultural system – The coppice shoots are strong light demanders and therefore they must be worked under systems involving clear-felling. At the most, some standards may be kept. The silvicultural system under which coppice regeneration is obtained depends upon the method of obtaining regeneration. When natural regeneration is obtained form seedling coppice, the silvicultural system is a high forest system because the essence of a coppice system lies in obtaining the new crop from stool coppice under short rotations. Thus, seedling coppice is used to obtain natural regeneration of sal and teak under clear-felling system in Bihar, M.P., and parts of Maharashtra and under uniform or Indian irregular shelterwood system for sal in U.P. When natural regeneration is obtained from stool coppice, the silvicultural system may be either simple coppice system, coppice-with-standards system or coppice-with –reserves system.

Stool mortality in coppice – Trees can not keep on coppicing indefinitely and they die after sometime. Therefore in every coppice forest, some stools do not coppice in each in every coppice forest, some stools do not coppice in each rotation. The mortality of stools in coppicing varies with species and locality. For example, while in dry fuel forests of Tamil Nadu the mortality in stools has been observed to be about 10 to 15%, the mortality in khair in Ramnagar division (U.P.), has been observed

to be 20 to 75%. The mortality can be made up by encouraging seedling regeneration to come up and develop into trees. If this does not take place, coppice reproduction may be supplemented with sowing or planting.

**TENDING OF STOOL COPPICE**

Usually each stool produces several coppice shoots. In order to enable them to develop into good poles, it is necessary that the number of shoots be reduced to 2 or 3 in the second or third year and on their developing further, the number be reduced to one. This has favourable effect both on height and diameter increment.

**NATURAL REGENERATION BY COPPICE UNDER VRIOUS SILVICULTURAL SYSTEMS**

As already mentioned, natural regeneration by coppice is generally obtained by simple coppice system, coppice-with-standards system and coppice-with-reserves system.

The simple coppice system is that coppice system in which coupes are clearfelled on short rotation to get new coppice crops. Naturally, this system is applicable to species which coppice strongly. As younger trees coppice more vigorously, coppice rotation is usually kept as 20 to 40 years. All trees of the coupe are clear-felled with no reservation for shelter-wood. In the year following the clear-felling, the coppice species where they may be interfering with that of better species and by climber cutting. If the number of coppice shoots per stool is more than two, the most promising two shoots are kept and the rest are cut back. After a year or two, only one shoot per stool is kept by cutting down the other. As stumps can not coppice indefinitely, natural seedlings appearing in the area are allowed to grow. The blanks in the coupes are regenerated by sowing or planting.

The coppice-with-standards system is that coppice system in which part of the crop is retained to form an uneven-aged overwood. Thus the resultant crop is two storeyed, the upper storey being of standards standing over the lower storey of coppice crop. The standards are generally of some wind-firm, valuable species and may be even of species other than the coppice. The rotation of the standards is a multiple of that of the coppice and when it is more than twice of the coppice rotation, the standards are retained in such a way as to give proper representation to all age class multiples of coppice rotation. The standards occupy about 1/3 to ½ of the area of the canopy and this space is equally divided into standards of all age classes. After selecting standards of coppice rotation and its multiples, the ret of the crop is clear-felled. The coppice shoots are cleaned and thinned like the simple coppice system.

The coppice-with-reserves system is a coppice system in which well-grown saplings and poles are retained in coupes to form part of the new crop and the rest is felled. The reservation is done with the object of improving the condition of the crop, providing protection against frost and erosion, supplying seed, protecting valuable species as well as species with edible fruit, etc. In this system, felling is done keeping the requirements of the crop in view and may range from clear-felling in certain portions to practically no felling in others. Thus, the regeneration of the area is not only by coppice but also by saplings and poles grown from seed. This system also provides for artificial regeneration in clear-felled patches if coppice does not come up. The new crop is tended regularly as in other systems.

