UNIT-II

General Concept of Forest Tree Breeding

Three terms are commonly used- forest tree breeding, forest genetics and forest tree improvement.

Forest tree breeding refers to the activities that solve some specific problems or produce a desired product (development of pest resistance or of strains possessing superior wood- quality).

In forest genetics the activities are restricted to genetic studies of forest trees.

Forest tree improvement indicates the improvement of overall yield and quality of the forest products by combining the forest management activities with control of parentage. Tree improvement includes the practices of silviculture and tree breeding meant to enhance the total yield. In simple words, tree improvement is an additional tool of silviculture that deals with the genetic make-up of the trees to be used in forest practices.

The main objective of tree improvement are to maximize the gain per unit time and space via selection and development of improved genotypes, and to maintain large and diverse genetic base for continuing successful tree improvement programs for many generations. Forest trees are mostly wild populations that are not yet greatly changed by human interference. Therefore this gives an outstanding opportunity to make improvement in such trees. In tree species large variability exists, which may be owing to geographic sources (provenance), stands and sites and geographic variation is important for its survival and adaptability. However individual tree variability is generally of the greatest importance for economic characteristics such as stem straightness and specific gravity of the wood etc (Zobel & Talbert, 1984)

Advantages of Tree improvement

1. Change in genetic makeup of the tree is permanent.
2. By means of vegetative propagation, the developed genetic material can be kept intact for an indefinite time.
3. Great genetic variability is present in most tree stand, which is not greatly changed by the action of the people.
4. The wide genetic variation enables the wider adaptability.

Limitations of tree improvement

1. Requirement of large area for storage o desired genetic material and for testing.
2. The size of the tree also creates problems to carry out different breeding activities, e.g. measurement of height, diameter, crossing, seed collection etc.
3. The cost and effort of producing new seed crops per year is large.
4. Different tree possess different growth curves. Therefore juvenile-mature correlations are not satisfactory for growth characteristics.
5. Lack of availability of seed with the known or desired genetic background.
6. Requirement of good, permanent record because tree improvement is a long term process.

Problems peculiar to tree improvement

1. Time
2. Use of indirect evidence
3. Uncertainty and need for continuous experimentation
4. Necessity of seed production
5. No come back
6. Scarcity of basic genetic information about trees

Selection of tree species and traits to be improved

The major factors to be considered in the establishment of species include the following:

1. Demands for a species for use in plantation
2. Economic value of the species (either an area basis or on individual tree basis).
3. Amount of genetic variation within the species
4. Anticipated cost of successful breeding and production of subsequent planting stock compared with the economic value and anticipated gains.
5. Research and development programmes being conducted by other organizations

Essentials of a Tree improvement Program

There are two aspects to any tree improvement program.

1. Relates to obtaining an immediate gain of desired products as rapidly and as efficiently as possible.

    - ✓ This is achieved by intensively applying genetic principles to operational forestry programs that will result in better quality, better adapted, and higher yielding tree crops.
    - ✓ Maximum gains are achieved by the use of a few of the very best genetic parents to supply planting stock for operational programs.
    - ✓ A benefit of a tree improvement program that is often not recognized is the production of large and regular seed crops that are suitable for the forest operations. Lack of suitable seed is one of the greatest deterrents to forestry.

2. The second aspect of tree improvement program is concerned with the long term need to provide the broad genetic base that is essential for continued progress over many generations. Although not emphasized in some current programs, the long term aspect of tree improvement is of great importance.

All tree improvement programs must have an operational (production) and a developmental (Research) phase.
The two are closely linked, yet they require different approaches and philosophies.

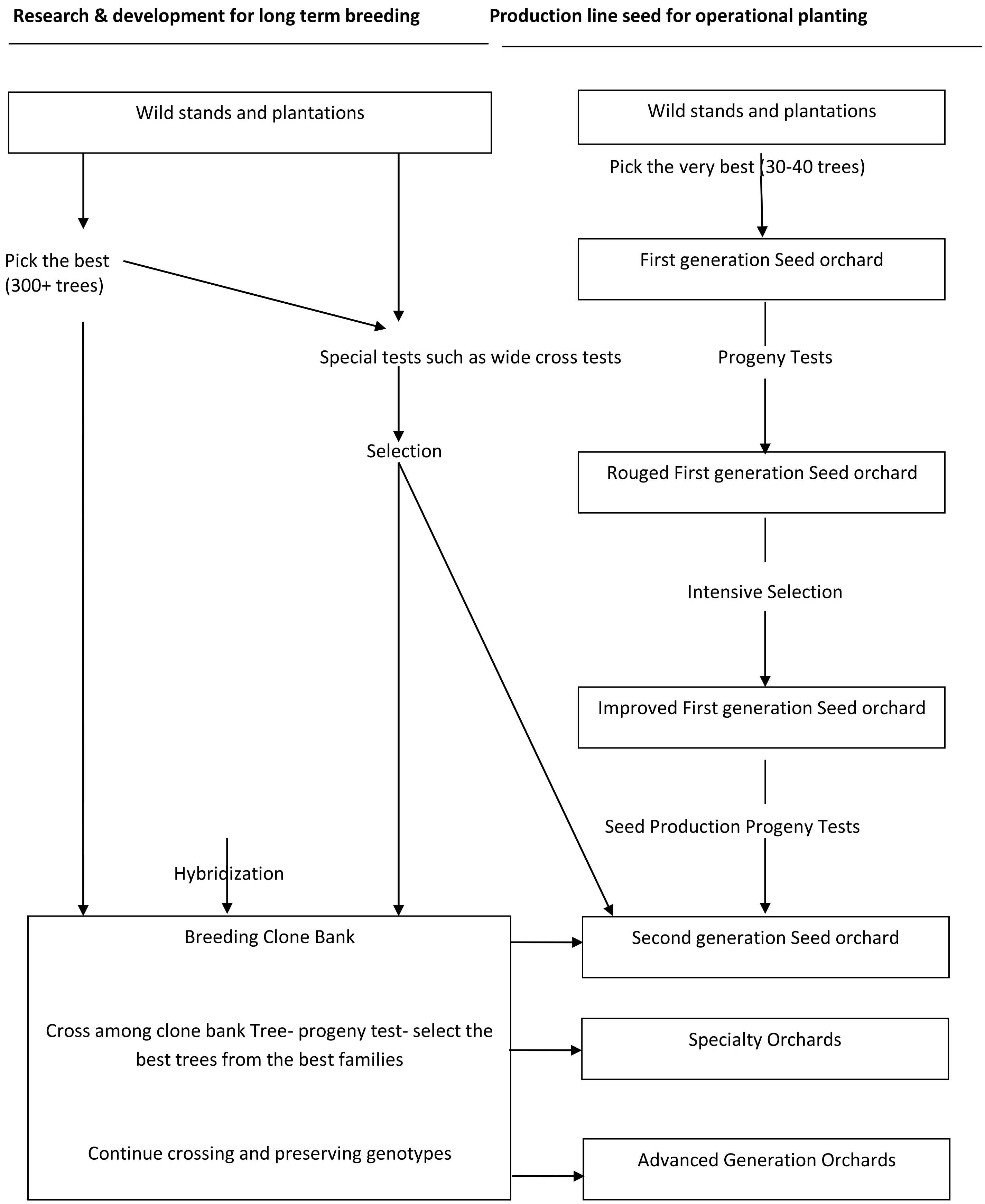
Here two phases are roughly outlined in figure:

The developmental or research phases are necessary for a successful long term program. As the programs mature, the operational activities become increasingly dependent on continued progress in the developmental area. Therefore to be successful, a tree improvement program must have the developmental aspects, initiated at an early stage in the program along with the operational activities.

The developmental activities are not begun until later years because of the press of work in operations and as a result, a gap develops in plants materials and information necessary for advanced breeding.

The operational phase produces quick economic gains from tree improvement and is the most easily understood and obvious to the general public and to forest managers.
This phase consists of obtaining improved planting stock as quickly and efficiently as possible and with as much genetic improvement as possible.
The main objective of the developmental phase is to obtain and retain a broad genetic base and to combine desired characteristics in to suitable trees that will be valuable for future generations.

No program can be better than the base of genetic material upon which it is founded, and although the developmental phase takes considerable time to yield useful result, the provision of the skill and money required maintaining it is mandatory.


Research & development for long term breeding
Production line seed for operational planting
Wild stands and plantations
Wild stands and plantations
Pick the very best (30-40 trees)
First generation Seed orchard
Pick the best
(300+ trees)
Special tests such as wide cross tests
Progeny Tests
Selection
Rouged First generation Seed orchard
Intensive Selection
Improved First generation Seed orchard
Seed Production Progeny Tests
Hybridization
Breeding Clone Bank
Cross among clone bank Tree- progeny test- select the best trees from the best families
Continue crossing and preserving genotypes
Second generation Seed orchard
Specialty Orchards
Advanced Generation Orchards

A large number of tree improvement programs ignore the developmental or research aspects. Because of the complexity and cost, the research or developmental work is ideally suited to a cooperative approach where several organizations jointly fund the work and share the results.

Starting a Tree Improvement Program

Establishing Objectives

Before a tree improvement program is begun, the situation needs comprehensive analysis. Tree improvement is long-term work, and a great deal of time and energy can be saved with some careful planning. The following factors should be considered.

1. Desired products
Wood properties necessary to produce the desired products
Required volume of wood

2. Possible species
Native or exotic (long-term consequences of using exotic species?)
Rotation length (shorter rotations give major improvements in gain per unit time)

3. Chosen reforestation system

Seed propagation or vegetative?
Bareroot or container seedlings?
Storage and distribution methods
Planting techniques and cultural procedures

4. Plantation evaluation/survival system
Required personnel
Numbers and skill levels
Required facilities and equipment
Required long-term budgets

Identifying the Raw Material to Be Used

Native versus exotic species. Are there native species available that are well-adapted to the planting sites to be used or would exotic species be more productive? The temptation to introduce an exotic species may be strong but there are a number of advantages of native species.

- They have evolved in harmony with their environment and usually have developed a mutual tolerance with competitors and pathogens. Exotics, on the other hand, may not perform well in a new environment—they have not been exposed to the stresses of this new environment and often have not had sufficient time to adapt to local conditions.

- Native species have well-defined management regimes that have been tested over time. Reforestation personnel have learned how to grow, ship, store and plant the seedlings or cuttings.

An exotic species introduced into a new environment does not necessarily produce wood with the same characteristics as in its place of origin. Excessive amounts of juvenile wood are common, as are wide bands of earlywood and narrow bands of latewood. These growth patterns lead to lowdensity wood and drying defects (Zobel 1981). There are notable exceptions, such as Monterey pines grown in New Zealand, but in general the wood quality of native species is more desirable than that of exotics. Public opinion is running strongly in favor of native species both in the United States and overseas. Plantation forestry with exotic species has encountered strong public resistance in a number of locations.

Terms Commonly used in tree Improvement

There are few general terms that will constantly be encountered throughout the tree genetics, tree breeding and tree improvement technique in forestry-

Gene: genes can be thought of as the functional units of inheritance.

Allele: Each gene may be represented in the population by one, two or more alternate forms. Each of the alternate forms for a given gene is called an Allele. ***Example:*** An allele at a gene locus that influences leaf size (*allele- A*) might code for long leaves, whereas another allele of the same gene (*allele- a*) might code for shorter leaves.

Phenotype: The phenotype is the tree we see. It is influenced by the genetic potential of the tree and by the environment in which the tree is growing, including the managerial history of the site. The phenotype is often indicated by the simple formula.

P=G+E (Phenotype = Genotype +Environment)

Thus phenotype of the tree is what we measure and what we work with.

Genotype: The genotype is the genetic potential of the tree. It cannot be seen directly, and it can only be determined through well designed test. The genotype is determined by the genes that reside in chromosomes in the nucleus of every cell in the tree.

Environment: the sum total of nongenetic factors that affect the growth and development of trees as called the environment. It is very general term applied to soils, moisture, weather and often also to the influence of pests and sometimes to the interference of people.

Progeny: The trees produced from the seed of a parent tree are called its progeny.

Progeny Tests: Progeny tests are established to determine the genetic worth of the parent trees or for determination of other genetic characteristics. Sometimes, a test of the vegetative propagules from a given donor is referred to as a progeny test, but usually it is called clonal test.

Population: this is very loosely used by workers in the field of tree improvement. The terms population will be used in a general way to designate a community of interbreeding individuals. No degree of relationship is assumed.

