सत्यमेव जयते

REGENERATION METHODS

বন বিভাগ
পশ্চিমবঙ্গ সরকার

DIRECTORATE OF FORESTS
GOVERNMENT OF WEST BENGAL

This edition is published by
Development Circle,
Directorate of Forests,
Government of West Bengal,
2016

Aranya Bhavan
LA – 10A Block, Sector III
Salt Lake City, Kolkata,
West Bengal, 700098

PREFACE

The subject 'Regeneration Methods' is the applied branch of Silviculture. Knowledge of this subject is an essential tool for a forester who needs to apply it his day-to-day work in the job of renewal of forest crop. The present course material deals with the basic elements of regeneration methods in thirteen lessons. Under the JICA project on 'Capacity Development for Forest Management and Training of Personnel' being implemented by the Forest Department, Govt of West Bengal, this course material on Regeneration Methods has been prepared for induction training of the Foresters and Forest Guards. The object of this training manual is to help the frontline forest personnel have a better perception about basic principles and procedures involved in regeneration methods.

The subjects covered in these materials broadly conform to the syllabus laid down in the guidelines issued by the Ministry of Environment of Forests, Govt of India, vide the Ministry's No 3 -17/1999-RT dated 05.03.13. In dealing with some of the parts of the course though, the syllabus has been under minor revision to facilitate better understanding of the subjects and to provide their appropriate coverage. The revised syllabus, with such modifications, is appended.

The contents of the course material have been compiled and edited by A Basu Ray Chaudhuri, IFS (Retd). Many books and literature including those available on the internet have been made use of in preparing this course material and references of such books and documents have been cited in the respective lessons. Shri A Basu Ray Chaudhuri is indebted to many forest officers who have helped in the preparation of this material. A special word of thanks is due to Shri T.K Das WBFS and Shri Abhijit Kar WBFS for providing valuable inputs to a number of topics.

The efforts that have gone into making this course material will be best rewarded if the frontline staff of the forest department finds it useful in their day-to-day work.

Kolkata, May 2015

A. Basu Ray, IFS (Retd)
For, IBRAD (Consultant)

N K Pandey, IFS
Chairman, SPMU, Forest Department,
Govt of West Bengal

SYLLABUS

Regeneration Methods (13* hours), Excursion 2 days, tour 5* days		
1.Natural Regeneration	1-1. Methods of Regeneration - Natural regeneration, Artificial regeneration 1-2 natural regeneration from seed - under clear felling system* - under shelter wood system* - under selection system* 1-3. natural regeneration from coppice -seedling coppice -stool coppice 1-4. assisting natural regeneration -gap planting in barren patches -tending operations* -thinning -soil and water conservation measures	2 hours
2.Artificial regeneration	2-1 Introduction - objectives -artificial vs. natural regeneration -choice of species -pure vs. mixed crops - kinds of mixture* - patterns of mixture* - exotics 2-2 methods of artificial regeneration* - sowing and planting, advantages and disadvantages* - kinds of sowing - planting methods 2-3 seed collection and storage - seed source-plus tree, seed stand, seed orchard - time of seed collection - methods of seed collection - seed extraction - seed storage - pre-sowing treatment	4* hours
3. Nursery	3-1 Introduction-definition 3-2 Kinds of nursery 3-3 Nursery works - site selection and fencing - layout, preparation of bed - use of root trainer - potting media - sowing in nursery beds*	3* hours

	- germination of seeds in mother beds* - pricking out* - direct sowing or dibbling of seeds - weeding, cleaning, hardening, watering - seedling nutrition - sorting, shifting, grading culling 3-4 Plant protection 3-5 Nursery register 3-6 Hi-tech nursery	
4. Planting Operations	4-1 Plantation work - Choice of species* - Site selection - Choice of method* - Spacing* - Arrangement of staff and labour* - Survey and demarcation, GPS tagging of site, Geo-tagging of site photographs - Regeneration plan map - Preparation of planting site* - Inspection path* - Boundary and contour trench* - Aligning according to spacing, staking/marking - Fencing, cattle-proof trench* - Pitting - Sowing of seed* - Planting season* - Transport of seedlings and planting - Weeding cleaning - Fertilization - Weeding mulching in south- west Bengal* - Irrigation - Replacing casualties - Nurse crop - Fire and general protection - Plantation journal 4-2 Study of estimate of plantation work	4* hours
Field Study	Entire nursery and planting operations will mainly be trained through fieldwork on two consecutive Saturday excursions including documentation with: • Nursery Journal • Plantation Journal	

* These are modifications with reference to the syllabus prescribed by MoEF, indicating revision/addition of topics and lesson hours.

	➢ **Pre-sowing treatment**	
7	• **Lesson Plan** • **Nursery** ➢ **Introduction-definition** ➢ **Kinds of nursery** ➢ **Selection of site** ➢ **Fencing** ➢ **Layout** ➢ **Preparation of bed** ➢ **Use of root trainer**	**38-43**
8	• **Lesson Plan** • **Nursery (continued)** ➢ **Potting media** ➢ **Sowing in nursery beds** ➢ **Germination of seeds in mother beds** ➢ **Pricking out** ➢ **Direct sowing or dibbling of seeds** ➢ **Weeding, cleaning** ➢ **Hardening** ➢ **Watering** ➢ **Seedling nutrition** ➢ **Sorting, shifting of seedlings** ➢ **Quality of seedling - culling**	**44-50**
9	• **Lesson Plan** • **Nursery (continued)** ➢ **Plant protection** ➢ **Nursery register** ➢ **Hi-tech nursery**	**51-57**
10	• **Plantation work** ➢ Choice of species ➢ Site selection ➢ Choice of method ➢ Spacing ➢ Arrangement of staff and labour ➢ Survey and demarcation, GPS tagging of site, Geo-tagging of site photographs ➢ Regeneration plan map ➢ Preparation of planting site ➢ Inspection path	**58-63**

Regeneration Methods

Lesson 1

Time 1 hour

Lesson Plan
Objective:
To study

- **Regeneration – methods of regeneration**
- **Natural Regeneration**
  - ➢ natural regeneration from seed
    - Seed production
    - Seed dissemination
    - Germination
    - Establishment

Backward Linkage- Lessons on 'General Silviculture' and 'Soil Science'

Forward Linkage- Lesson 2

Training materials required: Copy of Lesson 1 to be circulated beforehand

Allocation of Time

- **Regeneration – methods of regeneration** **5 mts**
- **Natural Regeneration** **5 mts**
  - ➢ natural regeneration from seed 40 mts
    - Seed production
    - Seed dissemination
    - Germination
    - Establishment
- Discussion/Miscellaneous 10 mts

1. Regeneration

Regeneration is defined as the renewal of a forest crop by natural or artificial means. Reproduction or regeneration of forest crop is an essential condition for the practice of scientific forestry, as failure or under-performance on this score will disrupt the sustainability of forest yield.

1.1 Methods of Regeneration

As the definition suggests, there are two methods to regenerate a forest - natural and artificial. However, in practice, a combination of these two methods is also adopted. Thus regeneration may be obtained in a forest by the following methods –

- Natural regeneration
- Artificial regeneration
- Natural regeneration supplemented by artificial regeneration

2. Natural Regeneration

Natural regeneration is defined as the renewal of a forest crop by self-sown seeds or by coppice or root suckers. Natural regeneration may thus be obtained from the following two sources.

- **From seed** – called 'high forest' or 'seedling crop'. This is the sexual method of regeneration in which the new plant exhibits the characters of both the parents.
- **From vegetative parts** – This is asexual method of regeneration and the new plant exhibits the characters of the parent plant only. When regeneration is obtained from coppice, it is called coppice crop, and the latter develops into a forest called coppice forest.

3. Natural Regeneration from seed

Natural regeneration from seed goes through the following four processes, namely

(1) Seed production
(2) Seed dissemination
(3) Germination
(4) Establishment

3.1 Seed Production

The most important prerequisite of natural regeneration is the production of adequate quantities of fertile seeds by the trees of the area or immediate neighbourhood. Seed production depends on (a) species (b) age of the tree (c) soil conditions (d) climate (e) crown , (f) other external factors.

- **Species-** Seed production is primarily a specific character. That is, all species do not seed annually and in equal abundance. For example, Teak, Sissoo and *Acacia*s seed almost

every year, whereas it is not so for many other species. For some important species, good seed years occur at Intervals as shown below.

Sal-3 years
Terminalia- 2 years
Cedrus deodara- 4-5 years

- **Age of the tree -** Best seeds are produced from middle- aged to medium-sized parent trees. Young as well as very old trees produce seeds with less germinating capacity and reduced vigour**.**

- **Soil condition -** Seed production is favoured in soil having sufficient bases, adequate nitrates and higher C/N ratio.
- **Climate -** In general, a warmer climate favours early and heavy seed production
- **Crown -** Large well developed lighted crowns bear more seeds and of bigger size than trees with poor and ill-lighted crowns
- **Other external factors -** Other external factors which influence seeding are (i) fire injury, fungus and insect attack and (ii) girdling.

3.2 Seed dissemination

Seed dissemination or seed dispersal is caused by the following agencies

- Wind – Seeds which are dispersed by the wind are either winged or hairy. Winged seeds are found in *Dipterocarpus, Termenilias, Conifers, Holoptelia, Dalbergia, Acer, Pterocarpus, Adina, Betula, Rhododendron, and Oroxylon.* Hairy seeds are found in *Bombax , Populus, Salix,* Family *Eupetorium* and grasses e.g *Saccharum* and *Imperata.*
- Water – Examples of water dispersed seeds are most mangrove species, Teak, *Dalbergia, Trewia*, and most of the wind dispersed seed, if they can retain their viability in water.
- Gravity – Seeds are dispersed by gravity in case of the following species, namely, Acorns of Oaks, *Juglans regia, Diospyros* and other heavy seeded species on sloping ground.
- Animals – Seeds of the following species are dispersed by birds- *Prunus*, Mulberry, *Loranthus* etc. Seed dispersals of following species are caused by animals- *Acacia arabica, Prosopis Juliflora, Ziziphus, Anthocephalus* etc.
- Explosive mechanism – Examples are Oroxylon and species of acanthaceae

3.3 Seed germination

The process that follows seed-fall is the germination of seeds. This process is dependent upon (i) Internal factors (ii) External factors.

A. **Internal factors-** Internal factors are the factors pertaining to the seed itself. Internal factors affecting germination are

- **Permeability of water** – A hard seed-coat prevents germination through lack of contact of the seed with moisture.

- **Permeability to Oxygen**- Oxygen is necessary for seed germination. Factors which inhibit moisture reaching the seed also prevent oxygen reaching it.
- **Nature of Embryo**- The embryo should be fully developed at the time of seedfall, otherwise the seeds will have to go through a period of dormancy till the embryo is fully developed.
- **"After ripening process"**- This is the most common cause of delayed germination due to the embryo being chemically unready. Such seeds germinate only when they have undergone a process of after ripening.
- **Viability**- Viability is the potential capacity of a seed to germinate. Seeds of some species retain their viability for a long period while those of certain other species lose their viability very soon. If the environmental conditions are not suitable during the short period of viability, such seeds do not germinate. For example, on the normal conditions Sal seeds remain viable for about a week. So if the monsoon is delayed, most of the seeds that fall on dry ground die.
- **Size of seed** – Very minute seeds are washed away in the rain water, whereas very big seeds do not get properly covered by soil or humus, and do not germinate.
- **Germination capacity** – Since all the seeds that fall on the ground do not germinate, natural regeneration is affected by **germination capacity** of seed, which is defined as the **percentage, by number, of seeds in a given sample that actually germinate, irrespective of time**.

Germination capacity of some species is given below.

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

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

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

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

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

B. **External Factors – Th**ese are factors of environment affecting germination.

- Temperature – Heat is necessary for germination. The range of temperature suitable for germination varies with the species. However, within this range, higher the temperature the better the germination.
- Moisture – A sufficient supply of moisture is essential for development of the embryo.
- Air/oxygen – Oxygen is essential for rapid respiration which accompanies the process of germination. Water-logged or ill-ventilated soil is not suitable for germination.
- Light – Most of the species are indifferent to light conditions for germination. However, some species require light, while some others require shade for germination.
  Species requiring light – *Rhododendron, Albizzia procera, Cassia fistula*.
  Species requiring shade – *Swietenia macrophylla, Santalum album*

- Depth of seed covering – If seeds lie on ground with shallow covering of soil, they germinate early. However, seeds which lie deeper give enhanced germination and establish per cent on account of adequate supply of moisture.

3.4 Seedling Establishment

Good germination does not necessarily ensure successful regeneration. A good number of seedlings die due to frost, drought or other climatic factors. Many suffer casualty owing to biotic factors like weeds, grazing, burning etc. Thus establishment of seedlings is what ultimately matters for successful natural regeneration. **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. Following factors affect establishment of seedling.

(a) Development of roots – It is essential that the root system develops rapidly and comes in contact with the deep lying moist soil before drought period sets in. Thus in the species in which root develops fast, the seedling mortality is less.

(b) Soil conditions – For their growth, seedlings require water and food, which they draw from the soil. Therefore, soil conditions are very crucial for establishment of seedlings. We discuss attributes of soil condition separately.

- Soil Moisture – During the growing season the seedlings require adequate moisture for which rapid development of the root system is essential. Root development primarily depends on carbon assimilation in leaves which in turn depends on available light and supply of moisture through root system. Hence if soil moisture becomes deficient, it will hamper root development and thus adversely affects the process of seedling establishment. Availability of soil moisture is the limiting factor in the survival of seedlings under dry and arid conditions. A typical situation of moisture stress is found in south west Bengal where seedling establishment is a difficult process.

- Nutrient Conditions - Though plants assimilate carbon and oxygen from the atmosphere, the majority of macro and micro-nutrients are supplied by ion exchange reactions, mineral weathering or organic matter decomposition – processes all occurring within soil (please see lesson 2 of 'Soil Science'). Thus deficiency in nutrients in the soil has an adverse effect on the development of seedlings. Forest soils in North Bengal, in general, do not exhibit any nutrient deficiency. However, forest soils in south- west part of the state are impoverished in mineral soil and organic matter. Establishment of seedlings, particularly of exacting and tender species, in such soil is difficult.

- Humus conditions – Presence of thick layer of undecomposed humus indicates deficiency of nutrients in the soil. It also presents a physical obstruction to the root to penetrate to greater depths to strike fresh mineral soil before the onset of drought season. Drought mortality is therefore aggravated with a thick layer of humus.

- Soil aeration – A well aerated soil with good texture ensures adequate supply of oxygen and facilitates early establishment of seedlings.

(c) Light Condition – Light is necessary for carbon assimilation by photosynthesis, and root development. It is the limiting factor in the establishment of seedlings in the humid regions. Light requirement, however, varies from species to species. Based on their light requirement plants are classified as (please see lesson 6 of 'General Silviculture') –

- Light demanders (requires abundant light for its best development
- Shade bearers (capable of persisiting and developing under shade) and
- Shade demanders (requires, at least in its early stage, some shade for normal development).

Seral species are generally light demanders and their regeneration can be obtained under overhead light conditions. However, climax species or species which occur in the later stages of succession are usually shade bearers, and their regeneration is best obtained under the shade of some overwood.

(d) Other Climatic factors – Extremes of temperature are harmful for establishment of seedlings. Similarly, moderate rainfall and proper seasonal distribution of rain is beneficial to seedling establishment.