**NATURAL REGENERATION BY ROOT SUCKERS**

Natural regeneration by root suckers is not being attempted on any large scale any where in this country. This method used to be followed, sometimes, on the canal bank plantations in U.P. and the chief species in which this was effected was sissoo. Where this method was followed, it was usually to dig continuous or discontinuous circular trenches with diameter of about 6 m round the isolated trees so that their roots may be severed and root suckers produced, which, with tending, could be developed into trees. The trees produced in this way are liable to wind-throw and poor in growth and therefore this method is not being favoured now. Diospyros root suckers are sometimes encouraged because the root suckers produce best biri leaves.

**OTHER OPERATIONS OF VEGETATIVE GROWTH**

The following operations, though they are not methods of obtaining natural regeneration, are, sometimes, carried out for obtaining new vegetative growth on trees for various purposes:

**1. Pollarding** – Pollard is defined as 'a tree whose stem has been cut off in order to obtain a flush of shoots, usually above the height to which the browsing animals can reach'. Thus pollarding is an operation in which the stem of a tree is cut off at a height beyond the reach of browsing animals with

the object of producing a crown of new shoots from buds below the cut.  The flush of new shoots is cut down periodically so that the pollard may produce fresh shoots again.

Examples:

(i) Salix is pollarded in the Kashmir valley to produce shoots for wicker work.

(ii) Hardwickia binata is pollarded in Andhra Pradesh to produce shoots suitable for fibre extraction.

(iii) Some species of mixed dry deciduous forests in North Coimbatore (Tamil Nadu) are pollarded to provide fuel of preferred dimensions for boiling jaggery.

(iv) Grewia oppositifolia is pollarded in Kumaon and Garhwal hills (U.P.) to provide shoots for fibre and fodder.

**2. Lopping and pruning** – Lopping means cutting of branches of a tree.  Incidentally the lopped trees produce new shoots which are annually or periodically lopped for various purposes.  Though pruning means cutting of branches from the bole of trees for improvement of timber of trees, this term is, sometimes, used for cutting branches to produce new shoots.

Examples:

(i) Butea monosperma, Schleichera oleosa, Ziziphus mauritiana, Ziziphus oxylopyra, Acacia Arabica, Acacia catechu, Albizzia lucida, etc., are regularly pruned to produce succulent shoots with thin back not only to provide proper feeding ground for the lac larvae but also to improve the general crown structure of the host plant.

(ii) Diospyros is regularly lopped to produce new shoots with tender leaves required for biri industry.

(iii) Quercus incana, Quercus dilatata, Quercus semecarpifolia, Acaia spp., Anogeissus spp., Grewia spp., Hardwickia binata, Melia zedarach, Moringa oleifera, Morus spp., Ougeinia oojeinensis, Schleichera oleosa, STereospermum personatum, Tamarindus indica, Terminalia tomentosa, Terminalia paniculata, Terminalia belerica, Kydia calycina are annually lopped for leaf fodder for domestic and gujar's cattle

(iv) Quercus incana, Morus spp., are regularly lopped for rearing tussar and silk worms.

## CULTURAL OPERATIONS

In the year following the year of regeneration fellings, it is necessary to carry out some operations, called cultural operations, in the regeneration area to remove the after-effects of felling and to improve the conditions of growth for the regeneration.

Cultural operation is defined as 'the operation, as a rule not directly remunerative, undertaken to assist or complete existing regeneration, to promote the proper development of the crop or to minimize the after-effects of felling damage.  It, therefore, includes subsidiary felling, weeding, cleaning, unremunerative improvement fellings, and thinning in groups of advance growth, girdling or poisoning of unwanted growth, climber cutting and even pilling of felling debris, and controlled-burning but usually not other ground operations nor pruning.  It is generally associated with silvicultural systems relying primarily on natural regeneration.'

In short, the cultural operations, done in the year following main or ny felling, usually consist of:

(i) Removal of marked trees left unfilled provided their felling is still considered necessary;

(ii) Removal of trees so badly damaged in felling that their retention is of no use;

(iii) Cutting back malformed and ill-developed advances growth if it can give a good coppice shoot;

(iv) Removal of inferior species or weed growth where it is interfering with the growth of the economically more important species and where advance growth has been coppiced to admit light for the coppice to develop;

(v) Thinning of even-aged groups of poles if it has not been done with felling; and

(vi) Climber cutting.