Stand: the word stand is often used synonymously with population; at other times, stand refers to a group of trees of special interest within a population.

Race: Group of populations that generally interbreed with one another and that intergrade more or less continuously is referred to as race. Many kinds of races are recognized, such as edaphic, climatic, elevational and so forth.

Family: individuals that are more closely related to each other than to other individuals in a population are called a family. Generally, the term family is used to denote groups of individuals who have one or both parents in common.

Sibling: A group of individuals within a family are referred to as siblings; the group of related individuals when only one is common is called a half-sib family; when both parents are common, they constitute a full-sib family. An open pollinated family is one in which one parent is common and the other parent is unknown.

Rotation Age: The age at which a stand of trees is to be harvested is called the rotation age.

Seed orchard: An area where superior phenotypes or genotypes are established and managed intensively and entirely for seed production is referred to as seed orchard.

Adapted: The adopted refers to how well trees are physiologically suited for high survival, good growth, and resistance to pests and adverse environments.

For exotics, it refers to how well the trees will perform in new environments. Adaptation commonly refers to the tree's performance over a full rotation in the new environment.

Exotics: The term exotics can be defined in several ways, but for the sake of simplicity, the following is useful. An exotics tree is one grown outside its natural range.

Provenance, Geographic source, or Geographic race: These denote the original geographic area which seed or other propagules were obtained.

Seed source: if seed from the trees grown in Zimbabwe were harvested and planted in Brazil, they would be referred to as the Zimbabwe seed source and the Coffs harbor Provenance.

Candidate tree: A tree that has been selected for grading because of its desirable phenotypic qualities but that has not yet been graded or tested.

Select, Superior or Plus tree: A tree that has been recommended for production or breeding orchard use following grading. It has a superior phenotype for growth, form, wood quality, or other desired characteristics and appears to be adaptable. It has not yet been tested for its genetics worth, although the chances of its having a good genotype are for characteristics with a reasonable heritability.

Elite Tree: A term reserved for selected trees that have proven to be genetically superior by means of progeny testing. An elite tree is the winner from a selection program and is the kind of tree that is most desired for use in mass production of seeds or vegetative propagules.

Comparison or Check tree: Trees that are located in the same stand, are of nearly the same age, are growing on the same or better site as the select tree and against which the select tree is graded. Tress chosen as comparison trees are the best in the stand, with characteristics similar to crop trees that would be chosen in a silvicultural operation.

Advance- generation selection: A tree selected from genetic tests of crosses among parents from the previous generation. Some form of family and within family selection is usually used to choose advance- generation selections.

Ploidy: The number of sets of chromosomes a tree has is termed **Ploidy**, and it can greatly affect the variability pattern within and among species. Usually, each parent contributes one set of chromosomes (1n) to the progeny, so the tree has two sets of chromosomes and is called **Diploid** (2n).

Polyploidy: Sometimes species, or individuals within species, have more than the usual sets of chromosomes these are called Polyploidy. Polyploidy is more common in hardwoods than in conifers. Example- Redwood, Poplar, Alnus, Betula, Ashes etc. it is estimated that one third of the hardwoods are Polyploidy aspens and are no better than the Diploids for tree breeding program due to inheritance patterns can be very complex and difficult to manipulation and cause.

Methods of tree improvement

Forest tree improvement is a new field in comparison with other branches of plant sciences. In fact, there are people who are unconvinced that it is a promising field to work. The literature on methods of tree breeding is also scanty.

There are four active elements to forest tree genetics and improvement (Libby, 1973). These are:-

1. Assessment of original genetic variability
2. Selection of desirable genotype or phenotype
3. Development of trees or populations containing desirable genotypes or phenotypes.
4. Capture of the benefits derived from genetic improvement.

Mathew, (1953) listed the following program of work in England on tree breeding:-

1. A survey of existing woodlands to locate the best possible seed sources and to select individual trees of outstanding merit 'Plus trees' for use in future breeding work.
2. The development of improved methods of vegetative propagation, the study of the biology of flowering and fruit formation, the trial of methods of stimulating flowering, and tests of methods of controlled pollination.
3. The testing of selected plus tress by means of clonal trials of the genotype and progeny trials.
4. The formation of seed orchards for the production of improved strains.
5. Interspecific and intraspecific hybridization between selected individuals with the aim of obtaining heterosis.

6. The development of resistance breeding and of inbreeding.
7. The use of naturally occurring and artificially induced polyploidy forms.

The important methods of tree breeding are tree introduction, selection and hybridization. All methods have their strong as well as weak points, all the problems to be solved in tree breeding show variations; besides, the tree species do not have the same genetic make-up. Thus the skill with which the tree breeder analyzes the problems and selects methods of breeding is good measure of his ability in the art of tree breeding. The approach also depends upon the characteristics, the nature of the problem to be solved, and the variation and inheritance in the tree species involved.

Through tree introduction, considerable benefit is gained by planting foreign species in some part of the world, particularly if there are no native species producing the same kind of wood.

Genetic selections to improve the yield of forest tress can be made at the levels of species, variety, provenance and individual tree. Such selections may be effective, because the native and naturalized species, variety or provenance do not always fully exploit the managed environment of a region.

They are usually adapted to survive the extremes of local climate and edaphic conditions rather than to produce the highest yields of the products required.

Where species are unsatisfactory for these or other reasons, yield can often be improved by proper introduction, testing and selection of best adapted and most productive populations of the exotics trees.

Selection of individuals for high yield can exploit the variation among trees within populations. Genetic improvement of a species will generally show fastest progress if selection work is concentrated only on a few traits.

Selection for additional traits greatly increases the number of trees that must be examined if a constant genetic gain is to be maintained for each trait. Conversely, for a given selection intensity, consideration of as many as three traits greatly reduces the effective selection differential for each traits. Interspecific and intraspecific hybridization have been used to improve the yield of forest trees and are promising methods of breeding under some circumstances.

Breeding Strategies in tree Crops

Components of General breeding Strategy

1. Surveying and identification of superior phenotypes/Candidate Plus Trees
2. Establishment of Clonal bank
3. Carrying out Clonal Mating
4. Carrying out Genetic tests
5. Manipulation of Time in breeding Cycle
6. Establishment of Seed Orchards/Hedge- orchards for Cuttings
7. Production of Quality Planting Stock
8. Maintenance of Broad Genetic Base
9. Maintenance of inbreeding in Breeding and Production Populations.
10. Continuity in Improvement Programme

Variation and tree improvement

It is the law of nature that the two individuals are not similar to each other. The people were aware that individual variation existed among the human beings. These variations formed the basis of differences between races, families and individuals. The same is true with the tree also, that every individual differ from other. During the study of variations in forest tree one finds a lot of diversity in nature. This diversity is more in the native species. There is saying that the place of origin of species is place of its diversity. This diversity is the major factor for bringing about changes to make the species adaptive to a particular environment and help them to change with changing environment for their survival. Owing to this factor, one finds same species growing in plains, hilly tracts and under different environmental conditions.

The natural variations are the result of continues environmental selection for generation each variation as we observe, differs phenotypically as well as genetically. These variations are important source for a tree breeder to improve a species through selection and hybridization.

The variation can be successfully utilized for the adaptability of a species to a particular area, e.g. cold hardiness, drought resistance etc. these variations can help in checking the epidemic caused by insect damage, in checking pathogen or a virus attack and in the selection of suitable genotype for different end uses of a species.

Most of the important commercial forestry species in India occur in different ecological conditions, and thee populations have been exposed for a long time to the particular environment and thereby have been adapting themselves to those environments.

Zobel *et al.,* (1960) have grouped the variations for wood properties in forest trees as geographic variation (Provenances), site variations within provenances, stand variation within sites, individual tree variations within stands and variability within individual trees.

Types of Variation

Variations in forest tree species can be divided in to two major groups:
1. Environmental variations and
2. Genetic variations.

1. The **environmental variations** are the result of nature's variability in rainfall, temperature, wind, soil depth; humidity etc. human beings also help in developing these variations by creating micro-environment while carrying out developmental activities like establishing industries, canals, dams and other developmental projects. These variations can be classified as ecological variation, racial variations, clines and ecotypes.

Geographical Race: geographical race as a subdivision of a species consisting of genetically similar individuals, related by common descent and occupying a particular territory to which it has become adapted through natural selection.

Ecotypes and Clines: An **ecotype** is a group of plants of similar genotype that occupy a specific ecological niche. In forestry, the ecotype is sometimes used synonymously with race but usually consists of a smaller discrete population.
The concept of ecotype was suggested by Turesson (1922) who defined it as a genotypical response of a species to a particular habitat. The whole concept is based upon the adaptability to a specific environment.
Cline was first defined by Huxley (1938) as a gradient in measurable characteristics. A cline by definition is based on single characteristics that have continuous variation; it may or may not be genetically fixed.
The ecotype and cline concepts have widespread utility in forestry. Because of the commonly observed continuous type of geographic variation, ecotypic differentiation is difficult to observe.

2. **Genetics variations** Wood quality and tree forms are the major sources of **genetics variations**. Genetic variations are divided in to two sub groups-
1. **Additive:** the additive variance is due to the cumulative effect of alleles influencing a trait.
2. **Non additive variations** are due to dominance and epistasis.

Many tree characters are believed to be under the control of additive variance, e.g. Specific gravity of wood, straightness etc. a dominance gene is one that governs the expression of a trait. Dominance gene and recessive gene are allelic to each other. A dominant gene will express itself in both homozygous and heterozygous states, whereas the recessive gene can express itself only in homozygous state. Epistasis variation is due to interaction among gene loci.

In most tree improvement programs, non additive types of genetic variability have generally been given little attention, because the additive portion of genetic variance is easier to utilize.

Causes of variation

1. Environmental
2. Geographic
3. Genetic
    a) Mating system
    b) Mutation
    c) Gene flow
    d) Man made variation

Environmental Variation: for adaptation of any species to a particular environment, its suitability to that environment is important. The nature itself does the selection work, if not disturbed by the human factor. The factors governing environmental variations are temperature, humidity, rainfall, wind, soil depth, nature of soil etc. depending on the environment we have plant species, e.g. Xerophytes, hydrophytes etc., as in Eucalyptus we have species to suit desert conditions, marshy areas, high rainfall etc. and similarly in teak also there are different races suitable for dry areas and wet areas. Due to change in environment, races and ecotypes are developed by growing in that environment for generations and they became adaptive to that particular area.

Geographic Variation: The longitude, latitude and altitude bring about changes in the species, through environment plays an important role in it. On climbing up the hill one see a clear cut change in the species, but where the species remain the same, its genotypes changes itself to adopt for that particular locality. The change of latitude has induced flowering in some plant species like Pine.

Genetic Variation: **T**he change in gene frequency or genetic makeup from one generation to another brings greater variability. These variations are by caused by (a) Mating system (b) Mutations (c) Polyploidy and (d) Gene flow

Mating system: The type of mating systems or pollination mechanism existing in a species has its effect on the variation. The cross-pollination increases heterozygous population, whereas self pollination leads to more homozygous population. Selfing not only bring homogeneity but also has adverse effect on seed setting, germination and growth rate. Most of the forest tree species are cross-pollinated and hence they have more variations. The best examples are Eucalyptus and poplar, where natural hybrids are very common.
Mutations: Mutation is defined a sudden change of genotype, De Varies was the first person who used the term mutation. Mutation helps in maintaining

variability in a species. The mutated gene is the source of hereditary variability. Various types of mutations may be broadly classified as gene mutation, chromosomal mutation, somatic mutation and genomatic mutation. These mutations can be spontaneous (natural) or induces and are classified as follows:

1. **Cytoplasmic mutation:** Hereditary changes that arise in the cytoplasm and are transmitted by it are called cytoplasmic mutation.
2. **Nuclear mutation:** Such a type of mutations occur due to change in chromosome number and are of following types:
   Gene Mutation
   Chromosomal Mutation
   Somatic Mutation
   Genomatic Mutations- Polyplody, Euploidy, Autopolyploidy, Allopolyploidy, Aneuploidy etc.

Gene Flow: the migration of gene from one population to another or the spreading of gene through crossing is called gene flow. The gene migration takes place either through seeds, or also when introductions are made in a locality by using provenance/introduction trials and hybrid trials, when the out crossing takes place with the original population of the resulting in gene migration and thereby causing variations.