(e) Condition of weed growth – Density of weed growth has a great influence on establishment. The competing weeds may be grass or shrub or combination of both. A dense growth of grass and when it forms dense mat-like roots is very harmful to forest crop. Similarly, dense growth of shrubs is very harmful to the desired species, as these shrubs cut off light.

(f) Grazing, browsing and burning – While light grazing and browsing are not harmful, uncontrolled grazing and browsing destroy the regeneration. In the same manner, controlled burning does not cause any harm and rather keeps the growth of shrubs in check. However, uncontrolled burning is very injurious to establishment.

Reference materials:

(1) L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun

(2) A B Lal 1967 Indian Silviculture Jugal Kishore & Co Dehra Dun

Regeneration Methods

Lesson 2

Time 1 hour

Lesson Plan

Objective:

To study

- **Natural Regeneration (continued)**
  - Natural regeneration from seed
    - under clear- felling system
    - under shelterwood system
    - under selection system
  - Natural regeneration from coppice
    - Seedling coppice
    - Stool coppice
  - assisting natural regeneration
    - gap planting in barren patches
    - Tending operations
    - thinning
    - soil and water conservation measures

Backward Linkage- Lessons 1 of "Regeneration Methods", Lesson 13 & 14 of "Silviculture of trees and silvicultural systems", Lesson 16 & 17 of "General Silviculture"

Forward Linkage - To see, during tour, natural regeneration**.**

Training materials required: Copy of Lesson 2 to be circulated beforehand

Allocation of Time

- **Natural Regeneration (continued)**
  - Natural regeneration from seed — 20 mts
    - under clear- felling system
    - under shelterwood system
    - under selection system
  - Natural regeneration from coppice — 15 mts
    - Seedling coppice
    - Stool coppice
  - assisting natural regeneration — 15 mts
    - gap planting in barren patches
    - Tending operations
    - thinning
    - soil and water conservation measure**s**
- Discussion/Miscellaneous — 10 mts

1. Natural regeneration under different silviculture systems

The mode of obtaining natural regeneration varies with the silviculture system. We discuss them separately.

2. Natural regeneration under clear-felling system (**please see lesson 11** of 'Silviculture of trees and silviculture systems)

In clear-felling system mature crop is removed in one operation. If reproduction is planned through natural regeneration, it can be obtained by one or more of the following methods.

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

2.1 When regeneration is to be obtained from seeds borne on the adjacent old stand

- The seeds must have mobility and should be dispersed in sufficient quantity to reach the extreme end of the clear felled area. With seeds of low mobility the clear cut area should be in the form of narrow strips
- The cutting may proceed against the direction of wind
- The cutting should be done before seed-fall.
- The species must have annual good seed years.

2.2 When regeneration is to be obtained from seeds lying dormant on the ground

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

2.3 When regeneration is to be obtained from seeds borne by the trees before they are felled

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

2.4 **When regeneration is to be obtained from advance growth**

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

2.5 After the regeneration has come up

- Weeding and cleaning should be undertaken
- When the crop reaches pole size, it should undergo thinning.

Instances of clear felling followed by natural regeneration are not common in our country.

3. Natural regeneration under shelterwood system (please see lesson 12 of 'Silviculture of trees and silviculture systems)

In shelterwood system over wood of mature crop is removed in a number of stages depending on the progress of regeneration. The first felling is the seedling felling and the last one is final felling. Other felling, if any, is called secondary felling. The interval between the seedling felling and final felling on a particular area such as a compartment is called regeneration period. The primary intent of this system is to protect and shelter the developing regeneration.

3.1 The form and nature of regeneration depends on the manner in which the mature crop is felled. For example, in **Uniform Shelterwood system**, where the seedling felling is done in gaps well distributed over the whole compartment, regeneration comes up in those openings uniformly over the whole area. Again, in Group Shelterwood System where the seedling felling is done in groups, the regeneration also comes in groups. Similarly, in Irregular Shelterwood system where advance growth in the form of saplings or poles is retained, the resulting regeneration gives rise to irregular crop.

3.2 The basic principle of all these shelterwood system is to allow regeneration to grow up under the shelter of seed trees. Several operations are carried out to facilitate natural regeneration under this system. The operations are

- Seed supply- Sufficient number of middle aged trees with well developed crown is retained to supply adequate seeds. Number of trees required to be retained depends on the species. For example, while 1 or 2 trees of *Adina cordifolia* is enough per hectare, 30 to 40 trees will be required per hectare in case of Sal.
- Adjustment of light– The function of the overwood is not only to supply seeds, but also to permit optimum light reaching the forest floor for germination. This is primarily achieved by suitable manipulation of canopy, that is by removal of certain trees of overwood which are not required for supply of seeds. As light is obstructed by the middle storey and undergrowth as well, middle storey is suitably thinned, and undergrowth density is reduced to admit sufficient light to the forest floor. The standard method of containing the density of undergrowth consists of regular cutting back, uprooting, controlled burning, use of weedicides etc.

- Soil condition- Soil needs to be permeable to help the tap roots of seedlings reach the depths of permanent soil moisture. It may therefore be necessary to undertake site-specific soil working measures to improve the permeability and porosity of the soil. In order to correct the condition of moisture deficiency, soil works like contour bunds may be done.

- Weeding and cleaning- Immediately after the germination of the desired species, weeding is done to protect the young seedlings against weeds which compete for light and moisture. Generally weeding is done before the weeds get a chance to suppress the regeneration of desired species. When regeneration grows upto the stage of sapling, cleaning is undertaken. Cleaning consists of removal or topping of inferior growth, climbers etc when the latter interfere with the growth of the favoured species.

4. Natural Regeneration under Selection System (please see lesson 13 of 'Silviculture oftrees and silviculture systems)

Selection system, in its simplest form, consists in **harvesting trees of rotation age from the whole forest every year** and allowing regeneration to come up in the gaps created by felling of selection trees. Since such annual working of entire area of the Felling Series is neither practicable nor desirable, the usual practice is to divide the area into a number of coupes (cutting sections) each of which is worked at an interval of a planned number of years, known as Felling Cycle (F.C.).

4.1 If the felling cycle is N years, annual increment is taken from one coupe whose area is – th of the area of felling series. Intensity of felling in the coupe is N times heavier compared to the degree of opening which would take place if the whole felling series would have gone over every year under the true selection system. The longer the felling cycle the more is the disturbance to the site conditions.

4.2 Felling cycle may be manipulated to obtain regeneration of a desired crop. For example, selection system with a short felling cycle is suitable for regeneration of climax shade-bearing species, while a long felling cycle may be utilized for securing regeneration of sub-climax light demanding species. Selection system requires not only harvesting of selection or exploitable sized trees, but also undertaking of simultaneous thinning in all the age classes in the coupes so that normal distribution of age classes is maintained in the resulting regeneration.

5. Natural regeneration from coppice (please see lesson 14 of 'Silviculture of trees and silviculture systems)

Natural regeneration by coppice can be obtained either by (1) Seedling coppice, or (2) Stool coppice.

(1) **Seedling Coppice** – It is defined as the coppice shoots arising from the base of seedlings that have been cut or burnt back. This method of regeneration is applied to woody shoots and established reproduction which has not made statisfactory progress. It is generally used in case of Sal and Teak. In situations

where advance growth of Sal or Teak remain stagnant, it is cut back and given proper light conditions to help grow fast.

(2) **Stool coppice**- It is the coppice arising from the stool or a living stump. Regeneration is obtained from the shoots that develop from the adventitious buds of the stump of felled trees. The reproduction through stool shoots is made use of in the coppice silvicultural system. The Silvicultural system may be either simple coppice system, coppice with standards system or coppice with reserves system.

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

B. **Coppice with standard system-** This system produces a multi-storey stand which consists of (i) an even-aged coppice underwood, and (ii) an uneven aged upper storey of standard trees grown at wide spacing. The rotation of the standards is a multiple of that of the coppice. The coppice shoots are cleaned and thinned like simple coppice system.

C. **Coppice with reserve system-** It 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 felt. The objective of the reservation is (i) to protect the upcoming crop from frost and soil erosion, (ii) to supply seed and (iii) to preserve valuable species as well as species with edible fruits etc. The regeneration is not only by coppice but also by saplings grown from seed.

6. Assisting natural regeneration

6.1 Gap planting in barren patches

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

6.2 Tending Operations

As a measure of assistance to natural regeneration, the regenerated crop is subjected to tending operations. The object of tending operations, as part of forest management, is to contain the degree of competition for light, food and water (i) between the desired species and the undesired ones and also (ii) between the trees of the desired species. By reducing the competition among the plants, tending facilitates provision of larger share of essentials for the desired individuals. Tending is defined as an operation carried out for the benefit of a forest crop, at any stage of its life between the seedling and the mature stages (L S Khanna 1999). It covers operations both on the crop itself and on the competing vegetation. Tending includes –

- Weeding
- Cleaning
- Thinning
- Improvement felling
- Pruning
- Climber cutting
- Girdling of unwanted growth
- Coppice thinning

Any or more of the tending operations described above, depending on their requirement for a naturally regenerated crop, may be undertaken to facilitate development of natural regeneration and establishment of the best individuals.

6.3 Thinning

A forest stand arising out of natural regeneration begins with a large number of seedlings /saplings per unit area. Even as the stand goes through a process of natural selection, the healthier and stronger individuals survive through a fierce struggle for food and water. Notwithstanding the fact that this process of natural selection favours the trees of superior growth, the forest stand if left to natural selection, allows retention of more stems per unit area than would have been optimum for growth of the desired trees. In other words, without silvicultural intervention, the density of the stand would remain high and would adversely affect the growth of even the dominant trees. It is thus necessary that the number of trees per unit area is reduced as the stand advances in age.

6.3.1 Thinning is an operation of felling carried out in an immature stand where the main objective is to reduce the density of trees in the stand, improve the quality and growth of the remaining trees and produce a healthy mature product. Thinning, strictly speaking, is carried out in pure, even-aged, or relatively even-aged crops.

6.4 Soil and water conservation measures

A growing natural regeneration, like any other developing forest stand, would require favourable soil and water conditions for optimum growth and early establishment. The natural regeneration will therefore be aided considerably, if soil and water conservation

measures, specific to the site, are undertaken. The measures may include construction of suitable earthen dam, contour bunds or trenches, gully control measures etc.

Reference materials:

(1) L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun

(2) A B Lal 1967 Indian Silviculture Jugal Kishore & Co Dehra Dun

Regeneration Methods

Lesson 3

Time 1 hour

Lesson Plan
Objective:
To study

- **Artificial Regeneration**
  - Introduction
  - Objectives
  - artificial vs. natural regeneration
  - choice of species

Backward Linkage- Lessons 1 and 2 of "Regeneration Methods",
Forward Linkage- To see, during tour, artificial regeneration**.**
Training materials required: Copy of Lesson 3 to be circulated beforehand
Allocation of Time

- **Artificial Regeneration**
  - Introduction 5 mts
  - Objectives 10 mts
  - artificial vs. natural regeneration 15 mts
  - choice of species 20 mts

- Discussion/Miscellaneous 10 mts

Lesson 3
Artificial Regeneration

1. Introduction

Artificial regeneration is defined as the renewal of forest crop by **sowing**, **planting** or other artificial methods. In common parlance such a crop is called 'plantation'. It is interesting to note that while the practice of sowing or planting has been in use in agriculture and horticulture crops since long, such practices have been adopted in forestry recently, and still more recently on a larger scale.

1.1 Sowing in artificial regeneration refers to direct sowing. It means sowing of seed directly on an area where a crop is to be raised, and not sowing in nursery. **Planting** refers to transferring of seedlings or plants in the area to be regenerated after they have successfully passed the critical phase of germination and initial development. The planting stock is generally raised in a nursery.

2. Objectives

Artificial regeneration is carried out for the following two objects.

(1) Reforestation – It means restocking by artificial means of a felled or otherwise cleared woodland.

(2) Afforestation – it means establishment of a forest by artificial means on an area from which forest vegetation has always or long been absent.

2.1 Reforestation is carried out for

- Supplementing natural regeneration
- Replacing natural regeneration, where natural regeneration of the desired species has not been successful or cannot be accomplished within reasonable time and cost.
- Changing the composition of the crop by increasing the proportion of more valuable species.
- Introducing valuable exotic species

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

- Productive purpose, i.e for raising a particular kind of forest crop – examples: afforestation of wastelands, afforestation of grass infested area.
- Protective purpose, i.e for conservation of soil and water – examples: afforestation of catchment areas, afforestation of swampy areas.

- Bio-aesthetic objects, i.e for conservation of wild life and recreation purpose- examples: ecological parks.

3. Artificial vs. natural regeneration

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

- **Risk of deterioration of soil** – The points to be considered are that natural regeneration involves minimum exposure of soil, while artificial regeneration exposes the soil for a longer period. Long exposure of soil may invite soil erosion, particularly in slopes, and affect fertility of soil.
- **Crop composition** – Natural regeneration does not give the desired proportion of valuable species, whereas in artificial regeneration one can manipulate the crop composition. Artificial regeneration has become the standard practice to enrich the crop with larger proportion of valuable species and increase the productivity.
- **Crop quality** – In natural regeneration despite exercising the best control, one is never sure that regeneration comes from only genetically superior trees. But in artificial regeneration one has the option to use seeds and clones from genetically superior trees and produce a quality crop.
- **Risk of damage by pests** – In general, mixed crops resulting from natural regeneration are far more resistant to attack by insect pests than those resulting from artificial regeneration. Physical separation of food plants in mixed natural forests inhibits the spread of insect pests.
- **Time factor** – Time is the factor that overrides, most of the time, other factors in deciding between natural and artificial regeneration. Natural regeneration is a long, and at times, uncertain process. In a delayed process, the gaps may be invaded by weeds, or the sites while remaining exposed may undergo serious deterioration through intensive leaching, erosion and desiccation. On the other hand, artificial regeneration can bring vegetal cover quickly in open barren areas. One great advantage of artificial regeneration is that it is independent of occurrence of good seed years and can continue every year if there is good stock of seeds.
- **Cost** – This is definitely an important factor of consideration. Artificial regeneration is apparently a costly method, as it involves elaborate operations like procurement of seeds, creation of planting stock, maintenance of nursery, carriage of seedlings, fencing, planting , tending etc. all of which require spending on account of material and/or labour. In contrast, natural regeneration does not involve any initial cost of formation except slash disposal and fencing, where necessary. However, in natural regeneration the weeding and shrub cutting may have to continue for a very long time and may turn

out to be very costly. Cost has also implication in the operation of harvest. In natural regeneration removal of mature trees has to be deferred till regeneration has been obtained on ground. As a consequence, some of the mature trees may become over-mature and unsound, resulting in financial loss. Besides, in natural regeneration, harvest of mature trees is done over a number of years in several stages, and it is done after taking due care of not damaging the young regeneration. This makes the operation of logging and extraction costly. Artificial regeneration allows removal of mature trees without any loss in the value of timber. Besides, logging and extraction becomes short and simple operation without any chance of damage to young reproduction.

3.1 Ultimate choice

There is no thumb rule to decide between natural and artificial regeneration. The choice should be made keeping in view the above factors in a given set of conditions prevailing at a given site. Academic considerations seem to suggest that natural regeneration may be followed for a reasonably short period and then regeneration operation may be completed by supplementing natural regeneration with artificial regeneration. However, the recent trend is in favour of artificial regeneration, that is, man-made forests.

4. Choice of species

Since plantation is an expensive operation, the species to be established should be judiciously selected. Choice of species should be governed by the following factors.