## NATURAL REGENERATION SUPPLEMENTED BY ARTIFICIAL REGENERATION

Often the natural regeneration is not complete during the regeneration period and part of the regeneration area remains blank.  Under such circumstances, there are two alternatives to deal with the situation, viz., (i) either increase the regeneration period and allow the area to remain under regeneration for some more years, or (ii) fill up the blank patches artificially and complete the work. As the first alternative creates complication in management, the failed patches of the regeneration area are generally filled up by artificial regeneration either by sowing or planting.  The earlier his work is done the better because delay results in the invasion of the failed patches by grass and weeds making the artificial regeneration work difficult.  In addition, delay also results in the increase in the period of closure to grazing and protection against fire, both of which cause annoyance in the local population.

This work is done in practically all types of forests, viz., - in sal, chir and deodar forests managed under shelterwood system, in teak coppice coupes and natural regeneration areas deficient in advance growth in Madhya Pradesh and Maharashtra, in the teak-bearing deciduous forests, in the tropical moist deciduous and wet evergreen forests and in bamboo forests where bamboo has flowered and died. Supplementation work is done either by sowing seed, or by planting root-shoot cutting or any other kind of cutting, naked root planting, or planting plants raised in containers such as polythene bags, etc. Examples of methods of supplementing natural regeneration of some species:

Sal – Sowing of seeds or planting container plants raised in polythene bags, e.g., in Midnapur (West Bengal) and Dehradun (U.P.)

Teak – Stump (root and shoot cutting) planting.

Deodar – Naked root planting.

Chir – Sowing seed or planting 2 year old plants raised in polythene bags.


## ARTIFICIAL REGENERATION

Natural regeneration described in the last chapter, is a special feature of forestry, which makes it fundamentally different from other branches of land use. Nobody thinks of regenerating agricultural or horticultural crops by natural means. Sowing and planting methods have been in use in these enterprises for hundreds of years but in forestry they have been adopted relatively recently, and still more recently on a larger scale. The ratio of artificial regeneration areas to natural regeneration areas varies from state to state and even from division to division. While in some western countries, it may be as high as 50% or more, in India it was only about 2% upto the end of the 4th plan.

DEFINITION

Artificial regeneration is defined as 'the renewal of a forest crop by sowing, planting or other artificial methods. It also refers to the crop so obtained.' Normally such a crop is called by another term 'plantation' which is defined as 'a forest crop raised artificially, either by sowing or planting.' Sowing refers to direct sowing which is defined as the 'sowing of seed directly on an area where a crop is to be raised as opposed to sowing in a nursery' Planting refers to transferring of seedlings or plants in the area to be regenerated after they have successfully passed the critical stages of germination and initial development.

The planting stock may be procured from some other forest, and in that case it is referred to as wilding which is defined as 'a natural seedling (in contrast to a nursery grown seedling) used in forest planting.' But it is usually more economical to raise them, as in agricultural or horticultural crops, in controlled conditions in an area called nursery which is defined as an area where plants are raised for eventual planting out.' Planting is a far more dependable method of artificial regeneration, than direct sowing which can be done successfully only under very favourable conditions.

OBJECTS OF ARTIFICIAL REGENERATION

Artificial regeneration is mainly carried out for the following two objects:

(A) Reforestation (B) Afforestation.

Reforestation may be defined as the 'restocking of a felled or otherwise cleared woodland' by artificial means. In other words, reforestation is the raising of a forest artificially in an area which had forest vegetation before. On the other hand, afforestation is the 'establishment of a forest by artificial means on an area from which forest vegetation has always or long been absent.'

REFORESTATION

OBJECTS OF REFORESTATION

Reforestation is carried out with the following objects:

(1) To supplement natural regeneration – This has already been described in the last chapter.