Man Made Variation: the increase in demand of wood has led to clear felling of large areas, thereby causing gene erosion. To reforest these areas is difficult task, and one tries to introduce new variations to suit these localities in the form of introduction trial or trying different geographical variations to suit that locality. Besides, variations are also created by doing research activities on induced mutagenesis polyploidy and controlled hybridization.

Study of Variation

The variation can be studied either by direct observation of a phenotype or by indirect means through correlation of morphological or biochemical estimates.

The direct observations can be growth form and wood quality to study between population, within population and tree to tree variations in provenance trials.

In the indirect study, correlations are first established and on this basis further variations are studied.

In environmental stress situations proline and amino acid appear to increase in concentration and provide some protective effect.

Abscisic acid and Gibberellin play a role in development of winter dormancy and hardiness. Similarly correlations have been made for resin content and needle colour in pines. Significant differences have been found in the fibre length of teak provenance from Nilamber, North Bambey, Burma and South Burma.

Provenance Trials

Provenance has been formulated from the Latin word, provenine, means to come forth. Provenance is the source or place of origin of the reproductive material.

A provenance trails/ test is an experiment in which seeds are collected from a number of widely (usually natural) and the seedlings are grown under similar conditions to select a seed source for better growth and adaptability.

It may be defined as the geographical area and environment to which the parent trees are native and within their genetic constitution has been develop through natural selections.
Provenance trials are the best source to study geographic variations available in a species. In India some of the worked out with species like Teak, Sandal, Sissoo, and Neem etc.

In Teak MP teak is good for veneering because of its slow growth due to dry area, Nilamber Teak, grown in wet area has a faster growth with clear bole. The coastal area Teak of Gujrat known as Bankya has slight bend and due to this its wood is used for boat making depending upon these genetic variations different terms have been coined by scientists. A population where genetic variation is continuous or clinal is called a cline. The population that differs from another either genetically distinct population or a portion of a cline is termed Race. A race, which has adapted itself to a particular environment, is termed Ecotype.
The genetic variation calculated through provenance trial is tentatively 70-85 % between population and 15-30 % within population.

To assess such variations in a species, provenance seeds are collected from 20-40 seed sources and trials are laid out with 9 -25 trees per plot in 4-10 replications these studies can include some of the characters like, estimation of ability to withstand drought by studying the leaflet ration, leaf length and internodal distance between the leaves.

Characters for timber production can be height, clear bole height, diameter or circumference and the number of branches.
Characters for fodder production can be crown shape, crown diameter, leaf production and quality of fodder.
Characters for phonological studies can be leaf fall, time of new flush, first flowering, and intensity of flowering and percentage of fruit set.
Characters for seed variation studies can be seed size, seed weight and biochemical aspect of the seed. Study of the non wood forest produce is also very essential, and it can include characters like oil contents, gum contents, resin content etc.

Role of Provenance Tests in tree Improvement

1. Provenance testing is essential to obtain maximum yield per unit area.
2. Plus trees selected without provenance testing may not be superior.
3. The breeder wants to be sure that he has the best race, considering the locality before starting the breeding work.
4. Though native population is more adaptive, at times introductions may prove better than native populations.
5. To screen the naturally available genetic variation and to choose the best available type for further breeding work.

Uses of Variations in Tree Improvement

1. To raise large plantation of economic value, it is essential to use seeds that are genetically improved for the desirable traits.
2. Variability in the forest trees combined with their breeding has the highest potential for maximizing yield per unit area and time, along with bringing about improvement in the quality of forest products from the plantation.
3. To develop genetically improved quality of a planting material, it is essential to exploit genetic variability existing in that species for various end uses like breeding for adaptability to different environments and soil condition, timber productions, wood properties, resistance to diseases, minor forest products, agro-forestry etc.

Quantitative genetics and selection

The primary objective of an applied tree improvement program is to change the frequency of desired alleles that influence important tree characteristics in such a way that the improved plants are superior in performance to unimproved material.

The way of accomplishing this is through the process of **selection,** which can be defined as choosing individual with desired qualities to serve as parents for the next generation.

Although selection can be a major tool for studying the way traits are inherited, in applied tree improvement program selection is primarily used for the improvement of economically important characteristics.

The practice of selection in tree improvement is both a science and an artistic skill that must be developed by the tree improver.

Some Terminology

Genetic values: he genetic values of parents are expressed in terms of combining abilities-
There are two types of CA of special interest to the tree breeder and these will be explained as **General Combining ability** and **Specific Combining ability**.

General combining ability is defined as the average performance of the progeny of an individual when it is mated to a number of other individuals in the population. It is usually more convenient and meaningful to express the as deviations from the overall mean.
Specific combining ability is a term that refers to the average performance of progeny of a cross between two specific parents that are different from what would be expected on the basis of their general combining ability alone.

Heritability

The concept of heritability is one of the most important and most used in quantitative genetics. Heritability values express the proportion of variation in the population that is attributable to genetic differences among individuals. It is therefore a ratio indicating the degree to which parents pass their characteristics along to their offspring. Heritability is of key importance in estimating gains that can be obtained from selection program.
There are two types of individuals tree heritabilities are important in applied tree improvement –

1. Broad sense heritability (H^2): defined as the ratio of total genetic variation in a population to phenotypic variation, and its value range from 0 to 1.

$$H^2 = \sigma^2 G/\sigma^2 P = \frac{\sigma^2 A+\sigma^2 NA}{\sigma^2 A+\sigma^2 NA + \sigma^2 E}$$

2. Narrow sense heritability (h^2): is the ratio of additive genetic variance to total variance and it also range from 0 to 1.

$$h^2 = \sigma^2 A/\sigma^2 P = \frac{\sigma^2 A}{\sigma^2 A+\sigma^2 NA + \sigma^2 E}$$

Selection and genetic gain

Selection is based upon the principle that the average genetic value of selected individuals will be better than the average value of individuals in the population as a whole. For metric or quantitative traits gain from selection is usually measured as a change in the population mean.
Selection differential:

It is defined as the average phenotypic value of the selected individuals, expressed as a deviation from the population mean and it is symbolically represented by **S**. If there is much phenotypic variation for a given characteristics, then the selection differential can be large.

$$S = Xs - X$$

Genetic gain = Narrow sense heritability **X** Selection differential

Or

$$G = h^2S$$

Selection Methods

There are several different methods available to the breeder, depending upon the types of information available. The selection systems commonly used in natural stands and unimproved plantations.

1. Mass selection
2. Family selection
3. Sib selection
4. Progeny testing
5. Within family selection
6. Family plus within family selection

Mass Selection involves choosing individuals solely on the basis of their phenotypes, without regard to any information about performance of ancestors, siblings, offspring or other relatives. Mass selection works best for highly heritable traits, where the phenotype is good reflection of the genotype. It is the only type of selection that can be used in natural stands or in plantation where tree parentage is unknown. Mass selection is rarely used when pedigrees are known, as in advanced-generation genetics tests, because more gain can be obtained using other methods. The terms mass selection and individual selection are used synonymously.

Family Selection involves the choice of entire families on the basis of their average phenotypic value. There is no selection of individuals within families and individual tree values are used only to compute family means. The family selection works best with traits of low heritability, where individual phenotypes are not good reflection of genotypes. When family averages are based upon large numbers of individuals, environmental variance tends to be reduced and family average become good estimates of average genetic value. Family selection by itself is rarely used in forestry even with traits of low heritability because more gain can be obtained from other methods that include family selection as a part of the method. Family selection may slo lead to increased rates of inbreeding because entire families are discarded, thus reducing the genetic base of the population.

Sib Selection this is a form of selection in which individuals are chosen on the basis of the performance of their siblings and not on their own performance. When family sizes are large, it is very similar to family selection. Sib selection is rarely used in forestry but may be application when destructive sampling must be used to make measurements and it is not feasible to preserve genotypes by grafting or other techniques before sampling begins.

The goal of tree improvement should be to achieve the maximum amount of gain per unit time. Progeny test is more efficient in accomplishing this goal. **Progeny testing** involves selection of parent trees based upon the performance of their progeny. It can be very precise selection methods, because it allows direct estimation of breeding values to use in the selection process. This is what occurs when parents from a seed orchard are progeny tested and orchards are then rogued of parents that prove to be poor genetically. Progeny testing is not generally the initial form of selection for most breeding programs. Initial selection by progeny testing considerably lengthens the generation interval, which means a critical loss in time.

Within Family Selection here individuals are chosen on the basis of their deviation from the family mean and family values per se are given no weight when selection are made. Of all the selection methods, this one gives rise to slowest rate of inbreeding, which is a major problem in most programs. In practice, family selection is rarely used in tree improvement because large increments of gain can be obtained from selection on family values. Thus the family and within family methods are almost always combined.

Family Plus-Within Family Selection this two stage method involves selection on families followed by selection of individuals within families. It works well with low heritability and is a predominant form of selection used in most advanced generation tree improvement programs. It consists of choosing the best families along with the best individuals in them. A refinement of this method is combined selection where an index computed that rates all individuals based upon their family value combined with their individual phenotypic values. Coefficient or weights used in the index equation depend upon the heritability of the trait, with more weight given to the family average for traits with low heritability and with more weight given to the individual when heritability of the trait is high.

Concepts of Seed Production Area/Seed Stand

A seed production area is referred to as a phenotypic superior stand made up of vigorously growing trees, upgraded by thinning to remove poorer phenotypes and then treated and managed to cause abundant seed production.

Since the culling of inferior trees is recommended, it is also called a negative selection, because we select inferior phenotypes as for removal from the seed stand. The genetic gain obtained through selection is 5-10 %.

Seed stand constitute a reliable source of seed of certain genetic quality, until such time the seed orchards some in to production.

Seed stands are a stage prior to the formation of seed orchards. The genetic improvement through seed stands depends on the quality of the formation and on the characteristics under consideration. A gain to 5- 10% may be possible but, since the trees in the stand are not usually subjected to progeny trials, real genetic value is not known.

Seed production area should be located in the best natural forest area or plantation with good stocking, good health, almost half that of the rotation age.

Once the area has been selected, the phenotypic quality of the individuals and the initial average production are assessed morphologically and quantitatively. This will help in laying down the criteria for establishing the seed stand and in having a basis for calculating the genetic advance to be expected in plantations grown from the seed produced in that stand.

The main management activity in a SPA is thinning. Poor phenotypes with deformed bole, short height, weak growth and unhealthy trees, should be marked for removal.

The trees retained must be vigorous in growth, having good clear bole, straight stem, and free from knots, fluting and buttressing, as well as from disease and insect attack, having wider branch angle and self pruning ability and giving higher yield of seed can be obtained. The trees retained should help in opening up of canopy for good trees, so that good seed yield can be obtained. The trees retained should be left in such a way that pollination activity is not hindered.

Adequate protection should be provided to the SPA from wild animals.

Manure and fertilizer application will help in increasing the seed yield. Generally application of manure and fertilizer before flower bud initiation will help in more fruit setting.

To reduce pollen contamination, the SPA may be given an isolation zone. Where it is not possible to give such a treatment the area may be planted with other species to reduce pollen contamination from the neighboring trees.

Selection of phenotypically superior trees

Plus trees are the individual trees of outstanding merit, initially selected on the basis of superior phenotypic characters like height, diameter, clear bole height etc.

The selection criteria differ according to the end product.

The criteria for selection of plus trees for wood characters may includes:

1. Specific gravity
2. Lumen diameter
3. Cell-wall thickness
4. Fiber length
5. Cellulose
6. Hemicellulose
7. Lignin content
8. Other extractive.

Characteristics for timber purpose

The general characteristics of should a tree should be: (i) rapid growth (ii) straight bole, (iii) no forking (iv) branches: thin, small, slow growing and arising at 90^0 to the trunk, (v) narrow green crown (vi) thin bark, (vii)self pruning habit, (viii) quality timer (density, fiber, grain etc.), (xi) tolerant to particular environmental stresses (heat, frost, drought, wetness, and problematic soils, pest and diseases etc.).