(1) Climate and micro-climate – This should be the primary guiding factor. Only those species which can grow in the regional climate and the micro-climate of the plantation site should be considered. So far as indigenous species are concerned, those species which have grown well in the neighbourhood, and those which performed well in the coupe (in case of planting after clear-felling), can be considered as suitable species. However for exotics, climatic conditions prevailing in their land of origin may be compared with those prevailing in the site before making a selection.

(2) Soil conditions – Suitability of a species to the soil and moisture conditions is an important factor to govern the success of the species in the site. The species suitable to the soil conditions should be selected. In immature soil seral species which come in the early stages of the succession, and in mature soil climax species or those which come in the advance stages of succession should be selected. The undergrowth growing on a site also sometimes gives a good indication of species that can be successfully raised.

(3) Object of management – Choice of species is also guided by the object of management. For example, if the object is to raise pulpwood, the species which can yield pulp of good quality and quantity (for example, Eucalyptus could be one) may be chosen. If the object is to produce mining timber, a major part of planting stock could be of Sal. The object of

management is clearly written in the Working Plan. In fact, the Working Plan also prescribes the species to be raised.

(4) Stakeholders' requirement – Stakeholders' requirement is partly reflected in the market demand. One of the factors to guide the choice of species is how and whether such species can fulfil the stakeholders' requirement. In a way stakeholders' requirement should also influence the previous factor, that is, the object of management. Besides the Forest Department of the state Government, one major stakeholder in forest management is the members of the Joint Forest Management Committee (JFMC). The requirement of the JFMC members should therefore be ascertained while making choice of species.

(5) The silvicultural system – The silvicultural system under which the forest will be worked will be a guiding factor. For clear-felling system, strong light demanding species should be selected. For shelterwood system, species of intermediate light requirement is needed. For Selection system, shade-bearing species are suitable.

(6) Availability of suitable exotics – If indigenous species cannot meet some specific demand of the locality or some industrial demand, exotic species with proven suitability for the site can be selected. An exotic is a species which is not native to the area in question. There are quite a few examples of exotics which have been successfully introduced in WB and some of them have almost naturalised in the regional climate and soil. Examples are Eucalyptus and *Acacia auriculiformis* in the south-western part, *Casuarina equisetifolia* in the coastal area, and *Cryptomeria japonica* in north Bengal hills.

(7) Growth rate – The growth rate also influences the decision on choice of species. To meet the increasing demand of industrial timber and fuelwood, the present trend is to focus on fast growing species.

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

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

Reference materials:

(1) L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun

(2) A B Lal 1967 Indian Silviculture Jugal Kishore & Co Dehra Dun

Regeneration Methods

Lesson 4

Time 1 hour

Lesson Plan
Objective:
To study

- **Artificial Regeneration (Continued)**
    - pure vs. mixed crops
    - Kinds of mixture
    - Patterns of mixture
    - Exotics

Backward Linkage- Lessons 3 of "Regeneration Methods",
Forward Linkage- To see, during tour, artificial regeneration**.**
Training materials required: Copy of Lesson 4 to be circulated beforehand
Allocation of Time

- **Artificial Regeneration (Continued)**
    - pure vs. mixed crops 25 mts
    - Kinds of mixture 10 mts
    - Patterns of mixture 5 mts
    - Exotics 10 mts
- Discussion/Miscellaneous 10 mts

Regeneration methods

Lesson 4

Time 1 hour

Artificial Regeneration (Continued)

1. Pure vs. mixed crops

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

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

- Teak is an exacting species. It remains deciduous for a number of months in a year. As the soil remains exposed during the period when the crop is nearly leafless, pure Teak crop leaves a chance of soil deterioration. Lately, Teak is planted in the mixture of other species in north Bengal.
- Pure Eucalyptus plantation in south-west Bengal forests renders the soil compact and devoid of humus.

(2) Resistance to disease – it has been observed that pure crops are more likely to be destroyed by insects, plant parasites or fungi. In West Bengal, pure crops of *Michelia champaca* have been attacked by *Urostylis punctigera* (sap sucker); those of *Toona ciliate* by shoot borer *Hypsipyla robusta*; pure *Gmelina* plantation by *Loranthus*. Please see lessons of Forest Protection to know about damage to pure Sal and Teak.

Mixed crops are supposed to minimise epidemic attack by (i) mechanical separation of the sensitive species, and (ii) providing a reservoir of parasites and predators which feed on the main pest.

(3) Damage by wild animals – The species of a pure crop may be a favourite food for any wild animal available in large population in the locality. In such a case, the plantation

may be damaged severely. For example, bamboo plantations in areas having elephant population are generally destroyed by them. Again, choice of species in a mixed crop may be such as to invite damage by wild animals. For example, if Teak is mixed with *Gmelina* or *Dalbergia latifolia*, the wild animals which browse the latter, damage the latter by rubbing against them. Thus the key issue of consideration is the susceptibility of the main and as well as accessory species to damage by local animal population.

(4) Total yield – In pure crops, the site qualities are not fully utilised resulting into reduction in volume yield per unit area. In the mixed crops the soil and the atmosphere are utilised in a greater extent and so there is more volume production per unit area compared to pure crops. However, necessary conditions for achieving enhanced production are (i) that the species in the mixed crop should be capable of sharing space without interfering with each other's growth, and (ii) that they should mature more or less at the same age. If the number of species is large, it becomes difficult to satisfy these conditions.

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

(6) Conservation of biodiversity – Object of management is not always to have maximum production of tangible resources. While part of forests may be worked for production of timber and other marketable produce, other parts may be worked with the object of conservation of biodiversity. Focus of management in this latter case is to sustain the regulating and supporting services of forest ecosystem. It is obvious that mixed crop being richer in biodiversity serves this focus much better than the pure crop.

2. Kinds of mixtures

Mixtures may be of two kinds, viz.

(1) Temporary Mixtures
(2) Permanent Mixtures

2.1 **Temporary Mixtures**

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

2.2 Permanent Mixtures

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

- Horizontal or Even-aged mixtures are those in which species mixed are in the overwood and of the same height. For example, in north Bengal Sal plantation, the main species Sal is mixed with many associates and the association is horizontal and even-aged. The main species Sal and the associates are worked on the same rotation.
- Vertical or Uneven-aged or Storeyed Mixtures are those in which the main species is in the top canopy while the accessory species are in the middle canopy. This may be due to varying rate of height growth or late sowing or planting of accessory species.

2.3 Patterns of mixtures

The mixtures amy be of the following patterns.

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

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

(3) Strip mixture – Strip mixture is one in which the mixed species are raised in different strips. In case of sowing, seeds may be sown in the strips in lines or scattered all over. In case of planting, each strip will consist of lines in which seedlings are planted. One typical example is Sal plantation in north Bengal. Prescription in Sal plantation is to sow eight lines of Sal alternated by eight lines of Sal associates. Thus Sal is grown on strips each of which comprise eight lines, and each strip of Sal is alternated by a 8-line strip of miscellaneous species.

(4) Block Mixture – Block mixture is one in which different species are raised in different blocks of the plantation. One form of block mixture was tried in south-west Bengal miscellaneous plantations, where Eucalyptus clones and Sal were raised in blocks forming part of a plantation area.

3. Exotics

Exotic species are introduced when indigenous species cannot meet the fast growing requirement of industrial timber or any specific requirement of a forest area. While there should not be any inhibition in introducing an exotic, the following points should be taken into consideration while selecting an exotic.

- It should serve the purpose in view better than an indigenous species.
- It must be suited to the climatic and soil conditions of the locality.
- It should be easy to grow and regenerate.
- It must not suffer from local risks.
- It must be more valuable than the indigenous species
- One has to be sure that the exotic is not vulnerable to attack by an indigenous parasite against which it may not possess any resistance, and that it should not inadvertently introduce a foreign pathogen (please see lesson 9 of Forest Protection).

3.1 Any exotic worth consideration for introduction should pass the experimental trial to prove its suitability to the local conditions. It is also to be borne in mind that performance of an exotic over a short period may not guarantee that it will have disease-free life cycles in the long run, because pathogens and pests take time to build up.

3.2 Examples of successful exotics are

- *Cryptomeria japonica* in Darjeeling hills, though large scale plantation (carried out in the past) is now discouraged.
- *Acacia auriculiformis* in south-west Bengal
- *Eucaluptus hybrid* in south-west Bengal
- *Casuarina equisetifolia* in coastal areas.

3.2 Example of failed exotics are

- *Paulownia* tried in north and south-west Bengal
- *Acacia mangium* and *Acacia holosericea* tried in south-west Bengal

Reference materials:

(1) L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun

(2) A B Lal 1967 Indian Silviculture Jugal Kishore & Co Dehra Dun

Regeneration Methods

Lesson 5

Time 1 hour

Lesson Plan
Objective:
To study

- **Artificial Regeneration (Continued)**
    - Methods of artificial regeneration
    - Sowing and planting, advantages and disadvantages
    - Kinds of sowing
    - Planting methods

Backward Linkage- Lessons 3 and 4 of "Regeneration Methods",
Forward Linkage- To see, during tour, artificial regeneration**.**
Training materials required: Copy of Lesson 5 to be circulated beforehand
Allocation of Time

- **Artificial Regeneration (Continued)**
    - Methods of artificial regeneration 3 mts
    - Sowing and planting, advantages and disadvantages 15 mts
    - Kinds of sowing 20 mts
    - Planting methods 12 mts
- Discussion/Miscellaneous 10 mts

Regeneration methods

Lesson 5

Time 1 hour

Artificial Regeneration (Continued)

1. Methods of artificial regeneration

Artificial regeneration can be accomplished either (1) by sowing of seeds directly in plantation area or (2) by planting seedlings or cuttings raised in nursery. And it can be a combination of both the methods.

2. Sowing – advantages

- Sowing as a means of forest regeneration is less costly and takes less time than planting.
- As seeds are sown directly on the site, there is no disturbance to roots which normally happens while transferring planting stock from nursery to planting site.

3. Sowing – disadvantages

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

4. Planting – advantages

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

5. Planting – disadvantages

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

6. Choice between sowing and planting depends on -

- The species to be raised – as a general rule, slow growing species or species whose seeds are enclosed in a hard coat should preferably be raised by planting.
- Conditions of the site – In poorer and difficult site, planting is preferred as rate of success of sowing in such site is low.

- Availability of seed – Species which do not seed adequately every year is preferably raised by planting.
- Cost – The factor of cost has to be considered together with degree of success of the method. The method which gives success at reasonable cost is preferred.

7. Kinds of sowing

- **Broad-cast sowing –** Sowing is done all over the area. The seed is scattered after ploughing or digging up soil all over the area and levelling it roughly. This kind of sowing is used for stocking burnt areas, desert areas, landslides, grassy blanks, rocky barren sites. Depending on the situation, sometimes no soil preparation is done. Thinning becomes more important in this method than other methods of sowing. In Assam, it has been used to supplement natural regeneration of *Terminalia myriocarpa*.
- **Line sowing –** It is sowing in drills or single lines. The lines are made at specified interval after digging the soil in those places. Normally trenches are dug and dug out soil is filled back after weathering. A drill, i.e a shallow depression is made on the filled up earth with a hoe or a wooden peg. When the drill runs continuously from one end of the plantation to the other end and sowing is done along the drill, it is called continuous line sowing. The line sowing can be interrupted or interrupted and staggered (please see Fig 5.1, 5.2 and 5.3)

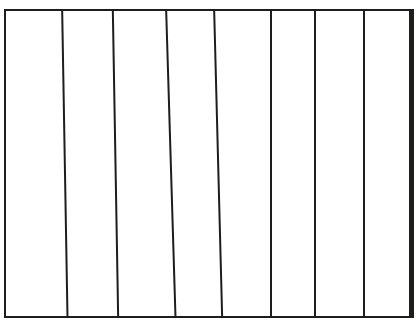

Fig.5.1 Continuous Line sowing

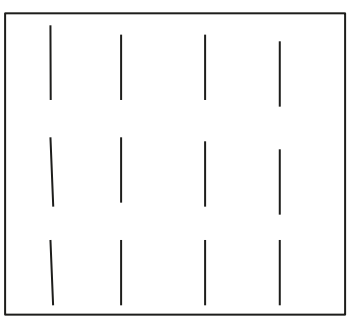

Fig.5.2 Interrupted Line Sowing

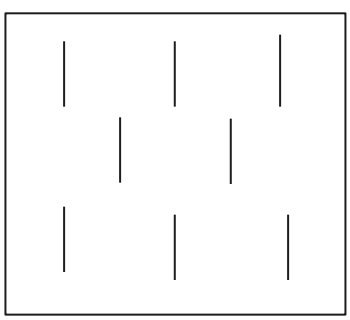

Fig.5.3 Interrupted-staggered lline sowing

- **Strip sowing** – Sowing is done on narrow strips prepared usually at definite intervals from one another. The soil is dug up in strips, allowed to weather and then made into seed bed. Seeds are sown in two or more rows along the strip. Like line sowing strip sowing may be continuous, interrupted or staggered. As there are multiple rows along the strip, chances of failure of germination is remote. This method is very suitable for areas infested with grass and other weeds. A typical example of strip sowing is done in Sal plantation in north Bengal. In the strip of 30 cm width sowing is done in three rows 15 cm apart.
- **Patch sowing** – it is sowing of a number of seeds in specially prepared patches made at regular intervals. Soil is dug upto a depth of 15 to 25 cm and filled back after weathering. Sufficient number of seeds, depending on the seed-size, are sown, though one is expected from each patch. This method requires less seed compared to line or strip sowing. Seeds are less damaged by birds or animals on account of the scattered nature of the patches. The method is useful for rough sites covered with stones, stumps etc where line or strip sowing is not feasible.
- **Dibbling** – it is defined as sowing of seeds in shallow holes made with suitable instruments at regular intervals. Soil working and sowing is done simultaneously and a stake is fixed by dibbled site to enable locating the site in future. It is applied for large and heavy seeded species. In south-west Bengal Arjun seeds are dibbled in plantations in moist soil during the onset of monsoon.
- **Ridge or mound sowing** - In moist soils, or high rainfall areas, sowing is done on ridges or mounds, and it is called **ridge or mound sowing**.
- **Trench or Pit sowing** - In dry or low rainfall areas, seed is sown in trenches or pits and accordingly it is called **trench or pit sowing**. In Sal plantations in south-west Bengal, Sal seeds are sown in contour trenches.

8. Planting methods

- **Planting natural seedlings from the forest** – Natural seedlings of *Michelia champaca*, *Amoora wallichii* and *Anthocephalus cadamba* can be used for plantation work. However, as a rule, use of natural seedlings is discouraged.
- **Planting nursery grown seedlings** – In this method, plants are grown from the seed bed in the nursery and the entire plants (with or without ball of earth) are directly planted in the field without transplanting or pricking out. This method can be used for many species under favourable conditions.
- **Planting of transplants/containerized seedlings** – These are plants which have been reset one or more times from mother nursery bed to another place and then planted out in the field. The recent practice, however, consists in pricking out seedlings from the mother seed bed and transplanting into polythene bag or root trainer. That is, pricked out seedlings are not transferred in transplant beds, rather put in polythene bag or root trainer. For many species, seeds are directly sown in polythene bag or root trainer. The transplants in containers, when ready for planting, are taken to the field.