(2) To give up natural regeneration in favour of artificial regeneration – When natural regeneration of the desired species is very slow and uncertain, it is not economical to regenerate areas by natural regeneration. In such cases, artificial regeneration is adopted in place of natural regeneration, to ensure quicker, cheaper and more certain stocking of the regeneration areas. Artificial regeneration of fir and spruce forests in Chachpur (H.P.), sal forests in parts of U.P., Bengal and Assam and teak forests in parts of M.P., Maharashtra, Kerala etc., are examples of this object. Sometimes, artificial regeneration is adopted to improve the quality of timber, example being artificial regeneration of twisted chir areas with seed from straight grained trees.

(3) To restock forests destroyed by fire and other biotic factors – Even in case where natural regeneration can be ensured, artificial regeneration has to be adopted if the forests are destroyed by fire and no seed bearers are left in the area to supply seed for natural regeneration. Similarly, the forests destroyed by excessive felling followed by unrestricted grazing and lopping have to be regenerated artificially to cover the area with forest vegetation soon. This type of work has been done in Hoshiarpur siwaliks (Punjab), Panchayat forests of Tamil Nadu, and in the catchment areas of the rivers with hydroelectric projects.

(4) To change the composition of the crop – Sometimes, the natural forests are of low value as the proportion of the valuable species in the crop is low. Selective fellings of valuable species reduces their percentage still further. Mixed deciduous forests and wet evergreen forests are examples of such forests. Their work is being done in most of the states in dry mixed deciduous forests. In the temperate forests, the attempt to raise deodar in oak forests and in the lower zone of fir and spruce forests is an example of this type of work.

(5) To introduce exotics – Sometimes, the indigenous species are so slow grown that they cannot satisfy the objects of management or the requirements of any industry. In such circumstances, it becomes necessary to introduce some exotics which can be raised successfully in the locality and yet fulfill the objects of management or the requirements of any industry. Plantations of Eucalyptus, tropical pines, poplars, etc., are examples of this object.

FACTORS AFFECTING THE CHOICE BETWEEN ARTIFICIAL AND NATURAL REGENERATION

Before taking up artificial regeneration work on a large scale, it should be seen as to which of the two methods of regeneration, viz., natural or artificial, satisfies the objects of management more efficiently in the given set of conditions. The choice between the two methods is governed by the following considerations:

(i) Risk of loss and deterioration of soil – While in the natural regeneration, there is minimum exposure of the soil, the artificial regeneration involves its exposure for a longer period. The exposure of the soil results in erosion by water on sloping areas and by wind on sandy flatter areas and deterioration elsewhere. Thus, the fertility of the soil is reduced. The situation is worsened if agriculture is also practiced prior to and / or after the sowing or planting. But this does not happen in natural regeneration.

Therefore where deterioration of loss of soil is likely to be serious, natural regeneration should be preferred to artificial regeneration.

(ii) Crop composition – In the renewal of the forest by natural regeneration the composition of the original crop is more or less maintained. Therefore, if the original crop consists of only few valuable trees, natural regeneration cannot improve the new crop in terms of value. On the other hand, artificial regeneration can drastically change the composition of the new crop either by raising mostly the valuable species occurring on that site, or by introducing other valuable indigenous or exotic species suitable for the locality, in pure crops or in desired mixtures. It also provides an opportunity of raising a cover crop or a soil-improving crop along with the forest species. Thus, where crop composition has to be changed to get a better return from the new crop, artificial regeneration has to be adopted.

(iii) Genetical consideration – Even where the crop composition is not to be changed, it is at least desired that the new crop should consist of trees of good quality. In natural regeneration, the seed for the new crop is obtained from the trees occurring on the site. Though it is expected that the selected seed bearers would be genetically superior trees, the continued selection and felling of good trees, generally leaves the area full of inferior or average trees. Under these circumstances, the new crop would also be of inferior or average quality trees. If the quality of the trees forming the new crop is to be improved, it is absolutely necessary that the natural regeneration should be given up in favour of artificial regeneration in which seed from the genetically superior trees is sown or plants raised from genetically superior seeds, are planted. In twisted chir pine areas, there is no way of improving the quality of the trees of the new crop except by artificial regeneration.