The criteria for non wood forest produce may include:

1. Tannin content
2. Resin content
3. Gum yield
4. Medicinal value
5. Catechin content
6. Seed protein content
7. Dye
8. Seed oil content
9. Santalol content

Characteristics for Fodder Tree

For selecting trees for more fodder yield, the tree must have the following characters (i) small-to medium sized tree (ii) highly branched, (iii) more leaf size, (iv) more foliage per unit of branch wood weight, (v) no pubescent leaves, (vi) capacity of regrowth after lopping, (vii) high palatability and digestibility of fodder, (viii) proper chemical constituents, particularly more protein content, (ix) tolerate adverse environmental conditions and insects, pests and diseases

For agro forestry, besides the characteristics important as per the end-use, the small crown, straight clear bole and deep rooting behavior are most important parameters. In addition, trees are often selected for their important by-products (essential oil contents of seed, resin yield from pines, tannin, gum yield etc.) and adaptability to adverse environmental conditions.

Characteristics for fuel wood

For fuel-wood species, there is need for more small wood than the large, straight, clean bole. The following characters are to be observed for a good fuel-wood tree: (i) rapid growth, (ii) stem of medium height, (iii) wood with medium to high density, (iv) excessive branching, (v)minimum bark, (vi) thorn less, (vii) good coppice, (viii) adaptable to high density, (ix) short rotation, (x) adaptable to wide agro-ecological regions, and (xi) tolerate the attack of insects, pests and pathogens.

Selection of traits

The range of primary parameters that can be used to describe the tree may be placed broadly in 6 groups, and within each of these groups, the traits may be qualitative or quantitative and may be assessed subjectively or objectively. The groups are, mentioned below.

1. Stem : height, diameter, forking, straightness, taper, bark thickness
2. Branches: number, diameter angle, distribution
3. Crown: length, width, symmetry, foliage
4. Wood: density, fiber ,dimensions, grain, workability
5. Photo chemicals : yield, composition, quality
6. Adaptation : effect of drought or other environmental factor s, tolerance to pest and pathogen attack

Reproduction should also be taken into consideration as selection criteria, because the utilization of the improved material will be difficult without flowering and good seed production, unless large-scale vegetative propagation is a realistic alternative.

For maximum recovery of wood of high quality, rapid volume production is required in a vertical, cylindrical bole, without bifurcation with minimum taper. The wood should have high density with uniform long fibers. Branches should be short with less diameters and grow at right angles to the stem to keep knot size to the minimum and to reduce the likelihood of forking. The branches should be evenly distributed up the bole with no defined grouping. A narrow, conical crown with pronounced be apical dominance and a low crown: bole volume ratio is desirable for higher wood productivity on a unit area basis.

The high-resin yielders should have a high proportion of the most valuable terpenes (a-pinene) and high-quality resin (e.g. light colour, resistance to crystallization, high melting point, good viscosity etc,).

The ideotypes of trees in natural populations have evolved through selection for altogether different purposes. The conceptualization, identification and assembling of a particular set of characteristics and the development of tree ideotypes require a high degree of knowledge and experience.

The characteristics of trees with various end-uses will differ; even for even for even end-use, they may differ depending upon whether the trees are to be grown in a plantation or under agro-forestry conditions. Therefore, there is need to develop ideotypes for specific end uses.

Limitations of Criteria

Very often one will have a list of many characters mentioned by growers and consumers. Some of these characters may be independent and some may be genetically correlated with each other. But, the positively correlated traits, improvement is not much difficult; but in the negatively correlated parameters, progress in one character will cause a decrease in the other. This id often the case with quantitative and qualitative characters; the increase in the growth of trees lowers down the quality traits like specific gravity and it makes selection more difficult. Moreover, if the characters to be improved upon are negatively correlated, the increase in number of character for selection results in a decrease in the gain in each character .height growth and the quality traits are negatively related, and improvement in one trait will result in loss of improvement in another. It is, therefore, necessary to restrict the characters to the minimum, otherwise the breeding programme shall gave to split in more directions, which probably may be the best solution but most often it is more time consuming and expensive.

The net value of an individual is dependent upon several traits. It is therefore necessary that selection is applied simultaneously to all the traits of economic importance. Some form of multiple-trait index is required, which in turn requires information on the economic value of each trait. But as the number of traits of interest increases, the difficulty of selecting the right tree also increases and the gain per trait decreases. Sometimes improvement in one trait may cause deterioration in the associated traits, which important in a tree species. The traits to be considered for simultaneous selection will depend to a large extent upon their genetic significance, economic values and their genotypic correlations. Wood volume may be considered separately from wood density for fuel-wood. The value of a tree for shade may not be as quantifiable as its production for fodder, whereas for timber purpose the quantity and quality of the wood is considered simultaneously.

Selection for all the characters is not possible at the same time. Some characters are clearly expressed in the juvenile phase, whereas others may possibly be assessed in the mature stage only. For example, the character of drought resistance is very important in the juvenile stage;

resistance to fungi and insects may be related to either the juvenile or the mature stage; and the characters like stem form, volume and wood quality are best assessed when the trees are not too young. It is therefore important that selections of traits that express at the same stage of development are included in one programme.

All the characters are a sum of their genetic value and the environmental influence. What we measure, as stated, as stated earlier, is called the phenotypic value. Characters that are controlled to a high degree by the genes ha*ve a genetic value close to the phenotypic value*, and such characters can with good result be subjected to phenotypic selection. But the other characters such as volume, growths etc. are highly influenced by the environment, and their genetic value can be estimated only through progeny or clonal tests. In genetic terms, the phenotypic selection can be used for the characters with high heritability, whereas genotypic selection by me means of progeny or clonal testing is necessary for low-heritability characters.

In commercial forestry, superior phenotypes are selected by cruising all plantations when they reach an acceptable age, and indentifying the superior individuals by comparison with their neighbors or with a regional baseline. However, it would be for more difficult for any agency to cruise al the plantations because of patchy, spatial and temporal distribution of the species. Also, phenotypic selection would be imprecise owing to the variation in management and wide natural variation of the species.

The selection process involves two considerations viz;

1. Preliminary reporting of the outstanding tree, called **candidate tree.**
2. Final phenotypical appraisal and approval as **plus tree**.

Evaluation of these trees is carried out depending on the location of candidate tree, whether in plantation or in natural stand. There are basically two methods applied for selection of a plus tree- first **Comparison tree selection** and second **Baseline selection.**

1. Comparison tree selection Method: the comparison tree selection or check tree selection is commonly used in even aged stands for a species.

The first step is the selection of the candidate tree.

Once the candidate trees are selected, they are screened for traits of interest in relation to a few surrounding trees, called **comparison tree or check tree**.

If candidate tree exceeds the comparison tree, it is selected as **plus tree**.

The objective behind comparison tree is to adjust or correct the phenotypic value of the candidate tree for environmental effects common to that particular stand.

It is presumed that environmental difference between stands or areas that vary in soil, climate or stand history would make it difficult to evaluate the breeding value on the basis of phenotype.

The environmental check through the use of comparison trees is believed to result in an improvement in the accuracy of recognizing with good genotype and not merely good phenotype.

1. **Baseline selection:** the selection of plus tree in uneven aged stand growing mixed species, the method adopted is the baseline selection.

In this method the individuals are located and their value for traits of interest is compared with the average of the region in which the selections are made. The average is a baseline, giving the system its more common name baseline selection method.

If the candidate tree exceeds the baseline by a considerable amount, it is selected and incorporated in the breeding population.

The baseline may take form of a regression equation, relating height or diameter to age, but it could even be a multiple regression equation, that takes in to account physical factors of the site. The candidate tree in this case is not compared with the surrounding trees. The candidate tree in this case is not compared with the surrounding trees.

UNIT- III

Establishment of Seed orchards

Seed orchards: a seed orchard is a plantation of selected clones or progenies that is isolated or managed to avoid or reduce pollination from outside sources and managed to produce frequent, abundant and easily crop of seed.

The concepts of seed orchard stared with the use of quality seeds, as suggested by **Burgdorf of Germany in** year 1787, using special plantations raised through vegetative propagation in forest tree breeding.

Establishment of seed orchards converted from seedling of known seed origin was suggested by **Sylven** in 1918.

Scrymgeour Wedderaburn established first forestry seed orchard in Scotland.

This method of tree improvement was taken up by most of the western countries and later on by all over the world for production of quality seeds.

Through the programme of quality seed production is a long term project, the expected genetic gain from such orchards are 30-40%. The advantage of this breeding system can be obtained if the future plantations are raised from the seeds produced by such orchards. Seed orchards are of two types: first is **Seedling seed orchard** and second one is **Clonal seed orchard.**

Seedling seed orchard:

Seedling seed orchards are raised from the seeds collected from superior phenotypes of seed production areas or seed stands. The seedlings planted from these materials are roughed to remove inferior trees, leaving the best trees of the best families for seed production.

In general the quality seed production in forest trees is limited to clonal orchards, the suggestion given by Sylven in 1918 regarding conversion of seedling of known seed origin in to seedling seed orchard has laid down the foundation of seedling seed orchard.

When compared with the clonal seed orchard, these orchards required a bigger and larger area, more number of trees for block planting as families and it takes longer duration for seed production.

Clonal seed orchard:

A seed orchard is composed of vegetatively propagated trees established primarily from the clonal material of superior phenotypes for the production of seed of proven genetic quality.

The stated goal s of seed orchards are to produce genetically improved seed of forest trees, to promote frequent seed crops and to facilitate harvesting.

In India clonal seed orchards have already been develop for a few important timber species like Teak, Sissoo, *Bombax ceiba* .

Maintenance of clonal seed orchards: some of the point that may be considered for establishment and maintenance of orchards as fallows-

1. The seed orchards must be in good physical condition and the number of clone must be at least 30.
2. The ramets of each clone must be spatially distributed so that the probability of self pollination is low.
3. The proportion of outside pollen contamination must be below 15-20%
4. The geographic range of the orchards must be limited, to facilitate synchronization of flowering and determination of the area of utilization
5. Each ramet of the orchards should be identifiable. Rootstock should not be allowed to take over and suppress the grafted scion material.

6. The site selected should be such where abundant seed production is possible
7. The ramets should be maintained at a convenient height, which will help seed collection as well as control the pollination studies.
8. The orchards must be managed for healthy ramets and for abundant flowering and fruiting
9. Progeny trial must be laid out establishing second generation seed orchard for higher genetic gains.
10. Study must be conducted on stock-scion relationship and assessment of graft incompatibilities
11. All details of this seed orchard are properly recorded in a performance register.

Progeny Test

Elite Tree: a genetically proven tree of established good combining ability is termed an elite tree. The superior phenotypes are selected after through survey of the population, depending on the characters showing relatively high heritability such as specific gravity of the wood, resin yield, adaptability environmental conditions, straightness of bole and growth character.

Heritability estimate vary with species, populations within species and the age and characters assessed. Specific gravity and resin content are highly heritable.

The genetic parameters can be studied by progeny trials, parent- offspring regression and without raising progeny trials.

Progeny trials are carried out to assess the genetic potential of the selected material either by half sib progeny or full sib progeny trials. In half sib progeny trials only the seed parent is known and full sib trials both seed and pollen parent are known.

To carried out half sib progeny trial, open pollinated seed are collected to lay out the trials for the assessment of general combining ability along with other parameters. However, in full sib progeny trials the control cross pollinated seeds are collected to known the specific combining ability along with the other genetic parameters. Both the
Experiments are carried out in replicated design at minimum two different locations to nullify the environmental effects.

Different growth parameters are observed and recorded in initial stage at shorter interval and later on at longer intervals to assess the difference among families. The data collected are tested through analysis of variance to know the variation due different sources.

Importance of the Progeny Test

1. General and specific combining abilities can be calculated.
2. Genetic parameters like heritability and genetic gain can be calculated.
3. After knowing the genetic worth of phenotypic selections, they are termed as elite tree.
4. Progeny tested seed orchards can be established, expecting a genetic gain of 35-40 %.
5. These progeny trials can be used for producing quality seed and converted in to seedling seed orchard.

Heritability and Genetic Gain

In any tree- improvement program, some sort of section is applied with the expectation that a genetic gain is achieved, since genetic variation is the base is for the improvement program. Some spices show large variation and some are more uniform. The greater the variation, the more genetic gain is likely to be obtained. There are certain characters such as stem straightness, wood density, etc., which are likely to be carried on from one generation to the next. The other characteristics, such as branchiness and other and other growth parameters are to a large extent influenced by the environment. The breeder is supposed to identify the element of genetic variation (heritable characters) that passes on from parents to progeny. In other words, heritability values express the proportion of variation in the population that is attributable to genetic differences among individuals. It is therefore a ration indicating the degree to which the parents pass their characters to their offsprings. It is a measure of the accuracy with which selection for a genotype can be made from the phenotype of the individual or a group of individuals. Heritability is of key importance in estimating the gain that can be obtained from the selection programmes.