- **Planting root and shoot cutting or stump planting –** This is used for Teak and many other species. In case of Teak, one or two year old stumps are used. Please see "Silviculture of trees and Silvicultural Systems".
- **Planting brach or stem cutting –** Some of the species can be artificially propagated by branch and stem cuttings. For example, *Ipomea, Vitex, Lannea, salix, Sissoo, Dendrocalamus* etc. Clones obtained from stem cuttings in nursery are now used on a large scale for Eucalyptus plantation. Cuttings are placed in the rooting medium in root trainers in a mist chamber. The object of the mist chamber is to produce a micro environment of high humidity and moderately high temperature. Such environment facilitates early rooting. When the cuttings have developed a sufficient root system, they are taken out of rooting chamber and placed in hardening chamber for about 15 days before they are considered ready for planting in the field (please see lesson 12 of Forest Botany).
- **Planting root cuttings –** Sections of tap root of *Stereospermum* and **Bombax** can be used.

Reference materials:

(1) L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun

(2) A B Lal 1967 Indian Silviculture Jugal Kishore & Co Dehra Dun

Regeneration Methods

Lesson 6

Time 1 hour

Lesson Plan
Objective:
To study

- **Seed collection and storage**

  - Source
    - Plus tree, seed stand, seed orchard
  - Time of seed collection
  - Methods of seed collection
  - Seed extraction
  - Seed storage
  - Pre-sowing treatment

Backward Linkage- Lessons 5 of "Regeneration Methods",
Forward Linkage- To see, during tour, seed source, seed storage, and pre-sowing treatment
Training materials required: Copy of Lesson 6 to be circulated beforehand
Allocation of Time

- **Seed collection and storage**

  - Source
    - Plus tree, seed stand, seed orchard — 25 mts
  - Time of seed collection — 5 mts
  - Methods of seed collection — 5 mts
  - Seed extraction — 5 mts
  - Seed storage — 5 mts
  - Pre-sowing treatment — 5 mts

- Discussion/Miscellaneous — 10 mts

Regeneration methods

Lesson 6

Time 1 hour

1. Seed collection

1.1 Source

For collection of seed, a forester should know, first of all, the proper source of seed, that is, where he should collect seeds from to produce a planting stock that would ultimately give good healthy crop. Ideally, the source of seed should be a **genetically superior tree** which is superior to other trees in its habitat from the point of view of its size, length, shape of stem, height, diameter and volume increment, timber quality, resistance to disease and other specific qualities. It is, however, obvious that the internal traits of a tree, determined by its **genotype**, or the genetic make up of the individual tree is difficult to ascertain and identify. A forester, therefore, for the purpose of collection of seed, looks for middle-aged good **phenotypes** (physical appearance of an organism as distinguished from its genetic makeup) in the locality. In other words, he selects middle-aged trees with cylindrical straight long boles and well developed crowns. These seed trees of good phenotypes are called **Plus trees. Plus trees** which serve as seed trees are marked with paint. Location, species and visible characters of plus trees are recorded for future use.

1.1.1 **Seed stand**

Plus trees are isolated trees in the forest. They cannot meet the seed requirement of large scale plantation. Further dependence on a few plus trees for supply of seeds is not advisable because such trees are vulnerable to damage by many factors, particularly biotic. Plus trees have, however, great utility in raising seed orchards which are discussed later. For meeting requirement of large scale plantation, It is advisable to establish **seed production area** or **seed stand. Seed production area or seed stand is defined as a crop of vigorously growing middle-aged to mature trees of good quality, properly thinned, and left to contain trees of good vigour and well developed crowns, with clear boles and managed exclusively for seed collection**. (L.S Khanna 1999) Only those areas are selected as seed stand where the proportion of desirable trees is high.

1.1.1.1 After selection of the seed stand area, following operations are undertaken for **formation of the seed stand**.

- The best phenotypes are identified and distinctly ringed with paint. The remaining trees are marked for removal and eventually removed. Only the best phenotypes are retained for seed production.
- If there is congestion even after removal of inferior trees, the selected trees are properly thinned so that the trees retained have sufficient space to develop good crowns so as to maximise seed production.

- In order to prevent cross pollination with inferior trees in the neighbourhood, such inferior trees in the neighbourhood are removed. Usually, an isolation strip of width 100 to 150 m is maintained around the seed stand and all inferior trees of this strip are removed.

1.1.2 Seed orchards

Seed stands are formed of superior phenotypes of the existing crop whose origin is not known. It is thus never certain that seeds of the stand will invariably produce genetically superior trees. Seed stand, in fact, is an interim source of seed before we establish seed orchards. **Seed orchard is defined as a plantation of genetically superior trees isolated to reduce pollination from genetically inferior ones, and intensively managed to produce frequent, abundant, and easily harvested seed.** (L.S.Khanna 1999). Seed orchards are of two kinds–

(1) **Clonal seed orchard (CSO)** – raised by grafting clones in the form of a scion or bud of plus trees on the stock of 2 or 3 year old seedlings, or by planting rooted cuttings of plus trees at proper spacing.
(2) **Seedling seed orchard (SSO)** – raised from the seedlings obtained from the seeds of plus trees.

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

1.1.2.1 Seed orchard - isolation

A seed orchard should be isolated to exclude the chance of pollen contamination from inferior trees of the same species. This can be done by (1) keeping a strip around the orchard free from any plantation or self-grown tree of the same species, or (2) by screening off the orchard by planting a belt of some other suitable species which does not intercross with the species of the orchard.

1.1.2.2 Seed orchard - advantages

- Seed orchards produce superior seeds;
- Seed collection becomes a concentrated activity, and therefore becomes an easy operation and less costly;
- They can be used for controlled crossing programme between selected clones to achieve improved seed source;

1.1.2.3 Seed orchard – site and maintenance

- The site of a seed orchard should be flat or gently sloping; it should be well drained and easily accessible;
- The size of the orchard should be such that it is economic to maintain;
- The orchard may be irrigated, preferably by a sprinkler system, and, if necessary, fertilized to get better production of seed.

1.2 Time of seed collection

Seed should be collected on maturity before dispersal. It means that proper time for collection of seeds is immediately after ripening when they are ready to fall off the tree. Change in colour and softening of the tissues of the fruit give some indication that the seed is approaching maturity. Most fruits turn reddish brown when ripe; pulpy fruits start getting soft and skin wrinkled. Most of the species have a fairly definite period in which they ripen and such information can be obtained from the literature (please see "silviculture of trres and silviculture systems" to know the seed collection time for some important species). However, the exact period of maturity of seeds of a species varies with locality, and sometimes varies from year to year in the same locality due to change in climatic conditions. Thus, besides the knowledge obtainable from literature, guidance should come from constant field observation to know the appropriate collection time of seeds of a species. During the period of seed collection, the seeds which ripen very early or very late are often found to be infertile, and should be avoided.

1.3 Methods of seed collection

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

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

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

1.4 Seed extraction

Many seeds or fruits can be sown or stored as they are collected. But for some species, seeds need be separated from fruits.

1.4.1 **Dry fruits**

There are three categories.

(1) The entire fruit is sown with seed contained in it, e.g Teak, walnut, Oak etc. Dry fruits of this category do not require any extraction.

(2) Part of the fruit is sown with seed contained in it, e.g Sissoo. Fruits are placed in gunny bag and given beating to break each fruit into as many parts as contain a seed or two.
(3) Seed is sown, e.g Conifers, *Leguminous* species, *Lagerstroemia, Acer* etc. This category of fruits requires complete seed extraction. The usual method is to spread out the fruits in the sun to dry when the seeds come out.

1.4.2 Pulpy and fleshy fruits

The pulpy portion should be removed as early as possible**.** The method depends on the kind of fruit. The usual method is to keep the fruits in water in a container for some time, followed by pounding and squeezing while still under water until the seeds are freed. The soft pulp floats on water and the seeds sink to the bottom. The two can be separated by decantation.

After the seeds have been extracted and dried, they should be cleaned off all foreign materials by winnowing or sieving. They are now ready for grading, sowing or storage. For single-seeded species, larger sized seeds should be preferred, but in multi-seeded fruits, size is no criterion to quality.

1.5 Seed storage

Storage of seeds becomes necessary if the time of ripening of seeds does not coincide with time of sowing. Naturally, seeds need to be stored after collection till the time of sowing. Seeds having long viability should also be stored for use in lean seed year. In general, the ideal storage condition should be similar to the environment in which seeds of the species are stored in the nature. The method of storage thus varies with the species.

- Species with seeds of short viability – They should be sown immediately after collection. Still, if it becomes necessary to store for a short period, this is done by spreading the seeds in shade, on hard floor, if possible, and sprinkling with water from time to time. Sal, most *Dipterocarps* can be stored in this manner.
- Species whose seeds ripen in autumn and germinate in spring – Usually the species of temperate region seed in autumn; their seeds lie under snow during winter and germinate when snow melts in spring. Such seeds need be stored in low temperature. Conifers generally require dry cold storage. However, broad-leaved species are reported to require wet cold storage, that is moist and cold condition. in Darjeeling district, *Quercus, Machilus* and *Juglans* seeds are reportedly stored in pits.
- Species whose seeds ripen in winter or summer and germinate in the following summer – Most species of the plains fall in this category. Seeds can be stored either by spreading them out in dry places with good circulation, or by light packing in loose gunny bags, and occasionally spreading them out in the sun to prevent dampness. For storing large quantity of seed, a special shed is built up. The shed may be fitted with bamboo shelves and movable trays to facilitate drying. The shed should be so constructed that it is not exposed to excessive damp or over-heating.

1.6 Pre-sowing Treatment

(L.S.Khanna 1999; Inputs by T.K.Das WBFS)

Quick and uniform germination is key to successful planting. Following are some pre-sowing treatments that hasten germination. One or the other treatment, as found appropriate for a species, is applied.

- **Cold water Treatment** – For seeds which need lot of water for germination, and at the same time have certain chemicals inside, which inhibit germination, the cold treatment is a good method. Examples: Pine, Amlaki, Kanchan, Kalasirish, Patka sirish, Khair etc. Process: Put the seeds in water, five times the volume of seeds and allow the seeds to soak for 1-2 days, change the water every 12 hours. Discard the seeds that float on the top. All the swollen seeds are ready for immediate sowing.
- **Hot water treatment** - The method is applied for seeds which contain hard seed coat, such as *Cassia, Sesbania* and *Albizia*.

  Process**:** Boil a volume of water, five times the volume of seeds. Let the water cool for 10 minutes and soak the seeds in hot water and keep the seeds in this water for 2 days or until most of them have swelled. Discard the seeds that have floated on the top. Change the water every day with cold water. Once the seeds swell, sow them immediately.
- **Boiling water treatment -** The method is applied for seeds which contain very hard seed coat, such as *Acacia, Albizia, Prosopis*, Oaks etc.

  Process: Boil a volume of water, five times the volume of seeds. Take the container off the fire and soak the seeds immediately for 1-2 minutes only. After 2 minutes replace the hot water by cold water and allow the seeds to soak for 2-3 days or until the seeds swell, changing the water every day. Once the seeds swell, sow them immediately.
- **Alternate wetting and drying** – Seed is alternately wetted for some hours and then dried. This is used for Teak (please see "silviculture of trees and silviculture systems").
- **Passage through animals** – Seeds are passed through the digestive system of animals or poultry. It is applied for treating Sandal, Nim, and *Acacia arabica* seeds.
- **Cow dung slurry treatment -** Fruits of *Terminalia chebula* and *Melia azedarach* are mixed with cow dung slurry and kept in pits for about 7-14 days to remove the thick seed coat. It also helps to overcome dormancy.
- **Chemical treatment** – Soaking in various chemical solutions softens the hard seed coat and hastens germination.
- **Mechanical treatment - Shell cracking -** Seeds of *Simarouba glauca, Zizyphus* can be cracked using a wood or light hammer before sowing.
- **Other specific treatment -** Some spp. require specific treatment to seeds for initiation of germination.

  – Dry fruits of Arjun, Asan etc. are placed in sunken bed and covered with straw and watering done in a regular interval till germination. Germinated fruits are put into poly pots/root trainers.

- Fruits of Peasal, Raktachandan are placed on sand bed under straw cover and kept wet by regular watering. Then germinated fruits are put into filled up poly pots/root trainers.

Reference materials:

(1) L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun

(2) A B Lal 1967 Indian Silviculture Jugal Kishore & Co Dehra Dun

Regeneration Methods

Lesson 7

Time 1 hour

Lesson Plan

Objective:

To study

- **Nursery**
  - Introduction - definition
  - Kinds of nursery
    - Temporary
    - Permanent
  - Selection of site
  - Fencing
  - Layout
  - Preparation of bed
  - Use of root trainer

Backward Linkage- Lessons 6 of "Regeneration Methods",

Forward Linkage- To see, during tour, nursery works.

Training materials required: Copy of Lesson 7 to be circulated beforehand, demonstration of poly pot and root trainer.

Allocation of Time

- **Nursery**
  - Introduction – definition 8 mts
  - Kinds of nursery 10 mts
    - Temporary
    - Permanent
  - Selection of site 7 mts
  - Fencing 3 mts
  - Layout 5 mts
  - Preparation of bed 10 mts
  - Use of root trainer 7 mts

- Discussion/Miscellaneous 10 mts

Regeneration methods

Lesson 7

Time 1 hour

1. Nursery – Introduction

In any plantation work, the planting stock comprising seedlings, transplants, root-shoot cuttings etc have to be raised in the nurseries. A **nursery** is defined as an area where plants are raised for eventual planting out (L.S.Khanna 1999). The major component of a nursery is nursery bed. **Nursery bed** is defined as a prepared area in a nursery where seed is sown or into which transplants or cuttings are put (L.S.Khanna 1999).

[**Transplant** (noun) is a seedling after it has moved one or more times in a nursery, in contrast to a seedling planted out direct from seed bed. **To transplant** (verb) means to move nursery stock from one part of nursery to another in order to obtain young trees suitable for planting. **Transplant beds** are those nursery beds in which seedlings are transplanted before planting out in forest.]

A nursery which has only seedling beds, i.e. in which only seedlings are raised, no transplanting is done, is called **seedling nursery.** Similarly, a nursery which has only transplant beds is called transplant nursery. In India generally, in the same nursery some beds are used as seedling bed and some as transplant bed. In West Bengal, common practice is to (i) maintain mother beds where seeds are sown and from which seedlings are pricked out, (ii) transplant seedlings or sow seeds directly into polythene pots and (iii) maintain such potted seedlings in polypot beds. Generally, whatever is grown in a nursery for planting out is called nursery stock or plants in a nursery.

2. Kinds of nursery

On the basis of duration of use, nurseries are classified into –

(a) **Temporary nursery –** It is maintained for supplying planting stock for a short period and then abandoned. Also called field nursery, it is normally located in the plantation area or in a place close to plantation.

Advantages

- Generally located in felled area, which contains humus. Needs little manuring.
- Elaborate soil preparation is not necessary.
- Being dedicated to a particular plantation, work can be focussed to raising planting stock of some specified species.
- Damage and cost involved in transporting seedlings may be avoided.

Disadvantages

- Intensive supervision is not possible; quality of nursery stock may thus be compromised.
- In absence of irrigation facility, growth of seedlings is slow and there are chances of mortality.
- In the long run, maintaining several temporary nurseries may prove to be costlier than a permanent nursery.

(b) Permanent Nursery – It is maintained for supplying planting stock on a long term basis. As it is maintained to serve the requirement of many plantations spread over a large area, it is relatively large in extent. It is normally centrally located, in range or beat headquarters.

Advantages

- Intensive supervision is possible.
- Used for large scale afforestation works
- Through irrigation facility and otherwise, suitable environment can be provided for better and rapid growth of seedlings.
- In the long run may prove cheaper than temporary nursery

Disadvantages

- Intensive manuring and soil management is necessary as the stock is raised in the same site year after year.
- Requires elaborate irrigation facility.
- Requires a large labour force.