(iv) Risk of damage by pests – It is generally said that mixed crops resulting from natural regeneration are far more resistant to attack by insect pests than the pure and unmixed crops resulting from artificial regeneration. Concentration of food of a pest at one place in pure plantations may result in building up population of that pest to epidemic proportion causing serious, and sometimes

irreparable, damage to the plantation. On the other hand, physical separation of food plants in mixed natural forests tends to inhibit the spread of the insect pests and also keeps their population under control. Similarly, plant parasites and fungi are reported to spread rapidly in pure plantations than in natural forest. Therefore where there may be danger of pure crops being attacked by insects, parasites and fungi, natural regeneration should be preferred to artificial regeneration as the former usually results in mixed crops.

(v) Flexibility of operation – In artificial regeneration, elaborate arrangements have to be made well before time of sowing or planting. For instance, the area has to be cleared and fenced and soil working completed by May. Having done all this, if the seed is not available or the monsoon fails, all the expenditure incurred is wasted. On the other hand, in natural regeneration, very little work is done before seedfall and therefore the work can be postponed without any serious loss of money or effort. Thus, in case of uncertain conditions, natural regeneration is to be preferred to artificial regeneration.

(vi) Density of stocking – In artificial regeneration, it is easier to obtain a correct and uniform stock while in natural regeneration, it is too dense at some places and too sparse at others because seed dispersal is governed by wind and the situation of the seed bearers. Thus, if uniform stocking is aimed at, artificial regeneration should be preferred.

(vii) Yield – The yield per hectare in terms of volume and its value is higher in case of artificial regeneration because of the saving in time of establishment, greater proportion of more valuable species, resultant full stocking of proper density and concentration of work. Even the less valuable species can be sold at higher price along with more valuable species because of concentration of work. Thus, for better volume and financial yield, artificial regeneration should be preferred to natural regeneration.

(viii) Time factor – Time is the most important factor in deciding the choice between natural or artificial regeneration. Natural regeneration is liable to considerable delays, especially with species which seed at long intervals and have uncertain establishment period. Delay results in increased cost of formation, loss of increment and lengthening of rotation. On the other hand, artificial regeneration completes the regeneration work quickly and therefore results in considerable economy in cost of formation and in better financial return. In addition, time is important from another point of view also. In our country, the local villagers have grazing rights or concessions and the regeneration areas cannot be kept fenced and closed to grazing indefinitely for obtaining natural regeneration. The greater is the time required for establishment of young crop, the greater are the chances of its failure. Therefore, if regeneration area can be stocked completely within reasonably short time by natural means, it should be followed; otherwise artificial regeneration should be taken up.

(ix) Cost – Cost is another important consideration affecting choice of method of reproduction. Naturally, cheaper of the two methods has to be selected. Natural regeneration is supposed to be cheaper than artificial regeneration. Though there is practically no initial cost of formation except slash disposal and fencing, where necessary, in natural regeneration, the weedings and shrub cutting have to be repeated for such a long time, that natural regeneration often becomes as costly as, and sometimes costlier than, artificial regeneration. Unlike plantations, results of natural regeneration are generally slower and, sometimes, even inconspicuous; whereas the success or failure of a plantation is apparent by the end of the very second year.

In short, natural regeneration should be preferred to artificial regeneration if it can be obtained satisfactorily, within reasonable time and cost. Otherwise, artificial regeneration should be preferred. Leaving the cases in which natural or artificial regeneration have proved their efficiency cent per cent, the golden rule should be to follow natural regeneration for a reasonably short period and then complete the regeneration operation by supplementing natural regeneration with artificial regeneration.