Heritability is of two kinds: narrow-sense (h^2) and broad –sense (H^2). When the material is propagated by sexual means, the non-additive effects of individual genotype cannot be passed on to their progenies. Hence the term heritability must be employed in narrow sense.

$$h^{2=}VA/VP=VA/(VA+VD+VI+VE+VGxE)$$

where h^2,narrow-sense heritability (the portion of the phenotypic variation that is contributed by the additive genetic effect); VA , variance in breeding values between individuals within the population; VD, variance in dominance deviation between individuals within the population; VI, epistemic genetic variance; VP, phenotypic variance between individuals within the population(the apparent observable variation);VE, environmental variance component caused by environmental variation; and VGxE = variance of genetic x environmental interaction.

On the contrary, when vegetative propagation is used, the effect of dominance and epitasis are passed on to the next generation, because the genotypes of the individuals are transferred unchanged. Hence the term heritability may be employed in its broad sense:

$$\mathbf{H^{2=}VG/VP=VG/(VG+VE+VGxE)}$$

Where H^2, broad-sense heritability (portion of phenotypic variance that is contributed by the genetic factors); genetic variance component caused by genetic variation,, it includes additive and non-additive(epistemic and dominance) genetic variances; VE, environmental variance component caused by environmental variation; VGxE, genetic X environmental interaction variance; and VP, phenotypic variance between individuals within the population , the apparent observable variation.

Narrow-sense heritability is more useful in predicting improvement that can be achieved in the offspring of selected parents. The h^2 is always less than H^2 , and generally narrow sense heritability in forest trees is less than 0.5 . This heritability concept is used to estimate the genetic response after one generation of selection by the formula G= h^2; where G, genetic response after one generation of selection; h^2 heritability for the character under study; and s, selection differential.

Advance-generation selection/ Advanced Generation Breeding

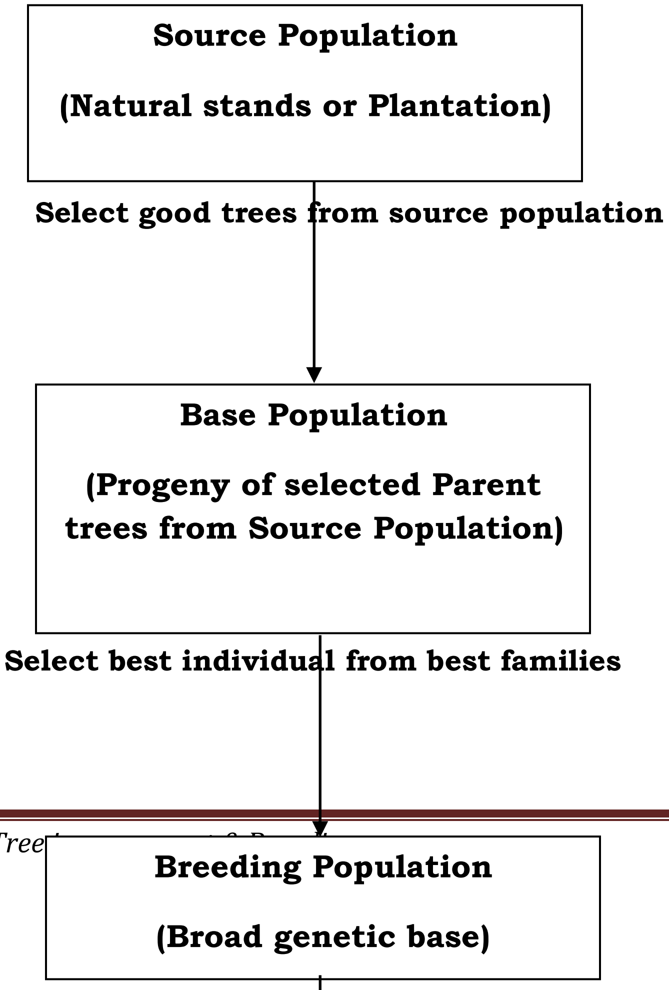
Advanced generation breeding is usually designed with a combination of selections from first generation progeny test plantations in conjunction with new selections from operational plantations or other sources. A major advantage of selection in plantations is that the environment is usually more uniform than in natural stands. Tree age, spacing, and soils are often relatively uniform, with the result that the phenotype more closely approaches the genotype. In this case, selection is more efficient and gain can be increased.

In most advanced generation breeding plans the best individuals are selected from the best families. It is important, however, to separate the production population from the breeding population to minimize the effects of inbreeding (Lowe and van Buijtenen 1986).

- ✓ It is the selection done from the genetic tests of crosses among parents from the previous generations.
- ✓ Advance selection is more advantageous than the first-generation selection, and its main objective is to get maximum possible gain per unit time.
- ✓ In Advance generation selections the important considerations are the method of selection, intensity of selection, lay-out of the mating design and proper management of genetic base (maintain sufficient genetic variability to ensure continued long-term gains).
- ✓ It involves recurrent selection, which means the crossing of the best progeny from the selected parents over successive generations.

- In the first-generation selection, the base populations usually consists of trees growing in natural stands or plantations, but in first-generation selection the base population is most often a genetic test, consisting of the progeny of selected parent trees from the source population or previous generation.
- The base population contains large number of genotypes, which maximize genetic diversity in the breeding populations.
- The breeding population contains large number of genotypes, which maximize genetic diversity in the breeding populations.
- The breeding population consists of the selected material from the base population. However, care is taken to keep the genetic base broad to carry out the breeding population, which is strictly for propagules purpose in the forestation program, is the best selected material of breeding population, which increased the genetic gain to the maximum. Production population, of course, is a dead-end from a breeding stand- point because of its narrow genetic base.
- In the first generation, mostly individual or mass selection is practiced, whereas in advance-generation tree- improvement programmes the family and within family selection system is followed. However, the individual selections per family are restricted to accommodate more number of families in the program, even selection indices have also been used in several tree species for advance-generation tree-improvement program.

Advance generation Selection



Select best individuals for seed Production for Afforestation

Hybridization

Synder has defined hybrid as an offspring of genetically different parents. Hybrids are made with a specific purpose to improve growth, form and wood quality and to induce disease resistance.

Before starting the work, variation studies are required to select the parents with desired characters.

It is not compulsory that the hybrid will always have a best character, worse character can also come. Usually hybrids show intermediate characteristics between its parents and sometimes it will carry the desired the characteristics for one parent.

Heterosis or hybrid vigour is the superiority of hybrids over the parents whether in growth, form, disease resistance or any other character. Hybrid can be natural as well as induced or control crosses.

Natural hybrids are of immense importance to forestry breeder, as they create greater variability in a species. Natural hybrids have been reported in forestry species, but it is difficult to identify them unless a person has deep knowledge about the species and its variations. Natural hybrids are common in Poplar and Eucalyptus.

In control cross pollination selected individuals for desired traits are crossed to produce seeds of known parentage that give combined characters of both the parents.

Introduction

"Forest genetics" is the general term often used for the study of inheritance in forest trees, whereas **"forest tree improvement"** usually refers to the applied use of forest genetics to actually improve the quality of the trees. "Tree breeding" is often used as a synonym for tree improvement, but it also may be found referring to specific activities such as controlled pollination. Zobel and Talbert (1984) define forest tree breeding as "activities geared to solve some specific problem or to produce a specifically desired product." Tree improvement will be the term used most frequently in this chapter.

It is important to understand that tree improvement is an integral part of silviculture. Tree improvement provides the raw material for artificial regeneration, which is one of the most important weapons in the arsenal of the silviculturist.
Tree improvement provides a direct avenue to introduce genetically improved seedlings (or cuttings) into the reforestation system with no additional "handling fees." It costs no more to plant a genetically improved seedling than a "woods-run" seedling. (Note that although the costs of producing genetically improved planting stock are not insignificant, they can be viewed as an investment in future increased productivity. Dividends accrue in terms of increased growth, better form and wood quality, and improved insect and disease resistance).

Tree Improvement versus Crop Improvement

The genetic improvement of forest trees has many similarities to the breeding of field crops. Most of the concepts are the same, namely the selection of above-average individuals from large populations, and subsequently breeding these individuals using a specified mating design. Following the breeding phase, the progeny must be tested on a variety of sites and under differing climatic conditions. Progeny tests are specially designed genetic tests that expose hereditary differences among trees, by bringing different genotypes together under a common set of environmental conditions.

When the progeny have developed sufficiently for a reliable assessment of their value, improved individuals or groups can be released for operational use and/or the breeding cycle can be repeated. There are two major differences between working with field crops and forest trees. The first is time. Field crops such as corn and wheat reach reproductive maturity in a few months, while most trees require many years. Crop rotations with corn and wheat are also only a matter of a few months whereas trees may not produce a marketable crop for 25 to 100 years! Even in the tropics, it is rare to harvest a timber crop in less than 8 or 10 years. In practical terms, this means that a corn or wheat breeder can complete a breeding cycle in 2 or 3 years compared to the tree breeder’s 8 to 10 years, at the very least.

The second major difference is that most field crop breeding is done with domesticated varieties that have been manipulated by humans for centuries and are often genetically homogeneous. Forest tree breeding, in contrast, usually starts with wild stands of trees that have been little-changed by humans. An exception here is “high-grading,” the common logging practice of cutting the best quality trees and leaving the worst to regenerate the next generation.

Unfortunately, tree improvement foresters are often forced to work with the results of one or more cycles of high-grading, namely trees of poor form and marginal value for breeding material. On the other hand, working with wild, unselected stands of trees does provide an opportunity to produce large gains in quality in the first few generations of breeding. Field-crop breeding, therefore, usually involves working with well-known varieties that are often pure lines (genetically pure). With corn, for example, pure lines are crossed to produce heterozygous (genetically different) progeny that exhibit hybrid vigor (improved performance due to the interaction of different genotypes). Site considerations are also important here, as the corn will be planted on uniform, wellprepared sites while the trees may be planted on rough, cutover sites with little or no site preparation. Adaptation is also a consideration as the corn is bred for a very narrow spectrum of soils, sites, and climatic zones. The trees, on the other hand, may be planted over a much wider range of soils, sites, and climatic zones.

Concepts of Genetic Improvement

Phenotype and Genotype

We see a phenotype, a living organism with its own unique genetic constitution, as modified by its environment. In contrast, the genotype of the organism is encoded in its DNA. Each tree, therefore, has its own individual set of genetic blueprints. These are the instructions that will determine the genetic potential of its progeny.

The formula that “phenotype is the product of the genotype as affected by its environment” is often written as P = G + E. The phenotype is the organism that we see, measure, and with which we work. Life would be much simpler if the genotype was as obvious! Geneticists spend a great deal of their time and energy working to ascertain the actual genotype of their target organism. A major reason for progeny testing is to gain a better understanding of the genotypes of the selections that we are breeding.

The Genetic Code

The physical basis of genetic information is the DNA molecule, a long double helix of base pairs. This molecule is sufficiently stable to provide for the continuity of the species, yet flexible enough to allow for periodic changes. DNA therefore serves as both the blueprint for cell structure and metabolism and also the template for replication of many exact duplicates. These unique properties enable evolution to proceed in a remarkably stable universe. The evolutionary forces of mutation, migration, hybridization, and natural selection are responsible for the great variety of life that exists today. New genotypes that result from mutations may move about (migration) and interbreed with other genotypes (hybridization). The new gene combinations that result are then sorted out by the process of natural selection. If these new genotypes are able to survive, reproduce, and leave more progeny than their competitors, they are “well-adapted.” Therefore the tree species, races, and stands with which we are working are well-adapted to a specific site by virtue of their survival and reproduction in that environment.

Chromosome numbers: Chromosome numbers can change as a result of mutations. Polyploidy has been an important evolutionary factor in the plant kingdom. In most of the commercially important conifers, chromosome numbers range from n = 11 to 23 (Saylor 1972). A notable exception is redwood—*Sequoia sempervirens* (Lamb. ex D. Don) Endl.—which is hexaploid (6n = 66). In contrast, chromosome numbers in the commercially important broadleaved trees vary widely, from n = 7 to 19, with a number of polyploids, including the genus alder (*Alnus* P. Mill.), birch (*Betula* L.), several *Prunus* species, and magnolias.