3. Selection of nursery site

(A.B Lal 1967; Inputs by T.K.Das WBFS)

The followings points are taken into consideration while **selecting a site of a permanent nursery**:

- Location: Site is in a central place in a Range or Beat headquarters to facilitate proper supervision.
- Topography: The land is almost flat with slight slope having good drainage facility.
- Area: There is sufficient space for nursery beds, pathways, agro-net shed, open area for hardening of seedlings, compost unit, labour shed , store etc.
- Soil: soil is well drained sandy-loam. Soil pH is between 5.5 and 7 (slightly acidic to neutral, which is the optimum pH range for most plants)
- Water supply: There is good water supply facility.
- Accessibility: The site is near the road for easy transportation of nursery materials as well as nursery stock.
- Labour: Adequate labour is available.

- Protection: The site is well protected.
- Exposure: There are no large over head trees in and around the site i.e. not a shady place.

4. Fencing

Immediately after site has been selected and the area decided, the nursery site should be fenced. The permanent nurseries are properly fenced with cattle-proof or game-proof fence, depending on the source of damage. In dry areas, a line of small trees or shrubs of species like Acacia Arabica, Duranta etc may be planted for protection against hot winds and wind erosion.

5. Layout

The site should preferably be rectangular. When the area is large, it is divided into smaller units with the help of paths and cross paths. The main paths are usually made 3 feet wide and paths between beds 1.5 to 2 feet. The irrigation channels should run along the paths. The lengths of the beds should run east-west and the short side north-south to facilitate shading. For extensive mechanized operations, there should be a tractor road after every two beds, that is, each nursery bed should have a tractor road on one side of its length and an irrigation channel on the other.

6. Preparation of Bed

(Inputs by T K Das WBFS)

Normal practice adopted in south-west Bengal is described below.

- Normally, size of bed is 5.0m X 1.20m with an easy arm's reach to the centre of width of the beds to facilitate pricking out, weeding and other operation.
- For preparation of mother beds, soil is hoed up upto 30 cm depth; top surface is prepared with mixture of cowdung manure and leaf mould dust or compost, medium sand, and sandy loam soil in a ratio of 1 : 1 : 1. Also added are insecticide Phorate -10G @ 500gm/cu.m of mixture and fungicide Dithane-M45 @250gm/cum. of mixture. Top surface is levelled with a slope of 1: 100.
- **Poly pot beds** are made sunken with depth up to 15cm. After placing the filled up poly pots the upper surface should be of uniform level.

  Size of poly pots used are- 20cm (length) x 10cm (width laid flat) for raising 3-4month old seedlings and then planting in the field. To raise and maintain one year old seedlings in the nursery, polypots of size 22.5cm -25cm in length x 12.5cm flat width are used.

6.1 Present practice is to prepare raised beds with side supports for the plants. The beds may be made of bamboo or iron frame. The filled up containers, either poly pots or root trainers, are placed in rows. The raised beds providing room at the bottom of the containers facilitate good

drainage from poly pots, aerial root pruning from both type of containers and easier growth monitoring.

Fig.7.1 Seedlings on mounted angle iron raised beds.

(Source: http://silvicultureconference2014.in/site/wp-content/uploads/pdf/MOHIT-GERA.pdf)

7. Use of Root trainer (hykopot)

(Inputs by T K Das WBFS)

Use of poly pots is now discouraged because of following problems.

- Poly pots hinder root development, including lateral roots;
- Poly pots tend to produce coiled roots resulting in restricted growth.
- Lest the roots strike the ground of polypot bed, the pots are required to be shifted and sorted on a regular basis; otherwise the roots will be damaged when the poly potted seedlings are finally moved for planting.
- The material being not bio-degradable, it is a problem to dispose the empty tubes after planting. The usual tendency is to leave the empty and used poly pots at the plantation site itself, which is not at all advisable.

To avoid this problem, use of Root trainers is encouraged. **Root trainer/ hycopot** is a conical container with two open ends, of which the lower end tapers gradually and has a smaller opening than the upper one. The container is provided with some internal ridges traversing

longitudinally from one end to another, which direct the root growth straight without coiling, and the roots get air pruned. It is designed to encourage lateral root development which also exits the container and gets air pruned. After planting, the root trainer seedlings show more vigor and rapid growth with long term survival than the seedlings grown in poly pots. Root trainers of different volumes are used in the nursery for various purposes. Root trainers of volume 45 cc, 60 cc and 150 cc are generally used in the modern nursery for production of clonal seedlings/ ramets. And 150 cc, 300 cc and 500 cc root trainers are used for raising seedlings of seed origin, the volume depending on the species and duration of stay of seedling in the nursery. Commonly 150 cc and 300 cc root trainers are used for raising 3-4months old seedlings and 300 CC and 500 cc root trainers for one year old seedlings.

It is easy and feasible to retrieve the root trainers after planting and reuse the containers a number of time.

Reference materials:

(1) L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun

(2) A B Lal 1967 Indian Silviculture Jugal Kishore & Co Dehra Dun

Regeneration Methods

Lesson 8

Time 1 hour

Lesson Plan

Objective:

To study

- **Nursery (continued)**
  - Potting media
  - Sowing in nursery beds
  - Germination of seeds in mother beds
  - Pricking out
  - Direct sowing or dibbling of seeds
  - Weeding cleaning
  - Hardening
  - Watering
  - Seedling nutrition
  - Sorting, shifting of seedlings
  - Quality of seedling - culling

Backward Linkage- Lessons 6 and 7 of "Regeneration Methods",

Forward Linkage- To see, during tour, nursery works.

Training materials required: Copy of Lesson 8 to be circulated beforehand, demonstration of poly pot and root trainer.

Allocation of Time

- **Nursery**
  - Potting media 10 mts
  - Sowing in nursery beds 4 mts
  - Germination of seeds in mother beds 3 mts
  - Pricking out 3 mts
  - Direct sowing or dibbling of seeds 3 mts
  - Weeding cleaning 3 mts
  - Hardening 2 mts
  - Watering 6 mts
  - Seedling nutrition 5 mts
  - Sorting, shifting of seedlings 7 mts
  - Quality of seedling – culling 9 mts

- Discussion/Miscellaneous 5 mts

Regeneration methods

Lesson 8

Time 1 hour

Nursery (continued)

1. Potting media

(Inputs by T K Das WBFS and Abhijit Kar WBFS)

Use of polypot and root trainer as plant container has been discussed in the previous lesson. We now describe the potting media, that is, the materials the containers are filled with.

1.1 The potting media should fulfil the following four functions:

1) Supply of plant nutrients.

2) Hold enough water to be available for the plants.

3) Permit gas exchange to and from the roots.

4) Provide an anchorage or support for the plant.

1.2 In order to serve the above functions, a good potting medium should have the following characters:

1. A stable organic matter content which will not diminish significantly in volume during plant growth
2. Decomposition of organic matter should be slow and minimum
3. Organic matter with reasonable carbon nitrogen ratio
4. Bulk density light enough to enhance handling and transporting but sufficient to prevent toppling of plants
5. High moisture retention along with good porosity or aeration after watering
6. High cation exchange capacity for nutrient reserve
7. Slightly acidic pH, as several mineral nutrients become unavailable at higher pH and most of the fungal pathogens become active in alkaline or neutral pH. Ideal pH is 5.4 – 6.5.
8. Low inherent fertility. Low inherent fertility of the growing medium helps in the control of mineral nutrition by helping in tying up of minerals.
9. Easy to store for a long period without much changes in physical and chemical properties
10. Free from salinity and toxicity
11. Free from insects, disease and weed seeds
12. Economic in preparation and handling

1.3 Components of potting media

Potting media consists of 2 or more different **components** that are selected to provide certain physical, chemical or biological properties. Other **amendments** like fertilizers, pesticides etc. are added during the mixture. A component is usually **more than 10%** of the mixture, whereas an **amendment** is **less than 10%** of the mixture. The best proportion of the organic components is 40-50%, which gives ideal porosity and ideal water holding capacity (WHC). The **common organic matters** used in growing medium are peat moss, compost, sewage sludge, rice husk and pine bark.

1.3.1 Inorganic components produce and maintain a system of macro pores that improve aeration and drainage but decrease WHC. **Vermiculite, Perlite and sand are the common inorganic components used**. Vermiculite is an aluminium – Iron magnesium silicate, light weight, neutral in pH with high CEC. Perlite is an alumino-silicate with low CEC, neutral pH with water adhering only to its surface. Vermiculite is unstable when moist and will compress with time. For this is may be mixed with Perlite, which prevents compaction. **Medium sand is the most common medium.**

1.4 Potting mixture in practice:

For polypts, mixture of surface soil, sand and FYM in 1:1:2 or 1:1:1 proportions have been conventionally used in south-west Bengal.

However, presently, potting mixture being used for poly pots and root trainers for raising seedlings of seed origin comprises of**: Burnt rice husk, sand and compost/cowdung manure in a ratio of 1:1:1. Thus, burnt rice husk has been substituted in place of soil.**

But**, for production of clonal seedlings, that is, rooting of stem cutting:** Vermiculite only is used as growing medium in root trainer.

1.5 Bio-fertilizer inoculation of the growing medium

In nature the rhizosphere (the region of the soil in contact with the root of the soil) is colonized by a number of free living microbes. These assist the plant in its mineral nutrition either by nitrogen fixation or phosphate mobilization. Free living microbes can be added to the growing medium directly, whereas the symbiotic microbes must be inoculated into the plant system either when it is germinating or at the time of transplanting or at the time of planting. The common bio-fertilizers :- Fungi- Ectomycorhizae, Endomycorhizae (VAM); Bacteria - Rhizohium for legumes, Azotobacter for non-legumes, Phosphobacteria, Frankia (Casuarina).

2. Sowing in nursery beds

The following methods of sowing may be used.

(1) Drill sowing – This method is used for larger seeds to ensure uniform distribution. Drills are made with the help of drilling board. [the drilling board is a board of width of the bed and a convenient length, and provided with battens of width, depth and shape of the drills to be made.] The drilling board is placed on the bed and pressed, and thus impression of drills is made on the bed. The board is lifted, placed on the adjoining part and the same operation continues. The spacement of sowing depends on the species and the size of seedlings required to be raised on the bed.

(2) Broadcast sowing – This is used for small seeded species under conditions where uniform spacing is not important. This method produces larger number of plants but subsequent weeding and pricking out become difficult. Very fine seeds of species like Eucalyptus, Kadam, Haldu, Gurikaram, Chikrasi etc. are broadcast on the upper surface of mother beds . A thin layer of light potting mixture is provided to cover the seeds and finally a layer of straw is placed over the top surface. Even for small seeds, it is preferable to sow them in rows to avoid difficulty in weeding.

3. Germination of seeds in mother beds

After sowing, watering of the beds is done carefully by watering can having very fine hole. Intensity of watering depends upon the weather condition and requirement of beds. If the bed surface is found having sufficient moisture, no watering is required. As soon as the germination starts, straw cover is removed, and **shade** is provided to avoid damage to tiny seedlings from hot sun in day time and sometimes to protect the plants from frost, and rain and hail. The shade is normally made of thatch, mat, split bamboo or polythene sheets. The shade material to be chosen should be locally available and should be such that the shade can be conveniently rolled up or removed and placed again, as necessary.

4. Pricking out

When 4-6 leaves appear on the tiny seedlings in mother bed and they attain a certain height and hardness, they are removed from mother bed and transplanted into filled up and moist poly pots or root trainers. This process is called pricking out. It is done in the late afternoon or evening. This work requires utmost care so as to avoid any damage or shock to the seedlings. Shade is provided to polypot beds and root trainer trays to protect the tiny seedlings from hot sun, frost and rain and hail. Watering is done carefully. Intensity of watering depends upon the weather condition and requirement of beds. Care should be taken to avoid excess moisture content of the growing media.

5. Direct sowing or dibbling of seeds

Large seeds are generally dibbled in filled up poly pots/root trainers. The polypot beds/root trainer trays are covered with straw. The straw cover is removed when germination takes

place. Watering and providing shade is done as usual as in case of raising seedlings in mother beds.

6. **Weeding cleaning**

Weeds and grasses are removed from the mother beds as well as polypot / root trainers by hand with care without damaging/uprooting of tiny seedlings.

7. Hardening

It is necessary to harden off the potted seedlings before they are transported out to field for planting. This is done by gradually reducing the period of shading. This is done in stages and so timed that during a short period before planting the potted seedlings are not provided any shade so that they get acclimatized with complete overhead light condition and can grow well later in the field.

8. Watering

Watering is a critical factor throughout the stage of seedling development. Mother beds and poly pot/ root trainers should be watered in such a way that the media is moist but not wet throughout the germination and growing period. Growth of moss on the nursery bed or on the growing media of the pots is an indication of over watering and is usually followed by yellowing of leaves and eventual death of the seedlings. Watering is normally done in the afternoon. Watering can be done in the following ways.

- By automizer – For minute seeds and tiny seedlings of Eucalyptus which is liable to suffer from damping off due to excess moisture, watering by automizer is preferred. This is a kind of pump by which moisture is applied in the form of water vapour. Watering by automizer is preferred in the very early stage seedling growth; when the seedlings attain a height of 10 to 15 cm watering can be done by a watering can.
- By watering can – Irrigation with a watering can is similar to rainfall and is suited to most of the species. Finest rose possible should be used with the watering can.
- By sprinkler – Tubes with small holes are fitted over the beds and root trainer trays. When water is pumped through them, it comes out in fine jets moving upwards and then falling on to the plants.

9. Seedling nutrition

(Source: Inputs by Abhijit Kar WBFS)

The nutrient availability to the plant is affected by various factors such as volume of the container, pH, composition of the growing media, water, content of the growing medium etc. To achieve optimal growth, there must be a constant and balanced supply of all nutrients. However, requirement of NPK comes uppermost among the nutrients and the NPK requirement varies with the stage of development of the seedlings.

9.1 Fertilizers can be added to the growing medium or can be mixed with the irrigated water. Incorporating dry fertilizers into the growing medium has several advantages – no special equipment is needed, easy to apply, less labour needed, mineral level can be maintained in the season when no irrigation is needed etc. But at the same time it is very difficult to control the concentration and maintain even distribution. Direct injection of fertilizers into irrigating water provides control over concentration and nutrient balance with even distribution. But it is costly as it requires irrigation system with injector, and additional time and labour.

10. Sorting, shifting of seedlings

As the potted seedlings grow, it becomes necessary to **sort**, **shift** and **arrange** the seedlings on the basis of height growth. This facilitates grading of the nursery stock, and knowing which part of the stock has become fit for planting out. Physical identification and transport of plantable stock also becomes easier and less time consuming. The operation has special utility for polypot seedlings. As the polypot seedlings are shifted and sorted, the root penetration into the beds is prevented, and chances of root damage while taking out for planting are lessened. Further, the seedlings are hardened by such movement and they can stand better the shock of final transfer to plantation site. The problem of root penetration into the ground and the resulting root shock can be taken care of, if the pots are maintained in raised beds. The said problem also does not arise in case of root trainers maintained in trays and placed on raised structure. However, shifting and sorting is an essential operation for all potted seedlings for the purpose of grading and culling. It is advisable to do sorting and shifting a number of times before the stock is lifted for outplanting. The operation of culling is described below.