Inspite of these academic considerations, the recent trend is towards man-made forests and, during the past few years, greater effort has been made to raise them with the following objects:

1. Increase the yield from forests to meet the fast increasing demand of timber for building construction, industries, defence and communications;
2. Shorten the rotation by raising fast-growing species;
3. Locating forests with relation to the location of industries;
4. Meeting the demand of agricultural implements, housing, fodder and firewood of the rural population;

5. Improvement of agro-ecosystem, control of erosion, and beautification of countryside;

6. Concentration of work resulting in easier supervision, easier mechanization of operation, cheaper logging and extraction; and

7. Increasing employment potential

## CHOICE OF METHOD OF ARTIFICIAL REGENERATION

After selection of species or site, as the case may be, method of artificial regeneration has to be decided. Artificial regeneration can be accomplished either by sowing of seed directly in plantation area or by planting seedlings or cuttings obtained from some nursery.

Advantages of sowing –

Sowing costs less and the work is completed soon.

As the seed is sown directly on the site, the result seedlings grows without any disturbance to its roots as happens in planting, consequently, there is no adverse effect on the growth of plant.

Disadvantages of sowing –

Sowing requires large quantities of seed, the birds and animals may destroy or eat up the seed sown. The seedling mortality is heavy. As weedings have to be done for relatively longer period, they become costly.

Advantages of planting – The quantity of seed required is much less; the damage to seed by birds is completely eliminated while that of animals is reduced. Success is relatively ensured and weedings are cheaper.

Disadvantages of planting – Planting is costlier than sowing; it requires more labour, particularly skilled labour and a nursery.

The choice between the two methods of artificial regeneration depends upon the

Species to be raised, conditions of site, availability of seed and cost.

**The species to be raised** – Though most of the species can be raised by both the methods, some of them, e.g., sal, khair, chir and kail were, till recent past, raised by sowing as their planting was considered difficult. But now even these species are raised by planting in many states or their parts, e.g., dona planting of sal has been in vogue for quite sometime in West Bengal except in taungyas. Khair and chir are also being planted as polythene bag plants in parts of Haryana, U.P. and Himachal Pradesh. Kail planting has also been attempted in Kashmir. As a general rule, slow-growing species or the species having seed enclosed in a hard coat are raised by planting. Ailanthus, Albizzia, etc., however, continue to be raised by sowing.

Condition of the site – In poorer and difficult sites, sowing is generally not successful and therefore, planting should be done. Infertile barren soils, places infested with grass and other weeds, places where long closure is not possible due to pressure of grazing, eroded soils and failed portions of natural regeneration and plantation areas are examples of places where planting is generally adopted.

Availability of seed – As already stated, sowing requires larger quantities or seed as all the seeds sown do not develop into seedlings due to adverse climatic and edaphic factors. Therefore, the species which do not produce large quantities of seed every year have to be raised by planting.

Cost – As a general rule, the method of artificial regeneration, which gives greater success at comparatively lesser cost, is preferred.

## KINDS OF SOWINGS

Sowing may be done in any of the following ways:

i) Broad cast sowing – Broad cast sowing is defined as the scattering of seed more or less evenly over the whole area, either that on which the crop is to be raised directly or a nursery bed. The seed is scattered after ploughing or digging up soil over the entire area and leveling it roughly, though sometimes, soil preparation may not be done at all. In large plantations, no attempt is made to cover the seed but in small areas, like that of a nursery, soil is turned over lightly with a khurpi. This kind of sowing is used for stocking burnt areas, desert areas, abandoned cultivations, landslides and grassy blanks. It is also used for improving the stocking in fuel felling coupes. In Assam, it has been used to supplement natural regeneration of Terminalia myriocarpa with artificial regeneration by scattering seeds on soil exposed by making an elephant drag a log through the blank portions of regeneration area. The only advantage of this sowing is that the area is covered soon but it has many disadvantages. Soil preparation has to be done over the whole area, making the operation costly. Large quantity of seed is required. Weedings are costly and difficult. A number of unremunerative cleanings and thinnings have to be done. Chances of damage by animals are greatly increased.