Selection: Almost every process of genetic improvement starts with selection. This is true regardless if we are working with dairy cattle, winter wheat, or forest trees. The concept of selection involves the selection of a very small proportion of a population for one or more desirable characteristics. The difference between the proportion selected and the population mean (average) is called the selection differential. Genetic gain or progress is measured by the

product of the selection differential and the heritability (degree of genetic control) of the trait in question (for example height, straightness, and volume). Therefore by selecting individuals that are well above average in height, and assuming that the heritability (h2) of height growth is sufficiently high to show progress, some gain in height should be expressed in the next generation. On the other hand, if the population in question is extremely uniform in height, and/or the heritability of height growth is low, selection may not be an effective approach. In some species, for example red pine—
Pinus resinosa Soland.—the population is so uniform that selection for many traits is not cost-effective (Fowler and
Morris 1977).

Hybridization: When populations are uniform and selection is not likely to be effective, one possible technique of genetic improvement is hybridization. Most of the successful hybrids in forestry have been interspecific (between species) hybrids. Examples include hybrid larch (*Larix leptolepis* x *decidua*), hybrid poplars (*Populus* spp. Widely hybridized with many cultivars), the *Pinus rigida* x *taeda* cross in Korea (Hyun (1976), and the eucalyptus hybrids (Campinos 1980). Heterosis (hybrid vigor) is a controversial topic among tree breeders. Many interspecific hybrids grow better than their parental species when planted in transitional environments. The actual quantitative documentation of heterosis is seldom published however. A great deal of effort has been expended to produce a hybrid chestnut resistant to the chestnut blight—*Cryphonectria parasitica* (Murr.) Barr. Unfortunately, the American chestnut—*Castanea dentata* (Marsh.) Borkh.— which was devastated by the disease in the early 1900's, has little resistance to the disease. It is possible to cross American chestnut with Chinese chestnut—*C. mollissima* Blume—which is resistant to the blight. The hybrids produced are resistant, but unfortunately their form is so poor that they have little value as timber trees. There are two possible approaches to this problem. One is genetic engineering; the other is back-crossing to pure American chestnut. The American Chestnut Foundation has produced many successful back-crosses with the potential of restoring this grand tree to its former dominance in the eastern hardwood forest.

Testing for Breeding Value

After the elite, select, or superior individuals have been selected, some system of testing their genetic value must be used. We have identified these trees as good phenotypes but we do not know their genotypes and therefore we are uncertain as to their value as breeding stock. Sometimes the outstanding trees in a stand may be taller than their neighbors due to an environmental advantage such as better soil or more moisture. It is important to use only trees with better than average genetic characteristics, as the environmental differences will not be passed on to future generations. In natural stands, it is critical to determine the age of individual trees. Trees growing together may have a similar size, yet be quite different in age. Obviously we would prefer that our select trees not be outstanding merely based on the fact that they are older than their neighbors.The usual way to test vegetatively propagated trees is to plant them in blocks and compare performance with a standard population. This may be a clone of known performance, or in some cases seedlings from a standard seedlot may be used. Tests that are designed to evaluate the relative performance of a specific clone are called clonal tests. Trees propagated from seed are usually progeny tested with one or more test designs modified from crop breeding.

Early work with trees involved open-pollinated tests in which cones or seeds were collected from select trees and the half-sib progeny (female parent known, males unknown) were evaluated in plantations. As technology evolved, control-pollinated tests were developed that provided much better estimates of breeding values.

Phenotypic selection

Phenotypic selection also known as ‘plus’-tree selection, can be defined as outstanding individual that occurs in natural stands or in even- aged stands, combining in itself as many desirable traits as possible. A number of trees are selected in stands according to a total impression of the phenotypes, and their expression combines the characters of interest. It is important to choose the right base population for phenotypic selection. For indigenous species, natural population will form a good material, whereas for exotics the situation is different. They ought to be growing at uniform site or spacing for the same time, whereas natural stands are mostly degraded. It is often difficult in natural stands to find good phenotypes and sometimes it is difficult even to get sufficient number of trees in a population, natural stands are also often uneven aged and are mixture of many species. This makes it difficult to compare one tree with another. However, in such cases minimum selection standards (MSS) are used to select a candidate tree as plus tree. A tree with highest MSS value for highest priority should be selected. For exotic tree species, trees are often selected in even aged plantations. This makes the selection procedure a lot easier. In comparison to natural stands, the plantations are subjected to cultural practices more typically of those that progeny of plus trees will experience at the testing stage. Selection, however, should be confined to middle-aged stands, close to future expected rotation age, but for exotic or unknown provenance the selection should not be done earlier to rotation age. Importantly, trees should be selected from the better-quality sites or from sites similar in type to those on which their progeny will be tested. Nonetheless, plus- tree selection is a team approach. It should not be done by an individual (to avoid the bias in allotting score to the trees) especially for quality parameters.

Knowing the criteria for which the selection is done, the next step is to consider how many trees should be selected. This depends on the importance of the species, the intensity of breeding programme, and the capacity of the organization carrying out the improvement programme. The intensity with which a breeder practices selection is the most important factor in determining the amount of genetic improvement. It is important to select trees from many stands, because there is genetic variability in stands as well. Selection differential, which is the superiority of selected parents over the population from which they were chosen, is the best measure. The genetic gain, genetic advance or genetic improvement is the change in the mean genotypic level of the population.

Genetic gain, genetic advance or genetic improvement is the change in the mean genotypic level of the population. Genetic gain is equals to the product of heritability and selection differential (h^2s) the heritability is largely an intrinsic property of a population, and the genetic gain can more easily be increased by increasing the selection differential(s=I p),where ‘s’ is the selection differential, *i.e.* the phenotypic differences between the selected individuals and the population mean .

The selection differential is dependent upon two factors, i.e. selection intensity and phenotypic standard deviation. The selection differential can be manipulated to some extent by varying the intensity of selection, i.e. selection a smaller fraction of the original population. The gains obtained from plus-tree selection are controlled by the quality of the trees selected and the means by which they are used to disseminate their genes such as seedling seed orchard or clonal seed orchard. As ’i’ is the selection intensity or standardized selection differential. P is phenotypic standard deviation, and thus the genetic gain is expressed as $G=ih2^e$ P. the genetic gain can be increased to a certain extent by manipulation the intensity of selection. Selection intensity is the intensity with which selection is done. It measures the number of standard deviations, the mean of the individuals selected that exceeds the mean of the base population. In other words, it is a standardized statistic, that according to the proportion of the population selected, and which may be looked up in published tables and graphs.

If the heritability of desired traits is low, the intensity of selection should also be low, but if the heritability is high, the selection intensity should be high. When the heritability is low, the environmental conditions exert a strong influence on the phenotypic expression of the traits being selected, thereby increasing the difficulty of selecting genetically superior plus trees. Therefore, it is important to select large number of trees in such cases; but for traits with high heritability, plus trees are the reflection of genotypic ally superior trees and in such cases fewer numbers of trees should be selected.

In practice, it is often difficult to select more than 30 good trees per population because of small population size and poor stand quality. At least 100 m distance between the selection (wind-pollinated) in natural stands is essential to avoid the possibility of relatedness, whereas in the species pollinated by insects or animals, a little greater distance should be kept between the selected individuals. No exact number can be given, but 3-4 selections per hectare are enough. Intensities of 1 tree per 700 ha and 1 tree per 1.2 ha have been used for *pinus radiata* in New Zealand and Australia respectively. One tree per 8,000 for *Cupressus lusitanica* in Colimbia and 1 per 750 (1 per 0.65ha) for *pinus caribaea* in Cachipo (Venezuela) have also been selected. In a plantation, uniformity allows more accurate selection for good genotypes than in natural stands. It is essential to maintain high selection intensity; even one tree in 100,000 may be selected.

The trees selected in natural stands are considered ‘candidate’ trees. When they prove better than the surrounding population, they are known as ‘plus’ trees. If the progeny of theses plus trees show good performance, the plus tree can be upgraded to ‘elite’ tree status. The basic genetic effect of selection is the change in the gene frequencies. Selection results in increased frequency of desirable genotypes. Since the changes in gene frequencies are not observable in metric characters, we therefore have to describe the effects of selection in terms of observable population values such as means, variances and covariance’s, which reflect the basic effects of selection.

Methods of plus-tree selection

After having decided the trait to be improved upon, the next problem is how the selection should be applied to these traits in order to achieve the maximum improvement of overall economic value.

Selection of plus trees should not be haphazard but should be done through a systematic procedure. As stated earlier, the characters of economic importance are identified priority-wise based on the objective of selection. Search should be made in maximum possible stands or plantations throughout the species distribution, and the candidate tree (the tree chosen for selection) should be selected form the good stands. Mostly 3-4 economically important traits are considered simultaneously for improvement in any breeding programme, exception single trait selection (tandem selection) specific purposes. Tandem selections is the selection practiced for one trait at a time until satisfactory improvement is achieved, and efforts are then directed towards the improvement of a second, then for a third, and so on, until finally each has been improved to the desired level . The choice of the priority trait depends upon the 0bjective of selection. It is useful only under specific conditions, i.e. adaptation to adverse conditions (problematic soils; resistance to insects; pests and diseases etc.). It is a simple method and assures gain for the characteristics under consideration, but its inflexibility and more generation interval are the main disadvantages.

PROGENY TESTING

The evaluation of the worth of the plant on the basis of the performance of their progenies is known as progeny testing. Is is the major component of variation study. The relative contribution of the of the genotype and environment towards phenotype of the selected plant can be determined through progeny test. It was developed by Louis de Vilmorin ;there it is also known as Louis de Vilmorin Isolation principle or in short, Vilmorin principle. The most reliable way to determine the effectiveness of plus-tree selection is to grow progenies from selected trees and empirically determine the amount of gain achieved. The following tests have to be estimated to understand the genetic worthiness of the parents, viz.(i)estimation of genetic parameters, (ii) evaluation of the parents, (iii) source for another cycle of selection, and (iv) development of seedling seed orchard.

Types of progeny

Before carrying out progeny test, it is essential to know the parent-progeny relationship. Two principal types, half-sib (semi-fraternal) and full-sib(fraternal), have been distinguished. Half-sib progenies are with one common parent, which is usually the female parent. They are free pollinating and the exact degree of their inbreeding is unknown; whereas full-sib progenies have both parents in common. This can be achieved through controlled cross-pollination.

Half-sib progeny tests are conducted in the beginning of a tree-breeding programme when quick results are required. Genetic gains achieved in half-sib progeny test are less in comparison to those obtained un full sib progeny test. The estimate of general combining ability (gca) of only one parent is obtained, whereas, in full-sib, information on gca of both the parents, in addition to specific combining ability (sca), is also obtained. In other words, full-sib family selection gives about twice the genetic gain to that obtained from half-sib family selection, because in full-sib family selection one unit of gain is obtained from each of the known parents. However, most progeny tests made so far in our country have been with half-sib, since the establishment of full-sib tests involves considerable time, work and expenditure. Many states of the country have taken up genetic testing programme and mostly open-pollinated seeds have been used. For example, progeny trials have been established for Tectona grandis, Gmelina arborea and Eucalyptus tereticornis in Orissa; pinus roxburghii, populous ciliate and Grewia optiva in Himachal Pradesh; Acacia nilotica, Dalbrgia sissoo, Eucalyptus tereticornis and melis azedarach in Panjab; Eucalyptus globulus , E.grandis and casuarinas equisetifolia in Tamil Nadu; Santalum album , T. grandis, Falbergia sissoo, Azadirachta indica, Eucalyptus camaldulensis and Bombox ceiba in Uttar Pradesh; T. grandis and Dalbergia latifolia in Maharashtra ; T. grandis, Gmelina arborea, Bombox ceiba and Terminalia myrocarpa in Arunachal Pradesh; prosopis cineraria and Dalbergia sissoo in Haryana and many more in other states.

Seed Orchards

LARGE scale afforestation programmes requires large quantity of improved planting stock Insufficient seed supply of suitable species is often seen as a major bottleneck of planting programmes Seed costs take up only a minor proportion of overall costs of plantation establishment and silvicultural management On the contrary, genetically improved quality seed has a major impact on the benefits obtainable from plantation forestry, Hence production of good-quality seeds in sufficient quantity will guarantee and ensure a stable supply of well adapted and genetically desirable planting slocks The standard method of producing genetically superior seeds in operational quantities is to use "Seed Orchard' approach (Anderson, 1960)

There are two ways of production of improved planting stock, in which seed orchard is one way d another by macro and micro propagation. Among these two, the seed orchard is the major and most widely adopted method to realize the genetic gain in shorter time with concentrated effect of tree improvement. Hence, in this chapter, the history of seed orchard, management, flowering, fruiting and seed production are described.