11. Quality of seedling and culling

(www.rngr.net/publications/spnh/PDF.2003-08-12.2552/at.../file; Inputs by T K Das WBFS)

Two of the major attributes of seedling quality are –

1. sturdiness, i.e., the ratio of height to the diameter of the root collar, and
2. shoot-root ratio (with consideration for root structure).

Most of the studies have shown that balanced medium sized seedlings with sturdy stems, and well-developed fibrous root system have a higher survival rate and make better initial growth than do either larger or smaller seedlings. The most useful criterion for quality of seedlings is the relation between root and shoot sizes. The best quality stock is that which has a relatively small top and a large fibrous root system. In general, the optimum **root shoot ratio** in case of current year seedling should be 1: 1 to 1:2.5.

11.1 Culling

It is almost impossible to produce seedlings of uniform quality and size when production is made on a large scale in a nursery. It is therefore necessary to pick and set aside the inferior quality stock in the nursery and this operation is known as culling. The object of culling is to separate the bad stock from the good and thus ensure that such inferior stock does not reach the field even inadvertently. For each species, a prescribed standard for plants, suitable for dispatch from the nursery, is usually set.

11.1.1 In general, culling of undersize seedlings is normally done on ocular determination of minimum specifications. While specifications for culling vary with species, following general rules may be followed.

- The first batch of plants to be culled comprises those which are too small, damaged or diseased. They should be removed and discarded.
- Seedlings with tap roots less than 5 inches should be discarded unless there are enough laterals to successfully plant them.
- Seedlings with broken or forked stem, stripped foliage, loose bark, split main roots or stripped laterals should be culled.
- in a particular seedling bed, the seedlings having height much above and below the average height should be discarded.

11.1.2 Culling may be practiced in different stages of plant growth in the nursery depending upon on the nature of growth of a species. There is often a tendency to keep the plants with poor growth in the nursery until they reach the size rather than cull to waste. Sometimes they are kept for infilling later in the season, sometimes even until the next planting season. Where plants are markedly inferior to average plants of the same batch, it is undoubtedly uneconomic to keep such plants. Irrespective of whether they are inferior because of genetic or physical reasons, they are unlikely to perform well in the field and would be better discarded.

Reference materials:

(1) L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun
(2) A B Lal 1967 Indian Silviculture Jugal Kishore & Co Dehra Dun
(3) Websites cited in the lesson

Regeneration Methods

Lesson 9

Time 1 hour

Lesson Plan

Objective:

To study

- **Nursery (continued)**
  - Plant Protection
  - Nursery register
  - Hi-tech Nursery

Backward Linkage- Lessons 6, 7 and 8 of "Regeneration Methods",

Forward Linkage- To see, during tour, nursery works.

Training materials required: Copy of Lesson 9 to be circulated beforehand,

Allocation of Time

- **Nursery**
  - Plant Protection 17 mts
    - Nursery Disease and their Management
    - Nursery Pests and their Management
  - Nursery register 8 mts
  - Hi-tech Nursery 30 mts
- Discussion/Miscellaneous 5 mts

Regeneration methods

Lesson 9

Time 1 hour

Nursery (continued)

1. Plant Protection

Needless to say that plant stock produced in a nursery needs protection against attack by disease and pests. The disease and insect attack on plants has been broadly dealt with in Lesson 9 of "Forest Protection" and may please be seen. In this lesson, plant protection in nursery is discussed in more details.

1.1 Nursery Disease and their Management

(Source: P. Ratha Krishnan et al 2014 Plant Nursery Management: Principles and Practices)

The seedling stress symptoms like damping off, wilt, root rot, rust and powdery mildew are caused by pathogen infection and results in stunted growth of seedlings. These pathogens may be soil, seed or air borne in nature. Nurseries established in the recently cleaned land hardly invite parasitic organisms.

As a **preventive measure**, sterilization of nursery mixture, pre-treatment of seeds with fungicide can control the disease. If the disease occurs, the casual pathogen may be identified by expression of symptoms and accordingly fungicide may be applied. Table 9.1 lists the important nursery diseases and their control measures.

Table 9.1 **Important nursery diseases and their control measures**

Symptoms	Affected seedling species	Control measures
Wilt, root rot, collar rot	Sisham, neem, *Casuarina*, *Eucalyptus*, tomato	Soil drenching with 0.1% Carbendazim
Leaf spot	*Eucalyptus*, pomegranate	Spraying Dithane M 45 or Fytolan 0.2% or Copper oxychloride 0.2%
Leaf rust	Teak, sisham, ber	Spraying 0.2% Zineb Spraying 0.2% wetable sulfer
Leaf blight	Neem, *Eucalyptus*	Spraying Carbendazim 0.2%
Powdery mildew	Teak, neem, *Casuarina*	Spraying 0.2% Dithane Z-78 or Bordeaux mixture 0.1%

1.1.1 Integrated Nursery Disease Management

- Collection of seeds/propagules from healthy trees, seed stand and orchards
- Seed dressing with 0.2% Carbendazim/Methylthiophanate/Benomyl/Thiram

- Sowing in sterilized/fumigated, clean beds and adequate watering
- Transplanting seedling after root dip for 3-5 min in 0.02% Carbendazim solution
- Healthy planting material maintenance by keeping them under proper sunlight, watering and clean environment
- Frequent examination of seedling health and removal of diseased stocks
- Foliar spray of 0.2% Carbendazim/Dithane M-45 at regular interval

1.2 Nursery Pests and their Management

A major injury to nursery stock is also caused by various groups of insects. These insect pests have been divided into **three categories** viz., **major nursery pests** (white grubs, cutworms, termites and crickets), **minor nursery pests** (defoliators, sapsuckers, grasshoppers) and **non-insect pests** (nematodes and vertebrate pests). Generally the damage caused by the insects may be controlled by **maintaining better sanitation** of the nursery area, adoption of **suitable cultural practices** and need based **application of chemical and biological pesticides**.

1.2.1 White Grubs: The adult white grubs feed on leaves and larval stage of the grub during monsoon months feed on roots. Deep ploughing, soil solarisation, poisoning and using light traps are some control measures against white grub attack. Application of 200 g phorate or 50 ml of chloropyriphos mixed in 50 ml water may be used to spray for one bed. Foliar spray of host trees available in the nursery vicinity with 0.05% monocrotophos or 0.03% quinalphos can also be helpful in controlling the adult population.

1.2.2 Cutworms: It damages the young seedlings soon after germination and is also a feeder of young leaves. Seedlings of Pine, Cedar, mango, sapota and *Casuarina* species are the most preferred by cutworms. Nursery site flooding and collection of cutworm after heavy rains are some preventive measures to avoid cutworm damages. Weeds and plant residue should be removed to help reduce egg-laying sites and seedling weeds that nourish small cutworms. Dusting of seed bed with a mixture of quicklime and ash or 1.5% quinalphos will control the insect.

1.2.3 Termite: They kill the seedlings by destroying the tap root or damage the seedlings and make them weak and susceptible for other pathogen and pest attacks. The termite attack can be controlled by keeping the nursery cleared of wood debris, using well decomposed FYM and application of termiticides such as chloropyriphos.

1.2.4 Crickets: The nymphs and adult stage cricket come out at night and cut off all the seedlings, low branches and drag the piece to their tunnels for feeding the young crickets. Ficus, *Casuarina*, Eucalyptus, Sisham, teak, rubber and mango seedlings are commonly affected by crickets. Deep ploughing during nursery site preparation, application of 200 g phorate or fenitrothinon 5% dust per bed can control the pest.

1.2.5 Minor and Non-insect Pests: Defoliators (beetles, weevils and caterpillars), grasshoppers and sapsuckers (green leaf hopper, white flies, thrips) are the minor pests. They can be controlled by the application of 100 g dose per bed of phorate 10%, or spray of formulation of any systemic insecticide eg. dimethoate 30 EC. Nematodes, rat, squirrel, hare, deer, mite and birds are some important non-insect pests. Proper fencing and manual scaring are the best methods to reduce damage by them.

2. Nursery register

Each nursery should have a nursery register. The purpose of maintaining the register is to provide all information relevant to the nursery.

2.1 Primary information

The register should provide following primary information

- Name and location of the nursery
- Year of formation
- Area
- Soil
- Fencing, green house, mist chamber, other units, beds, irrigation facilities etc that are available
- Layout map of nursery

2.2 Operational information

The register should also provide following operational information chronologically for each year.

- No of beds prepared, mode of preparation
- No of beds sown species wise
- Date of sowing
- Date of germination
- Weeding with dates
- Irrigation, manuring etc with dates
- No of Polypots /root trainers prepared with potting media
- Dates of pricking out species wise
- No of seedlings transplanted to polypots/root trainers species wise with dates
- Weeding, irrigation of potted seedlings with dates
- Shifting, sorting, culling with dates
- No of plants culled species wise with dates.
- No of fit seedlings raised bed wise and species wise.
- No of plants despatched to field, range etc. species wise with dates.
- Stock of seedlings on 1st of January and 1st of June or any other dates fixed on operational/administrative consideration.
- Annual expenditure.

3. Hi-tech nursery

(Source: Inputs by Abhijit Kar WBFS; Nursery Manual, Haryana Community Forestry Project, Haryana Forest Department, 1999; https://www.ucar.edu/learn/1_3_2_12t.htm#top)

High tech nursery is basically a combination of green house and agro-net house, and often supplemented by other ancillary units. The object of a hi-tech nursery is to produce superior planting stock in a controlled environment on a large scale and at a low cost. Thus it overcomes the limitations of a conventional nursery, namely, poor control over climatic factors, low germination, long period of establishment, and high cost. Following are the basic components of a hi-tech nursery.

3.1 Green House

The function of green house is to produce planting material by germination of seeds and rooting of cuttings. The focus is more on production of ramets (individuals of a clone) through rooting of stem cutting.

3.1.1 Green house is erected in direction parallel to east- west over angle irons, pipes, or wooden post. The structure is covered by ultra violet (UV) radiation proof polythene sheet. The structure should have a cemented floor and cemented working table. Inside the poly green house is installed mist formation device and humidity control system. Temperature is controlled by installing exhaust fans in front portion and a cooling pad at its back portion.

3.1.2 The transparent covering of the greenhouse allows visible light to enter unhindered, where it warms the interior as it is absorbed by the material within. The transparent covering also prevents the heat from leaving by reflecting the energy back into the interior and preventing outside winds from carrying it away. In temperate regions supplemental heat is provided by steam underneath the beds. Sometimes air conditioners are also used for large Green House. A Hygro –Thermometer is used for reading the inside humidity and temperature of Green House.

3.1.3 The sprinklers can be used in Green House for irrigation. For the purpose of producing mist, which is essential for rooting of cutting, the sprinkler line is fitted with appropriate misting nozzle. The nursery may have provision of a number of separate mist chambers for production of ramets. The purpose of misting is to maintain humidity artificially at high level with the help of mist installations, which spray water under pressure. Now-a-days use of **fogger** as a misting device has come into practice.

3.1.4 Fogger is a product which ensures droplet free humidification in any application. It works on the centrifugal principle and can effectively break the supplied water in very fine particle size of 5 ~ 10 microns. Due to its innovative design, the fog can be directed both horizontal and vertical, thereby allowing more flexibility of use. The fog particles quickly evaporate resulting in

increasing mist chamber humidity. It does not require compressed air or water pressure pumps for its working. Fog formation induces rooting and acclimatization. High relative humidity facilitates better root initiation and cooling effect prevents the cutting from drying out.

3.2 **Hardening Chamber**

A shade net house is essential for "hardening" the rooted cuttings/ tender seedlings discharged from Green House / mist chambers by keeping them under reduced light condition, in closed shade net coverage. This would ensure reduction of transpiration and prevent exposure to strong wind causing desiccation, and thus in a way "gradually condition" the rooted cuttings/tender seedlings before final planting in field. The size of the chamber may vary as per the requirement and the capacity of the nursery. The shade cloth (Agro net shed) that should be provided on the top and sides is of 50%, 75% or 25% as per the season. The structure is constructed by RCC posts with G.I. pipes. A protective brick masonry wall up to 15 cm height from G.L. is provided. The floor will be prepared by digging out 45cm of soil and filling the void with gravels of 10 cm depth, over 50 cm layer of coarse grained sand to allow good drainage. A sprinkler system will be provided for watering the cuttings / tender seedlings.

3.3 Shade House

It is another unit provided in a nursery where seedlings and ramets are kept for some time en route to plantation site before it is time to move them to field. It is a simple structure provided with 75%/50%/25% shade cloth depending on the field condition. The sides of the shade house are generally open. Temperature beneath the shade is much less compared to outside. Watering in shade house is done through micro sprinkling system. The root trainers with ramets/seedlings are kept in stand and trays inside the shade house. Shade house has good utility for the nursery stock in reducing excessive transpiration water loss during summer months and for treatment till final disposal.

3.4 Polly House / Polly Tunnels

These are simple frames with polythene (UV treated poly sheets) fitted all around. The function is to produce ramets/ seedlings in root trainers at a relatively low cost. The floor is generally made up with course river sand. It can be provided with water pipes with suitable mister or fogger as well as arrangement for adjustable side ventilation to control the humidity and temperature inside. The size of poly house depends upon the requirement.

3.5 Composting Unit

Use of compost in potting media is a very successful technique for getting good root system. The compost is light, friable and rich in nutrient to support the young propagules. But it is not suitable as a potting medium for rooting of stem cutting in root trainer, though can be mixed with growing media after green house propagation.

3.5.1 Compost making

Compost can be made of almost any organic matter such as tree leaves, agricultural residues, grasses and weeds, animal manure. The Nitrogen rich leguminous crops may be a major ingredient in the compost mix. Other ingredients are water and air. Compost can be made any time of the year except winter. Compost is made either in a heap or a pit. The organic raw

materials are chopped into pieces, smaller the pieces the better. The chopped organic material is mixed with organic manure and ash. The material is thoroughly mixed to hasten decomposition. When the compost pile is beginning to dry, watering is done to keep it moist. The pile is turned and mixed every second or third day until the fourteenth day when the compost becomes ready, though coarse. Another week of composting gives a finer product. During the process of decomposition, the temperature rises to about 70^0C, which kills most of the insects and weed seeds. High temperature is an indicator of healthy and quick decomposition. After about two weeks or so when the compost pile begins to cools down, it indicates that the composting process is nearing completion.

3.6 Clonal Hedge Garden

Clonal hedge garden supplies the stem cuttings that are used for producing ramets. Clonal hedge or Clonal Multiplication Areas (CMA) are required to be established from genetically known and superior identified stock for continuous and easy propagation of ramets throughout the year. The spacing of plants in CMA is made close, normally 1 m X 1 m i.e. 10000 plants per ha for proper and intensive management. Two to three years after creation, the plants of CMA can be utilized for Green House Propagation. The cuttings should be collected early in the morning before sunrise to avoid water loss due to evapo-transpiration. Only leading shoots are collected for clonal propagation. For collection of shoots for vegetative propagation, age of the stock is an important factor as it influences the rooting percentage.

3.7 Sprinkler Irrigation

Overhead sprinkler irrigation system is by far the most efficient in a permanent nursery. It delivers water through a system of pipes. Overhead irrigation system is normally of three types – perforated pipes, nozzle line and rotary sprinkler. The first two types are suitable for small seedlings. Rotary sprinkler is suitable for large sized seedlings as it delivers water in large drops. In green house/mist chamber for the purpose rooting cuttings, suitable spray heads or fogger is made use of to deliver water in very fine particles.