ii) Line sowing – Line sowing is the sowing of seed in drills or a single lines. The drills or lines are made at predetermined interval after digging the soil in those places. Normally, trenches are dug and the dug out soil is filled back in them after weathering for about a month or two. On this filled up earth, a drill, i.e., a shallow depression, is made with a hoe or a wooden peg. When the drill is made from one end of the plantation to the other end and sowing is done in it throughout without a break, it is called continuous line sowing. But if the soil is dug in small stretches, alternating with undug stretches, drill is made in dug up portion after filling the soil back and sowing done in the drills, the area will have dug up and sown portions alternating with undug and unsown portions. This is called interrupted line sowing. If the sown portion of a line is opposite to the unsown portion of the adjacent lines, the sowing is called interrupted and staggered line sowing. This is the usual method of sowing in most plantations. As compared to broad cast sowing, the cost of soil preparation and quantity of seed required is considerably less. Weedings are easy and less costly and the damage by wild animals greatly reduced. On the other hand, the disadvantages are that soil working requires skilled staff and labour because before digging, the lines and the portions to be dug therein have to be properly aligned, marked on ground and staked out, if necessary. The canopy takes longer time to close as compared to broad cast sowing.

iii) Strip sowing – Strip sowing is defined as the sowing of seed in narrow strips prepared for the purpose usually at definite intervals from one another. Strips are usually 45 cm to 90 or even 120 cm wide. Occasionally, they are made even 30 cm wide while in Assam, they are, sometimes, made as wide as 1.8 to 2.5 m. The soil is dug up in strips and after allowing it to weather, it is made into a seed bed. The seeds are sown in two or more rows or without rows all over the strip. Strip sowing differs from line sowing in having more than one row of sowing or broad cast sowing in each strip while line sowing has only one row of sowing in each line. Like line sowings, strip sowing may be continuous, interrupted or interrupted and staggered. As there are more than one row of seeds in each strip, chances of failure of any part of the plantation are remote. This method is very suitable for areas infested with grass and other weeds. But the cost of soil preparation, seed and weedings, though less than that in broad cast sowing, is more than that in line sowing.

Line and strip sowings are done either on ridges or in trenches, depending on the rainfall. In moist soils, high rainfall areas or areas liable to temporary water logging, sowing is not done at the ground level but on ridges and therefore it is called ridge sowing. In ridge sowing, the dug up earth is filled back in the trench to form a ridge in the centre about 10 to 15 cm higher than the general ground level. The advantage of making a ridge is that even if the filled up earth subsides during the rains, it does not form a trough below the ground level and so the seed does not rot due to excess of moisture. On the other hand, in dry or low rainfall areas, where water conservation is of paramount importance, dug up earth is filled upto about half the depth. Thus, the seed is sown in a trench and sowing. Apart from offering for the development of root of seedlings, this method, unless care is taken, may result in losing the top fertile soil by leaving it outside. In areas with uncertain rainfall, another method of sowing, called ridge ditch sowing is practiced. In this method, dug up earth is filled back in the trench in a sloping manner leaving part of the trench unfilled and the balance soil is used to make a ridge partly inside and partly outside the trench. The advantages is that in case of poor rainfall, lowest row sowing will be successful, in case of moderate rainfall, the middle row while in case of heavy rainfall, sowing on the ridge alone will be successful.

iv) Patch sowing – Patch sowing is defined as 'sowing a number of seeds in specially prepared patches', either circular or rectangular, made at regular interval. The size of patch varies from place to place depending on local conditions. In order to make patches, soil is dug upto a depth of 15 to 25 cm and filled back after weathering. Sufficient number of seeds are sown in each patch depending on its size though only one plant is expected in each. The greatest merit of this method is that the patches serve as small temporary nurseries inside the plantation area, whose extra plants can be used for planting up blank patches in it as well as adjoining plantations later. In addition, soil preparation and weedings are relatively much cheaper. But if the patches are smaller in size, there is a danger of grass and weeds suppressing the plants. Another disadvantage is that unless the patches are properly staked and made at fixed regular interval, a lot of time is wasted in locating them from weeding and subsequent tending and even then many are lost sight of resulting in the death of the plants.