SEED ORCHARDS

Zobel et al (1958) conceived a definition that has since been widely used. A seed orchard is a plantation of genetically superior trees, isolated to reduce pollination from genetically inferior outside source, and intensively managed to produce frequent, abundant, easily harvested seed crops. It is established by setting out clones (grafts or cuttings) or seedlings progeny of trees selected for desired characteristics Zobel stressed the importance of origin of the seed.

Feilberg and Seogaard (1975) used the following definition: 'A seed orchard is a plantation of selected clones or progenies, which is isolated or managed to avoid or reduce pollination from outside sources, and managed to produce frequent, abundant and easily harvested crops of seed'. Seed orchards, are not always solely for genetic improvement of specific characteristics, but can also be used to produce quantities of seed that are adapted to a specific planting location (Nanson, 1972). The definitions of seed orchard definitions given here apply specifically to situations in which seeds are needed immediately for large-scale operational planting programmes.

History of Seed Orchards

Seed collection is one of man's oldest occupations, and probably began when seeds were first harvested for food. Subsequently a part of the harvest was retained to provide a seed of a crop for the following year, and this step provided the transition from 'hunters and food gatherers' to agriculture. The establishment of man-made plantations from specially collected or harvested and processed seed was a silvicultural system seldom practiced before the start of the eighteenth century. With the increasing interest and acceptance of plantations as a better alternative to natural regeneration in most parts of the world, a growing demand for tree sced has simultaneously arisen.

The idea of plantations specially established for the productions of forest seed appeared in the literature as early as 1987, when Von Burgsdorf in Fermany suggested the use of vegetatively propagated material for the purapose (Hassenlkamp, 1952).

Clonal seed orchards were formed in 1880 by the Dutch in Java, in attempts to increase the quinine content of Cinchona ledgeriana (Sehreiner, 1962). Since 1919, in Malaya, clonal seed orchards had been used for breeding rubber (heavea brasiliensis (Keiding 1972). From the beginnie century, the idea of producing genetically improved seed through seed orchards in European forestry. Gunar Anderson in Sweden suggested the use of vegetative forest-tree breeding (Anderson, 1963). Johansen (1909) advocated the idea of establishing small 'Elite stands', in which progeny from selected individual trees was to be kept stands were to be rogued on the basis of progeny tests and the seed from them establishing much larger plantations from which greater amounts of seed could be purposes. Sylren (1918) proposed that seed should be produced in stands especially purpose with seedlings of known good origin, and Febricius (1922) included seed orchards in his proposal for a breeding programme with forest trees. Oppermann (1923) suggested s orchards for producing the seed of hybrid larch (Larixeurolepis), and Bates (1928) in the USA published an article on tree Seed farms in which he discussed seedling-seed orchards.

The first forest tree-seed orchard established in Britain was planted in 1931 by Serymgeonr. Wedderburn on his Birkhill Estate in Fife, Scotland (Fanlkner,1965). This orchard was based on sclected European larch and hybrid larch seedlings, and was designed with the intention of producing. Backcross hybrids having most of the hybrid larch vigour and the better wood qualities of the European larch parents. This orchard is still in seed production. The establishment of seed orchards for the mass production of improved seed began shortly after he end of World War II. The details of seed orchards in various countries is given in Table 8.1 The objective and methodology of seed orchard establishment may be modified when the seeds are not needed for immediate use but where there is a perceived future need for them. Kinds of Seed Orchards There are numerous kinds of seed orchards, but they can be classified into three broad classes. Based on the kind of planting materials used for the establishment of seed orchards, seed orchards can be grouped into the following:

1. Vegetative orchards or clonal seed orchards (CSO)

2. Seedling-seed orchards (SSO)

3. Extensive seedling seed orchards (ESSO)

Clonal Seed Orchards

Vegetative seed orchards are the most common type used world-wide. In clonal seed orchards the vegetative material (grafts, cutting or plantlets derived from tissue culture) of selected phenotypes (plus trees) is planted in areas with good isolation, under conditions favouring flowering and fertilization, and managed for production of maximum amount of seeds. The identity of each ramet (member of a clone) is carefully maintained by tags and maps. It is a characteristic of the clonal that main emphasis is given to crown development for maximum seed production by the use of wide spacing.

The establishment of a clonal orchard should be preceded, or at least closely followed, by progeny tests. The CSOs established by grafting are most commonly used. The CSO establishment of a clonal orchard should be preceded, or at least closely followed, by progeny by grafting are most commonly used (Zobel and Talbert, 1984). The greatest and disadvantages of grafted clonal orchards are the laborious work involved with scion collection grafting, maintaining healthy ramets in nursery before planting, and the incompatibility between the stock and the scion which may occur even several years after establishment. The two kind's seed orchards are: Clonal seed orchard without progeny testing and progeny-tested clonal of orchard.

Wthout Pogeny testing

This consists in tree selection in the wild or planted stands granting of scions on to rootstocks, and establishment of seed orchards. No progeny testing is carried out. The method depends upon a sufficiently high heritability of the character considered in selection to obtain some genetic gain and a high graft compatibility of scion and rootstock within the species. It may be a very appropriate method if the natural population is in danger of extinction or produces little seed in its natural habitat and for gene conservation, The method then fulfils a function in gene conservation. Progeny tested Orchard of this kind contains a large number of clones obtained through plus-treoselcetion and grafting. Progenies arotostedatter open or controlled pollination and the orchard is rogued on the basis of progeny- test results in which only the best clones are retainod, If the progenies of the clones are tested and then the undesirable trees were removed from the orchard, it is called 'Progeny-tested clonal seed orchard'. The steps involved in the development of clonal seed orchard is diagrammatically reprosented in Fig 8.1, and the progeny tested CSO of teak and casuarina are presented in Flg 8.2 and Pig 8.3 respectively. In vegctativescoed orchard, it largo genetie gain may be expected The methodl is a usefil first stepin continuing the selection programme and provides genetic information from the analysis of the progeny tests. Seedling-seed Orchards In seedling-seed orchards, progenies from open or controlled pollination of selected phenotypes are planted at normal plantation spacing. Isolation and other conditions should be as for clonal orchards. The identity of families is maintained in order to allow for roguing among families and among the individuals withinfamities, baed on their phenotypleperformanee, This thinning or roguing must be done before starting abundant seed production or collection. In a much as seedling seed orchards permit selection and roguing within as well abetween families, the genetic value of the seeds they produce is very closely linked to the diversity of the parents in the seed orchard. From Open Pollination Species that flower early in nature lend themselves to this approach and also those that arc subject to scion-rootstock incompatibility such as eucalyptus. In a series of plantations with the same progenies, all except 1 or 2 should be designed for progeny testing; the remaining 1 or 2 plantations should be laid out to allow for seed production after thinning on the basis of the test results, as indicated in the Fig 8.4. In a seedling-seed orchard, 2 separate progeny trials can be laid out (to save time), one for evaluation of progenies and the other for conversion of seed orchard. Based on the results of the progeny test, roguing of inferior progenies can be performed in the other one, which will serve as the seedling-seed orchard with tested parents, as depicted in Fig S.5. Under certain conditions, progeny trial can be converted to a seedling-seed orchard, thus fulfilling both the testing and seed-production functions at one site, which has both efficiency and advantage in meeting the time and seed requirement. However, t is not good to carry out both testing and seed production on the same site, because testing should be performed on the site where the provenances are to be planted with improved trees and such sites may not be ideal for good and efficient seed production (Zobel and Talbert, 1984) Further, the management criteria will differ for progeny testing and seedling-seed orchards, and therefore it is not desirable to combine evaluation or testing in one trial and then later on to convert it in to sccling-seed orchara From Controlled Pollination After phenotypic selection of plus trees in the forest, subsequent seed and scion collection, and the grafting and establishment of clone banks, controlled pollination is performed on the original parents or their grafts in the clone bank. The progenies obtained from these pollinations are then established as plantations. To carry out both progeny testing and seed production, the same design must be followed as in open-pollinated orchards. This method promises greater genetic gains than that based upon open-pollination, but is costlier and requires specialised personnel and facilities. early selection, at a time when the juvenile or mature correlation may still be low (Toda 1974). The 125 One disadvantage of seedling seed orchards is that their formation and future quality are based on

eedingslnhardsalho generally take longer to stan lowering and to reach full wudmiviy Lars Sthmidi, 1091) In general, it is agreed that only in spechal circumstances $50s are preferable to CSOs (aett, R5), tfor example: (i) where severe problems exist with thlealth of the ramite, sueh as de to incompatibility or root deformation of cttings, (l) where large number of phenaypeslectedees) are involved, eg, more than 100); and (ili) in species withı early flowering, such as many eucalyptus, acacias and topical pines. Which type of orchard is best in the particular siuation is dependent on the scies and breeding pomme. Some of the striking characteristies of the SSOs and CSOs are listed in Table 8.2 tensive Seedling seed Orchards ENtensivescedling seed orchards (ISSOs) are defined by Nikles et al. (1984) as: 'Stands established with special stock from a balanced mixture of seeds from at least G0 good parents (preferably of proven superior combining bilty) and gradually culled'. For the establishment of an ESSO, the tamily identity is maintained all through sced collection and nurncry to allow for the formation of balanoedscedling lots with equal representation from families In the field, however, the identity is given up and subsequent thinning is purclylvicual. The ESSOs are being used more and more where large numbers of families are involved. The loss of family identity distinguishes the ESSO from the normal SSO, and may be a scrious disadvantage. The ESSOs are not well suited as breeding orchards, since it is impossible to recognise, and so to avoid, the over-representation of some families in the new breeding population. They can perform a useful role as production orchards of limited duration

SEED ORCHARDS Advanced-generation Seed Orchards or Seed-orchard Generations Seed orchards are usually identified by gencration, i.e. first-, second- or advance- generation orchards, depending on how many cycles of improvement they represent. First-generation orchards usually derive from plus trees selected in natural stands or in unimproved plantations. In roguing (genetic thinning) , which is usually based on progeny testing , normally 50-15 % of the original number of clones or families are removed after successive evaluations. This roquires the iniualcstablishment of a large number of clones or families at close spacing Occasionally the term 1.5 gencration orchard' is used. Zobel and Tilbert (1984) conceived this term to cover an improved first-gencration orchard established by combining the best genotypes selected in one or more onchards, covering the same region (seed zone), in a new first-generation orchard of greatly improved genetic quality. No generation tun-over is involved. A 1.5 generation- seed orchard' is therefore still a first-generation orchard, but of an improved genetic composition. PLANNING OF SEED ORCHARDS Seed orchards are a major component of most tree-improvement programmes involving Important factors to be considered when planning an orchard programme are the aspects such as: () the biology of the species, viz sexual behaviour, mating system, degree of selfing, pollination, response to stimulation by hormones etc., flowering habit, flowering and environment, case of vegetative propagation, graft incompatibility etc.: (i) the choice of breeding method, viz., clonal propagation, sciection, hybridization, polyploidy etc.; (ii) the use of combined or separate breeding or sced- production populations; and (iv)combining progeny testing and seed production (van Buijtenen, 1970) Location, Establishment and Management of Seed Orchards as possible and at an acceptable price. Location All the matters relating to the location, establishment and management of seed orchards are concerned with maximizing the production of sced of high genetic and physiological quality as soon Of major importance is the selection of a region and sites that promote good flowering and seed development as well as provide isolation from contaminating sources. A wrong decision could mearn failure. Size, lay-out and isolation aim at maximum cross-pollination at minimum risk of inbreeding and contamination by outside pollen. The following conditions for establishment of seed sources, as summarized by Keiding and Barmer (1990, are also relevant to seed orchards. 1. Location on sites exceptionally favourable for early, abundant and regular production of good quality seed good performance production in the natural range. collection and transport of seed. authority; and for this reason government forest reserves may be preferred. 2. A location outside the natural range of a species may be jusuified if the species has shown very 3. Access to the proposed site should be adequate for establishment, protection, management, rest with the managing 4. Legal rights to use the site for the purpose should be clearly stated and To safeguard against future contamination from foreign pollen, the present and planned use other tree species in the area should be investigated before a site is approved for sced- orchad