Reference materials:

(1) L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun
(2) A B lal 1967 Indian Silviculture Jugal Kishore & Co Dehra Dun
(3) Plant Nursery Management: Principles and Practices by P. Ratha Krishnan, Rajwant K. Kalia, J.C. Tewari, M.M. Roy, Central Arid Zone Research Institute, (Indian Council of Agricultural Research) , Jodhpur - 342 003 (Rajasthan) 2014
(4) Nursery Manual, Haryana Community Forestry Project, Haryana Forest Department, 1999.
(5) Websites cited in the lesson

Regeneration Methods

Lesson 10

Time 1 hour

Lesson Plan

Objective:

To study

- Plantation work
  - Choice of species
  - Site selection
  - Choice of method
  - Spacing
  - Arrangement of staff and labour
  - Survey and demarcation, GPS tagging of site, Geo-tagging of site photographs
  - Regeneration plan map
  - Preparation of planting site
  - Inspection path
  - Boundary and Contour trench
  - Staking out
  - Fencing
  - Cattle-proof trench

Backward Linkage- Previous lessons on 'artificial regeneration' and 'nursery'

Forward Linkage- To see, during tour, plantation works.

Training materials required: Copy of Lesson 10 to be circulated beforehand,

Allocation of Time

- Plantation work
  - Choice of species 3 mts
  - Site selection 3 mts
  - Choice of method 3 mts
  - Spacing 5 mts
  - Arrangement of staff and labour 5 mts
  - Survey and demarcation, GPS tagging of site, Geo-tagging of site photographs 8 mts
  - Regeneration plan map 5 mts
  - Preparation of planting site 3 mts
  - Inspection path 3 mts
  - Boundary and Contour trench 5 mts
  - Staking out 4 mts
  - Fencing 5 mts
  - Cattle-proof trench 3 mts
- Discussion/Miscellaneous 5 mts

Regeneration methods

Lesson 10

Time 1 hour

1. Plantation work

Plantation work is the procedure of artificial regeneration, and aims to renew the forest crop by sowing and planting. It involves a number of operations which are now discussed in this lesson.

2. Choice of species

The species to be established in the plantation are normally prescribed in the Working Plan. The factors that are kept in focus to finalize the list of species have been described in lesson 3. Inclusion of species beyond the list prescribed by WP, if permitted by the WP and approved by the competent authority may be done, if regeneration of such species in the site is felt necessary and desirable considering the locality factors.

3. **Selection of site**

If the plantation operation is required to be undertaken in a felled coupe in terms of the silvicultural management system, there is no option for selection of site. In such case the felled coupe is automatically selected as plantation site and its significant features become the factors of consideration in the plan of plantation programme. However, in case of afforestation of barren area, grass land etc, selection of site is important and involves study of various factors in order to ensure success of plantation work. The major factors to be taken into consideration while selecting site are –

a) Aspect and topography;
b) Soil conditions.

4. Choice of method

Sowing and planting are the two methods of artificial regeneration. The advantages and disadvantages of the two methods and the factors that govern preference of one to the other have been dealt with in Lesson 5. However, there is no reason to consider that if one of the methods is chosen, the other cannot be applied. In practice, plantation involves combination of both the methods. Depending on species, one takes a bigger role than the other. However, now-a-days, for most of the species, plantation is virtually a planting programme which is supplemented by sowing.

5. Spacing

Spacing refers to the distance between successive plants put out in a forest plantation. Spacing to be adopted in a plantation is laid down in the Working Plan prescription. In general, in north Bengal, the spacing prescribed is 2m x 2m, whereas in south West Bengal it is 2.5m x2.5 m.

5.1 Spacing determines the stock or crop density, and thereby planting stock required to be raised. A 2m x 2m spacing means 2500 plants per ha, and 2.5m x 2.5m spacing gives a crop density of 1600 per ha. Considering that there are blanks in the plantation area in the form of inspection path and blank strip around the boundary, the actual crop density would be slightly less than the figures mentioned above.

6. Arrangement for staff and labour

Plantation is a labour intensive programme. It requires skilled, semi-skilled and unskilled work force. Arrangement of this work force is a prerequisite to successful plantation. In WB, this work force in most of the forest divisions comes from the Joint Forest Management Committees or Eco-development Committees. Over the years the JFMC or EDC members acquire the skill necessary for plantation work.

7. Survey and Boundary demarcation

After selection of site, the work to be undertaken is survey and boundary demarcation. The boundary of the plantation area is required to be demarcated on ground, and the plantation area should be surveyed. After survey of the outer boundary, a map of the plantation area on a scale of 1: 5000 should be prepared. The map may also preferably indicate nature and topography of the soil. The map should clearly indicate the location and orientation of the site, identifiable objects across the boundaries, area of the plantation so surveyed etc. With the help of GPS, the forester surveying the area should provide latitude and longitude coordinates of the prominent points of the boundary. Such Lat long coordinates of the boundary points should be indicated in the map. The map should bear name and designation of the officer who has surveyed the area.

7.1 Geo tagging of site photographs

Geo-tagging is the process of adding geographical identification data to various media such as a geo-tagged photograph or video, websites etc. This data usually consists of latitude and longitude coordinates, though they can also include altitude, bearing, distance, accuracy data, and place names. Geo-tagging can help users find a wide variety of location-specific

information. For instance, someone can find images taken near a given location by entering latitude and longitude coordinates into a suitable image search engine. Geo-tagging can tell users the location of the content of a given picture or other media, and conversely on some media platforms show media relevant to a given location. (http:// en.wikipedia. org/wiki /Geotagging). Recent guidelines on documentation are to do geo-tagging of the plantation-site photographs so that information on a specific plantation becomes readily available.

8. Regeneration plan map

On the plantation area map prepared, as stated above, should be described the regeneration plan in brief. It should indicate, among other things, principal species to be established, spacing to be adopted, blocks, if any, earmarked for any particular species or some specific kind of planting stock like clones etc. The regeneration plan map, so prepared, which carries information about location, area, soil conditions, regeneration plan etc is required to be approved by the divisional forest officer or any other officer, authorized in this behalf, before undertaking plantation work on ground.

9. Preparation of planting site

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

10 Inspection path

After preparation of the site, it should be divided into blocks, the number depending on plantation area. These blocks should be separated by roads to facilitate inspection of plantation. For large plantation, one or two main paths may be of such width as to be motorable. Other branch roads may be about 1 metre wide to allow inspection on foot. Besides, a path about 1.5 m wide should be left on the outer periphery of the plantation inside the fence.

11. Boundary and contour trench

Alignment of individual segments comprising interrupted boundary and contour trenches, and width of the segments are clearly marked on the ground as per approved specifications with the help of spade. Contour trench meant for soil and water conservation is normally done in south-west Bengal. When the position of trench segment has been marked on the ground, the trench of required size is dug along the marked line.

11.1 Boundary trench

Normally, the boundary trench has a width of 1 m at the top, 45cm at the bottom, and a depth of 60 cm. The boundary trenches are dug in interrupted manner, i.e, the trench is not made a

continuous one, so that it does not turn into a channel of water flow. The primary purpose of the boundary trench is to have the plantation boundary demarcated.

11.2 Contour trench

The construction and function of contour trench has been elaborated in Lesson 6 of "Soil and water conservation", which may please be seen. Contour trenches are short staggered trenches, 5 to 10 metres long (in South West Bengal forests, normally 5 metre long trenches are prescribed) laid in rows along contours with interspace between them. Usually, between two 5-metre long trenches in a row, an interspace of 5 metres is left. The trenches in successive rows will be staggered in such a manner that the interspaces in the upper row are directly above the trenches in the lower row. The optimum spacing or the distance along ground between two successive rows depends on the slope and the rainfall. Usually, in South West Bengal forests, the rows are laid 1 chain or 20 metres apart. The section of the trench may be trapezoidal or square depending on the nature of the soil. In south West Bengal forests, the trench section of 45cm x 45 cm is prescribed.

11.2.1 The dug up earth is arranged as a ridge on the lower side of the trench. Sowing and planting are done in the rainy season on the ridges as well as in trenches (partly filled) to make allowance for the vagaries of rainfall. In extremely wet seasons, the plants on the ridges do well, but in drier monsoons, the plants in the trenches survive and establish better. (R.C.Ghosh 1976 Handbook on Afforestation Techniques)

12. Staking out

Having done the inspection path, the boundary and contour trenches, then position and alignment of sowing/planting lines and pits are clearly marked on the ground by fixing wooden or bamboo pegs as per spacing envisaged. This operation is known as **staking out** and is necessary otherwise planting line may become zigzag and proper spacing cannot be maintained.

12.1. For digging trench for sowing, the ends of lines are marked by stakes and a rope is stretched between the two stakes to mark out the straight line with spade. When the line has been marked on the ground, the stakes and the rope are removed and trench of required size is dug along the marked line. For digging pits for planting, their positions as per envisaged spacing along the line of planting are marked by stakes. Pits of required size are dug around each stake. The stake may be retained beside each pit in order to provide support to the plants in post-planting stage against wind pressure.

13. Fencing

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

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

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

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

iv. Brushwood fence – When fencing is required to stay for a short period, say for the first year of plantation, an economic method is to go for brushwood fencing. The purpose is to keep away the cattle during the first growing season. Brushwood fence, often of thorny branches, is quie common in south-west Bengal.

14. Cattle proof Trench

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

Reference materials:

1. L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun
2. Ram Parkash 2007 Plantation and Nursery Technique of Forest Trees International Book Distributors Dehradun
3. R.C.Ghosh 1976 Handbook on Afforestation Techniques FRI & Colleges Dehra Dun

Regeneration Methods

Lesson 11

Time 1 hour

Lesson Plan

Objective:

To study

- Plantation work (continued)
  - Pitting
    - Objective
    - Dig and plant
    - Pits in south-west Bengal
    - Filling up of pits
  - Sowing of seed
    - Time of sowing
    - Depth of sowing
  - Planting
    - Planting season
    - Dispatch of seedlings

Backward Linkage- Previous lessons on 'artificial regeneration' and 'nursery'

Forward Linkage- To see, during tour, plantation works.

Training materials required: Copy of Lesson 11 to be circulated beforehand,

Allocation of Time

- Plantation work
  - Pitting 25 mts
    - Objective
    - Dig and plant
    - Pits in south-west Bengal
    - Filling up of pits
  - Sowing of seed 15 mts
    - Time of sowing
    - Depth of sowing
  - Planting 10 mts
    - Planting season
    - Dispatch of seedlings

- Discussion/Miscellaneous 10 mts

Regeneration methods

Lesson 11

Time 1 hour

Plantation Work (continued)

1. Soil work - pitting

Soil work for pitting means digging of soil and making pits at those places of plantation site where planting will be done. The places are already marked on the ground by stakes (Please refer to 'staking out' in Lesson 10). Pitting is normally done manually.

1.1 Objective

Soil work for pitting is done with the following objectives.

- To remove the roots of weeds and other undesirable species to minimize root competition;
- To help develop a healthy root system with a long tap root;
- To facilitate infiltration of rain water into the soil and sustain the improved soil moisture condition;
- To improve the physical soil properties like soil aeration, soil structure etc.

1.2 'Dig and plant' method in north Bengal

In north Bengal plantations, planting is normally done by what is called 'dig and plant' method. In this method no soil work for pits is done prior to planting. With the onset of monsoon, soil is dug out to the required depth with the help of spade at the places identified by stakes and the seedlings are planted. The logic behind this simultaneous 'dig and plant' is that fertile good soil of north Bengal does not require elaborate soil work, and by avoiding advance soil work quite a bit of expenditure is saved.

1.3 Pits in south-west Bengal

Digging pits for planting is prevalent in the laterite region of south west Bengal. Size of the pit (rectangular), normally adopted, is as follows.

- Length – 60 cm at the top, 45 cm at the bottom
- Width – 45 cm presumed to remain unchanged along the depth
- Depth – 45 cm.

Volume (V) of the pit or the earth work is calculated as follows.

$$V = \frac{\quad}{\quad} \times 45 \times 45 = 106312.5 \text{ cc} = 0.1 \text{ m}^3 \text{ (approximately)}$$

Please see Fig.11.1.

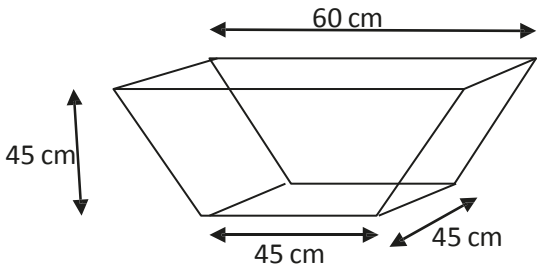

Fig.11.1 Pit for planting

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

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

1.3 Filling up of pits

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

2. Sowing of seed

Sowing of seed in the field and the different kinds of sowing have been described in Lesson 5. In the context of West Bengal, major operation of sowing consists in sowing of Sal seeds in strips in north Bengal (sowing still remains the predominant source of regeneration for Sal in north Bengal), sowing of Akashmoni, Babla, Minjiri, Sirish etc. on the ridges of boundary and contour trenches in south West Bengal, and sowing of mangrove species in the estuarine area. Besides, sowing or dibbling of seeds of some specific species is done in pits and depressions. The trend

in the choice of regeneration however, suggests that sowing has been assigned a secondary role, a role of supplementing regeneration by planting.

2.1 Time of sowing

As a general rule, sowing should be done shortly before the time when the seed germinates in nature. It lessens the risk of seeds being eaten away by birds and rodents, as the time the seed remains exposed to the risk is shortened. Further, such timing of sowing also ensures maximum length of growing season. However, in temperate zone, seeds are sown before snow fall, since sowing in spring when the snow melts, the time adjudged proper according to the general rule, is difficult. But for most of the species of tropical deciduous forests, sowing is done before the rains start or just after the first shower. Thus the regeneration gets the maximum period of growth. Even if there is a break in the rains causing mortality of some of the seeds, the affected area can be sown again when the rains resume.

2.2 Depth of sowing

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

3. Planting

After filling up of the planting pits, the plantation site becomes ready for planting which of course has to be done at the appropriate time. The different methods of planting have been described in lesson 5. However, in the context WB, planting of potted seedlings raised in the nursery is the major method of planting adopted. The potted seedlings still largely comprise poly pot seedlings, though root trainers are now being used in increasing number.

3.1 Planting season

The season or time of planting depends on –

- Local climatic conditions
- The species
- The method of planting

Based on season, planting is classified into following categories.

(1) Monsoon planting – This is the main planting season in India, as most parts of the country receive bulk of the precipitation from south-west monsoon. In WB, the monsoon usually extends from June to September (Please see Lesson 2 of "Soil and Water Conservation"). Planting should be carried out as soon as the monsoon has fully

set in, so that the regeneration gets full advantage of the rains. In north Bengal, planting is normally done in early to mid June and in south-west Bengal a little later during mid-June to early July. The ideal condition of planting is when the sky remains overcast or there is a little drizzle.

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

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

(4) Spring planting – Spring planting of conifers is done in parts of Kashmir where south-west monsoon does not reach. As the snow melts during this time, the resulting water is used in irrigating the plantation area.

3.2 Despatch of plants for planting

Only those seedlings which are fit for planting should be dispatched from the nursery. It has been described in lesson 8 how the nursery stock should go through the process of shifting-sorting and culling to separate out the quality stock. It has been explained that the **balanced medium sized seedlings with sturdy stems, and well-developed fibrous root system are the quality stock** because they have a higher survival rate and they make better initial growth than do either larger or smaller seedlings. The quality nursery stock should be set apart for dispatch to the plantation site. Before dispatch from nursery, the seedlings **should be irrigated** so that the potting medium does not get dislodged from the root on movement during transport and planting. The mode of transport is more often determined by the availability of transport and the cost. Man carriage of seedlings, though undertaken at times, is costlier. The criteria for selection of transport should be that it is able to reach the site and dispatch the seedlings within reasonable time. Tractor or small motorized van which has good maneuverability in the terrain where the plantation site is located can be a convenient mode of transport. The suitable mode of transport for dispatch of nursery stock should be chosen, considering the length and nature of the road, the terrain to be negotiated, quantity of stock, the timeline for dispatch and such other factors specific to the situation.

Reference materials:

1. L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun
2. Ram Parkash 2007 Plantation and Nursery Technique of Forest Trees International Book Distributors Dehradun
3. R.C.Ghosh 1976 Handbook on Afforestation Techniques FRI & Colleges Dehra Dun

Regeneration Methods

Lesson 12

Time 1 hour

Lesson Plan

Objective:

To study

- Plantation work (continued)
  - Planting
  - Weeding cleaning
  - Fertlization
  - Weeding mulching in south-west Bengal
  - Irrigation
  - Replacing casualties
  - Nurse crop
  - Fire and General protection
  - Plantation journal

Backward Linkage- Previous lessons on 'artificial regeneration' and 'nursery'

Forward Linkage- To see, during tour, plantation works and plantation journal.

Training materials required: Copy of Lesson 12 to be circulated beforehand,

Allocation of Time

- Plantation work
  - Planting 15 mts
  - Weeding cleaning 5 mts
  - Fertlization 5 mts
  - Weeding mulching in south-west Bengal 7 mts
  - Irrigation 3 mts
  - Replacing casualties 4 mts
  - Nurse crop 3 mts
  - Fire and General protection 5 mts
  - Plantation journal 8 mts

- Discussion/Miscellaneous 5 mts

Regeneration methods

Lesson 12

Time 1 hour

Plantation Work (continued)

1. Planting in the field

As soon as the monsoon gets steady, planting stock is dispatched to the field, which by this time with filled up pits is ready for the planting operation. Individual potted seedling of specified species is placed beside the pit where it should be planted. The supervising forester makes a quick check that the seedlings have taken position beside the right pit as per approved planting pattern.

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

1.2 Pattern of planting

A number of planting pattern has been in vogue from place to place. The pattern to be adopted in a working circle is prescribed in the Working Plan and accordingly the operation of staking out is done. It is advisable that the pattern adopted should be simple and easy to implement by the work force at the grass root level. In WB, the most common pattern adopted is the 'square planting'. However, in certain models of plantation 'line planting' was also adopted. We discuss below these planting patterns.

- **Line planting** – In this pattern plants are planted at a specified spacing in lines, while the lines are placed at some specified distance apart. The distance between successive plants in a line is not the same as distance between two adjoining lines. Therefore, the planted plants form rectangles. Please see figure 12.1.

  In the line planting, the number of plants required per hectare is calculated as follows.

  Number =———

  Where, d = distance in metere between plants in a line,
  D = distance in metere between the lines

Example – If d = 2m, and D = 4 m, that is plants are 2m apart in lines which are 4 m apart, the number of plants required per hectare will be –

Number = $\frac{\quad}{\quad}$ = 1250

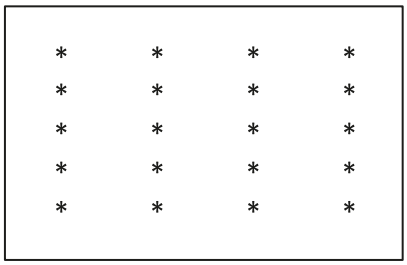

Fig 12.1 Line Planting

- **Square planting** – In this pattern, plants occupy the four corners of each successive square. In other words, in this pattern the spacing of plants in a line is the same as the distance between the lines. Please see figure 12.2. In this case the number of plants required per hectare will be given by –

  Number = $\frac{\quad}{\quad}$

  Where, s = Length in metere of a side of the square; s can also be defined as the distance between successive plants in a line or distance between the two lines, which are identical in square planting.
  Example – If planting is done at a spacing of 2.5 m X 2.5 m, the number of plants required per hectare will be –

  Number = $\frac{\quad}{\quad}$ = 1600

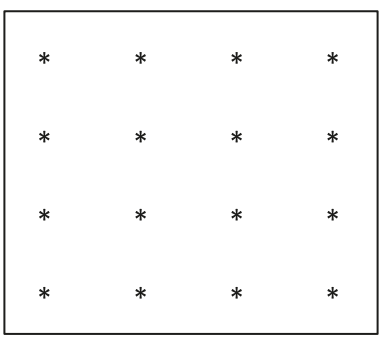

Fig.12.2 Square planting

2. Weeding-Cleaning

The operation of weeding and cleaning has been explained in 'General Silviculture'. Immediately after the planting operation, the next work that comes is weeding and cleaning. As explained earlier the object of weeding and cleaning is to remove and cut back plants of unwanted species which otherwise would interfere with the growth of the desired species that have been planted. During the operation, the grasses and weeds are removed from around the base of the plants and the space between the plants is cleaned of unwanted species, climbers etc.

2.1 In areas where weed menace is very serious, for example in most of the forests of north Bengal, the weeds often completely suppress the principle species and cause mortality. Thus in order to save the seedlings of desired species from the weeds, the operation of weeding and cleaning is required to be carried out at appropriate time. The number of weeding/cleaning to be carried out in a plantation depends on the intensity of growth of weeds and unwanted species. In north Bengal plantation, cleaning is usually required to be done 5 times in the first year, that is, in the year of creation. Cleaning with progressively fewer frequencies is carried out till the plantation becomes 5 years old. In south-west Bengal where weed growth is less intense, normally 3 cleanings are done in the first year, and cleaning with fewer frequencies is continued till the third year. It is to be borne in mind that the requirement of weeding and cleaning is situation specific, and it is a very important operation for establishment of the plantation.

3. Fertilization

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

4. Weeding-Mulching in south-west Bengal

(Inputs by Abhijit Kar WBFS)

The first weeding-mulching operation is normally done 3 weeks after the planting (during the 4^{th} week). The operation consists of the following steps.

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

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

The best time to do the mulching with fertilizer is after one or two heavy shower so that the fertilizer gets dissolved into the soil easily. If considered necessary, the second dose of fertilizer is given during the second weeding mulching which is normally undertaken after about a month or two. Forking in the base of the soil improves soil aeration, improves water infiltration and breaks the continuity of micro pores thus reduces the loss of soil moisture through evaporation.

It is not worth noting that the operation does not use any much material like cut grass, saw dust, rice husk to cover the soil. The reasons for not using the mulch material are –

- In the dry area, the materials are not easily available and involve cost.
- The materials invite termite attack
- The materials increase the risk of ground fire.

5. Irrigation

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

6. Casualty replacement or beating up

There is no guarantee that sowing or planting will be cent per cent successful. In fact, they will not be, and there will always be some failures leading to blanks in the plantation. **Casualty replacement or beating up** is **the operation of restocking blanks in a plantation area by sowing or planting.** Usually, beating up is done by planting. Following points are worth noting in this connection.

- Blanks in the sown area are identifiable soon after the normal germination period is over. Sowing should be done immediately. If there is still mortality or some blanks are identified late in the growing season, it should be beaten up by planting.
- Blanks in the planted area are beaten up by planting only.
- If some blanks exist even after the growing season is over, they should be beaten up in the next monsoon by planting, preferably with seedlings that have been maintained in the nursery for about a year.
- The nursery should have stock for casualty replacement.

7. Nurse crop

Nurse crop is the crop of trees or shrubs grown to foster the growth of another and more important tree crop in its early stages. Its function is to help the growth of principal species which may remain tender in the initial stage. As soon as the purpose is served, the nurse crop is removed. In south-west Bengal Sal plantation, it has been an old practice to raise *Cajanus* (Arhar) between two and close to Sal lines. Tolerant of drought condition *Cajanus* grows fast and provides shade to young Sal seedlings and reduces evapo-transpiration loss of moisture. The moisture stress is a critical factor for survival of Sal seedlings in the early stage after planting in south-west Bengal. *Cajanus* on being cut also serves as green manure at the site.

8. Fire and general protection

The plantation requires close supervision for protection against fire and grazing in the first couple of years. Cattle and animals can be kept off from the plantation by erecting and maintaining fencing. From December-January onwards the plantation becomes highly prone to fire damage. A preventive measure is to make fire lines around the periphery of the plantation. The width of the fire line should be at least 3 metres. Fire lines of shorter width (about 1.5 m) should be made within the plantation also. In fact, the network of inspection paths already created can be cleaned of vegetation and dry matters and so maintained to serve as fire lines within the plantation.

9. Plantation Journal

Plantation Journal is a register in which all works carried out in connection with the plantation are recorded from time to time. It is a very important record and should be prepared and maintained for each plantation separately. In general, following are the contents of a plantation journal

1. The administrative beat, range and division in which the plantation has been raised
2. Location with boundary
3. Regeneration plan map with certification about survey, checking of the area, brief regeneration plan and approval by the authorized officer.
4. History of the site, that is whether clear felled coupe or barren land etc.
5. General topography, soil, local climate.
6. Details of planting stock species wise
7. Advance soil work done that is, information about boundary trench, contour trench, pits with spacing
8. Sowing and planting done with dates
9. Details of inputs applied
10. Weeding-cleaning-mulching with dates
11. Financial data/Expenditure for each work in every financial year.
12. Pages containing remarks of inspecting officer and action taken thereupon

Reference materials:

1. L S Khanna 1999 Principles and Practice of Silviculture, Milton Book Company Dehra Dun
2. Ram Parkash 2007 Plantation and Nursery Technique of Forest Trees International Book Distributors Dehradun
3. R.C.Ghosh 1976 Handbook on Afforestation Techniques FRI & Colleges Dehra Dun

Regeneration Methods

Lesson 13

Time 1 hour

Lesson Plan

Objective:

- **To study** estimate of Plantation work

Backward Linkage- Previous lessons on 'artificial regeneration' and 'nursery'

Forward Linkage- To see, during tour, plantation works and plantation estimates.

Training materials required: Copy of Lesson 13 to be circulated beforehand,

Allocation of Time

- **Study estimate of Plantation work** 40 mts
- **Discussion/Miscellaneous** 20 mts

Note:

The trainer may explain to the trainees the work and the unit cost for each item. As and when necessary, reference may be invited of the previous lessons where the plantation works have been described. The discussion session may be utilized to obtain feedback from the trainees, in particular, suggestion on revision and addition of work items and on ways, if any, to economize the work.

Regeneration methods

Lesson 13

Time 1 hour

Plantation Work (continued)

1. Estimate of plantation work

The objective of this lesson, as has been stated, is study of plantation estimate. Preparation of plantation estimate is a major job of a forester and, therefore, he should have a clear idea of what constitutes an estimate and how to prepare an estimate.

1.1 Plantation estimate like any other work estimate describes the items of work to be carried out, unit rate of expenditure, and the estimated cost or expenditure item wise including the estimated total expenditure. Based on the estimate, a plantation work is accorded approval. While carrying out the plantation work and after, the estimate serves as a reference to check and monitor whether the work is progressing or has been carried out as per approved plan and within the fund envisaged.

1.2 The estimate of a plantation depends on many factors like the terrain, location of plantation and nursery, nature of plantation, planting stock, planting pattern, availability of labour and materials, protection measures required, fund available etc. In a word, estimate is plan specific and situation specific.

1.3 An illustrative estimate

While contents of estimate vary from one plantation to another, some broad work items remain common. To help the trainees understand the basic structure of a standard estimate and the kind of expenditures that are involved, **an example of a typical estimate for raising a plantation of quick growing species in south-west Bengal is given below.** The estimate has been drawn for one ha for illustrative purpose and should not be considered sacrosanct. Plantation over a small area of 1 ha or so is not economic and should not be undertaken unless it is unavoidable for some reason. The estimate has been drawn for 1 ha to give an idea of the average values of labour and materials per ha so that the same can be calculated over the total area of plantation, which is to be so planned as to be economic.

Model Estimate for Creation of QGS Plantation*

(Per hectare)

No. of Pits- 1600 Nos. Spacing 2.50m X 2.50m No. of seedlings to be raised in nursery 1800 Nos.

Sl.No.	Item of works			
A. Nursery works		Labour	Material	Total
1.	Cleaning , clearing bushes, jungle, thorn etc for preparation of nursery site incl. removing debris	0.50		
2.	Preparation of Mother bed of size 5.0m X 1.20m as per direction	0.50		
3.	Excavation and preparation of tube beds of size 5.0m.x 1.20 m.	0.50		
4.	Preparation of potting mixture with mixture of burnt rice husk, sand and compost/cowdung manure after sieving and removing foreign materials over 1.5 cu.m	2		
5.	Filling of 20 cm x 10 cm (flat) size polypots and arrangements in bed properly over 1800 Nos.	4.5		
6.	Sowing, dibbling of seeds in mother beds and tube beds	0.5		
7.	Pricking out of seedlings from mother bed to tube beds incl. replacement of lost ones.	2.5		
8.	Making nursery shed with bamboo, straw & local brush wood	1.5		
9.	Weeding cleaning and application of insecticide etc.	1.5		
10.	Watering over seedlings and maintenance of seedlings.	8.0		
11.	Sorting, shifting and culling of seedlings 3 times over 1800 seedlings	5.0		
	Total Mazdoors @ 216/-	**27**		5832.00
	Material component:			
12.	Poly pots 1.5Kgs.		200.00	
13.	Burnt rice husk incl. collection & carriage 0.50 cum.		200.00	
14.	Sand 0.50 cum.		180.00	
15.	Cow dung manure 0.60 Cum.		300.00	
16.	Seeds		100.00	
17.	Insecticide		100.00	
18.	Organic manure/ Neem oil cake etc.		100.00	
19.	Straw, bamboo, wire & rope , tin & watering can etc.		228.00	
	Total material			1408.00
	Total cost for nursery			**7240.00**
B. Field works				
1.	Survey and demarcation the area manually incl. GPS mapping and reading	2		
2..	Cleaning of thorns, bushes etc. over the area	10		
3.	Alignment and staking of pits at a spacing 2.5m X 2.5m	2		
4..	Digging Planting pits of size (60+45)cm/2 X 45cm X 45cm over 1600 Nos.	34		
5.	Filling pits with pulverized earth.	15		
6.	Erection of live hedge /brushwood fencing	12		
7.	Transplanting of potted seedlings incl. carriage of same from nursery to site and application of insecticide in pit	22		
8.	Infilling of casualties incl. carriage of seedlings	4		
9.	1st time, cleaning, weeding-mulching including forking around the seedlings and application of fertilizer	20		

10.	2nd time, cleaning, weeding-mulching including forking around the seedlings and application of fertilizer	15		
11.	3rd time, cleaning of weeds by spade	10		
12.	Cutting fire line in and around the area 3m. wide	6		
	Total Mazdoors @ 216/-	**152**		32832.00
	Material component			
13.	Insecticide		300.00	
14.	Fertilizer(NPK 10.26.26@ 40 gms/pit & UREA @ 20gms/pit per dose)		3400.00	
15.	Bamboo & sticks /brush wood for fencing incl. collection & carriage		3000.00	
16.	Contingency ; carriage of fertilizer etc.		228.00	
	Total material			6928.00
	Total cost in Field			**39760.00**
	Grand Total			**47000.00**

(* Inputs T K Das WBFS)