establishment. This is particularly relevant for wind-pollinated species, tor u recommended minimum distance for isolation is 300 500 m) it is better to 6. To secure an established sced orchard from obliteration (fire, windfall,pestsetc replicate the sced orchard in two or more sites. Since the seed orchard is planted entirely for the production of seed, the conditions flowering and fruiting. Selection of the appropriate site for the seed orchard will et during and after the establishment. Choice of an orchard site has always becn a main (Rohmeder and Schonbach, 1959), and in the last decade has been given greater c the experience that flowering and seed production is heavier in some locations than in osh also new tynes of orchards are being developed (Swcet and Krugman, 1977) or hecause ex orchards are being more intensively managed (Kosli 1975). shoulkdbenefi emphasis because of aadtstingprocipitation The species-specific requirements are: i) climate, which covers temperature, photoperiod, wind exposurc etc.; (ii) soil, including its texture, nutricnts, pH, drainage topography, including flater or hilly or mountainous as well as exposure; and (iv) altitude, the height (m) above mean sea level ele ca reproductive biology is crucial for Knowledge of the species-specific requirement and espocially proper matching of species and site, to ensure that the species will produce fruits at the site in The seed orchard should be established in the geographical arca of the species and cological range for exotics, and it should be established only after the flowering and fruiting have beensuessfuly in the area. The site should be selected in order to promote seed production only, unless à ik combined with a genetic test Macro and Micro Climate The importance of macro-climatic (geographic) and micro-climatic factors is recognised (Schmidting,1978) for higher seed production such as temperature. Temperature affects hth the formation and sex of flower buds. Generally higher than average temperatures are required to säimelare the formation of flower buds. According to Maguire (1956), who surveyed Pinusponlersa in Califomia for 23 years, if temperatures are higher than normal in April and May, heavy flowering can be expected in the following year. The importance of above-average June and July temperanures had been shown for Larixleptolepis (Yandagihara 1960) and Fagus syhatica (Holmsgaard and Olsm 1960). Low winter temperatures affect the sex of the flower buds in some monoecious species r example, the formation of female flower buds in oak is determined by low temperatures (Miaia 1961). Temperature regimes, extremes during the time of bud differentiation, are extremely imporant. Dry summers with high temperatures are known to affect bud formation, so that more reprutcaive buds are formed (Sweet 1975). Length of the photoperiod is also important for the formation of flowers (Werner 1975). In Thailand, occurrence of low temperatures at the time of bud formscion in November greatly influenced the development of male flowers in Pinuskesia and R car Soils and Topography The appropriate soil type for a seed orchard will vary with the specics. In general, the orchard sit should be average in fertility. It is recognized that poor sites are unsuitable for seed orchanks S reasons for poor seed production often observed on highly fertile sites are not as well undrsan They may be the result of freeze damage to the reproductive structures due to the fasct that the tms do not harden off or because the resting bud may not form soon enough for proper reproductive

SEED ORCHARDS development to be initinted before cold weather (Greenwood, 1981). Finally, they may begin growth too early in the season. Good sites often need an extended time for the orchard to become suitable for commercial seed production because of heavy vegetative and poor reproductive growth. Orchard proxuctivity can be partially manipulated by fertilization and sometimes by irrigation, but very fertile, oist sites do not leave the orchard manager the management options that are available on a less fertile site. Changes on topography may have a pronounced influence on the microclimate of the site, e.g. in temperate climates by the effect of cold air flows or pockets, resulting in forest damage and thus poorer seed formation. The difference between a location on a north or south slope may be considerable because of different in-coming radiation. A flat or slighly undulating area is generally preferred, since such an area is generally homogeneous in soil structure and fertility. Low temperatures during winter times may become critucal if accompanied by strong winds as well as droughts during summer on light sandy soils. Severe drought during seed formation is known to reduce seed yields conditions are required to obtain effective pollination in wind-pollinated species, but a constant wind direction during pollen dispersal appears to have an adverse effects; however, it cannot be applied to the mostly insect-pollinated tropical species. Soil type, fertility and drainage etc. have a earing on the vegetative growth and flowering as well as on the amount and quality of seed produced. Heavy soils with poor drainage are considered unfavourable for flowering. Conditions promoting good root development and soils of average or slighty better ferility are recommended, rather than of a high natural fertility, because it is better to manipulate flowering and growth through fertilizer application at times when specifically needed. In general, it is better to select an orchard site with the following characteristics: (i) site as level as possible for ease of operation: (i)site slightly sloping to provide good drainage:i) site with ample light and free from heavy shade from the neighbouring stands; (iv) soil that is warm, promotes flowering, and of sandy loam to loamy sand texture, and (v) a soil of moderate but balanced fertility. Latitude is the most important component of the geographical location which has a significant bearing on both the general and the local climate as well as on physiological and other related features that can modify the responses to vegetative growth and the reproductive processes, e.g. speed of meiosis in pollen-grain formation Pollen-dilution Zones An orchard must be protected from contamination by outside pollen. Although most tree improvement workers set the width of a dilution zone, an absolute minimum is essential. For example, in pine the minimum width of such a dilution zone is considered 122 m (400 ft), which should preferably be 152 m (500 ft). It is recognized that these distances are insufficient for complete isolation (McElwee, 1970). Foreign pollen will still be found in an orchard with a dilution zone of this size, but studies have shown that the bulk of the pollen from outside sources will be dissipated within the dilution zone. The considerations for the maintenance of dilution zones outlined for seed production areas also apply here. Economic losses from pollen contamination can be considerable, and despite large costs, the proper maintenance of dilution zones is almost always worthwhile (Sniezko, 1981) Dilution zones are most critical for advanced-generation orchards because of the greater potential loss of genetic gain, and hence profitability from pollen contamination. Effective pollen-dispersion distances of hardwoods are not yet well documented; therefore, the wise approach is to keep hardwood-seed orchards as distantly separated from the contaminating pollen sources as possible. Dilution zones should always be maintained between orchards from

FOREST TREE DREEDING lifterentphysiographie regions and between advanced-gencration and early-generation orchurds Many ypwiks, even somo in the same genus, do not need to be isolated from each other because they thouer at ditterent times, or they will not eross. This is common in the pines Such an information eoutcsabily is bunully needed for all tho important speccies, especially for those pollinated by inseets An rchard should be blocked as muclh as possible to permit maximum cross pollination among the members of the orchard and to reduce the edgo effect, It is better to orient the long axis of the orcharnd with the direction of the prevailing wind at the time of pollen dispersal if a rectangular conficuration is used Seed-Orchand Sze The appropriate orchard size is determinel by the number and the quantity of sced needed. To be ccrtain that cnough seed will be available, proluction capacity in cxcess of the anticipated nced is usually developod. The actual size of the orchard needed will vary from species to species, location of the nchanl, availability of seed from other sources, and the seed needs and costs. As an cxample, imst organizations do not consider an orchard of southern pines unless it is at least 2 ha (5 acres) in siro. Small land holders usually can obtain improved seed more economically by purchase from the Governiment or from other private organizations. As many seed-orchard costs are not directly related to the orchard size, the costs per unit of seed produced will decrease when the size of the orchard is increased Contrary to the preceding rule, similar orchard for speciality purposes are often established as a part of a larger orchard complex. Under most circumstances, with species where long rotations are used, a minimum planting programme of at lcast 400 ha (1,000 acres) per year must be underway to jusuty a full-fledged seed-orchanl programme. The rules related to some conifers are not often suitable for hardwoods. For example, gencra such as Cycunore (Platanus) or Eucalyptus produce a larye number of viable seeds per parent seed tree, and all the seed needed can be produced in a very small area If enough clones are to be included in oder to minimise the related matings by having a suitable large genctic base, at least 0.4 ha (1 acre) of the orchard is usually needed The nursery practices that are used will strongly influence the number of plantable seedlings that will be obtained from a given urea of the seed orchard. When calculating the seedling yields per unit weight of seed, it is essential to consider that sceds from a fertilized seed orchard are often larger more vigorous, have better germination, and often have more seed per seed-bearing structure than do those from wild stands that develop under a minimum nutrient status and without insect control. Determinations of the proper orchard size is difficult, as the needed area may vary by 2- or 3-fold, depending on the management given to the orchard. In Pinustaeda, for example, seed yields were more than doubled when the seed-destroying insects were controlled (De Bar, 1978). In fact, the economics of seed orchard can be greatly be affected by the level of seed SEED-ORCHARD DESIGNS Designs in seed orchards play a vital role from the managerial point of view. Here the terms 'clone or 'ramet' as applied to clonal seed orchards are used for deseriptive purposes. Similar d be used for secelling seed orchards, in which ease the word 'progeny' should be substituted for clom and family plot' for ramet. Family plots can consist of a single tree or groups composed of trees. The designs that can be practiced in seed orchards are narrated in brief here.

SEED ORCHARDS Pure Rows In some of the earlier orchards, and occasionally even today, the design is based on planting pure rows of individual clones. Disadvantages of this design is the increased risk of inbreeding within the clones, and very uneven spacing that results if undesirable clones are later detected and have to be removed Chess-board A chess-board arrangement for bi-clonal orchards can be obtained simply by alternating the two selected clones in each row and column of the orchard. The main value of chess board design is the production of hybrid seed by using proven or tested specific combiners or the use of male-sterile lines for hybrid-seed production. Completely Random Block The complete randomisation of all the available ramets of clones between the available planting positions on the site is the simplest of the designs to plan on paper, it can however pose practical management difficulties associated with planting or on-site grafting, and relocation of individual ramets at a later stage and particulatly when the orchard is large and contains many clo restrictions in complete random design is that no two ramets of the same clone may be planted in adjacent positions within the rows or columns, or where they will occur in adjacent diagonal positions, or that at least 2 different ramets must have separate ramets of the same clone. Randomised Complete Block In randomised complete block design, the area is first divided into equal blocks, each sufficient in size to contain 1 ramet of each clone or a multiple of that numberi the ramet positions within each block are completely randomized and then manipulated to avoid having similar ramets in adjacent planting positions. Each block is randomised independently taking care that the restrictions imposed hold true along the interfaces of the block edges. Fixed Block Some orchards use a systematic lay-out, in which a fixed single block design is replicated over the entire area. The value of this design depends largely upon the size of the basic block, its content of ramets per clone and their arrangement within the block Rotating Block To avoid replicating the same arrangement of ramets in consecutive blocks, a systematic shifting of the clonal arrangements within each replication of the block can be used. This design (Fig. S.6)

provides for limited changes in the composition of the neighborhoods around each ramer (fere 1973) Reversed Block Another modification of this approach is to use paired blocks with a reversed sequence of clones within them and with a different randomisation of each block pair. The design allows for systemansthinnings (Fig 8.7, after Krick 1971)

Unbalanced Incomplete Block e random block arrangement is used with a fixed number of grafts per block and e for the orchard. In this arrangement, the same set of replicates regardless of the number of clones availab clones is not always planted in each block, and therefore, the blocks cannot be treated as or the experimental comparisons of orchard treatments, which is one of the main advantages of the complete block design. A second approach to this design is to use blocks in which any clone used is represented by one or several remets, but with the blocks varying in size according to the availability of clones with sufficient number of ramets. Balanced Incomplete Block This design, recommended by Langner and Stem (1955), provides the opportunity for randomly mixing the clones and also the possibility of comparing the performance of the various clones most effectively. The mathematical principle behind the method is: that where t number of treatments (clones); k- number of ramets/block; b- number of blocks; and r number of replicates (rametspe clone). The design is considered balanced when any two clones occur together in the same number (a) of blocks (Fig 8.8). In a balanced incomplete-block design,the following relationship holds good.

n (t-1) r(k-1), rt. bk. where t 10; k 3; r-9; b-30; n-2 (after Langner and Stern, 1955) Advantages of this design are: (i). provision is made in it for the permutation of neighbourhoods within blocks, thus favouring panmixis; and (ii) they are better suited for experimental comparison of sced-orchard treatments and for comparative the clonal studies. Disadvantages of this design are: (i) it is suitable only for certain fixed combinations of clone numbers and number of ramets per clone, and therefore they have to be repeated for several times over the orchard area and (i), they are unsuktable for systematic thinning.

Cyclic Balanced Incomplete Block A special case of the balanced incomplete-block design is the one in which there are four ramets per block (where t 31; k -4; r -20 b 155 and n 2), planted in a square and in which the blocks redeveloped from each other in a cyclic way by adding or subtracting a fixed value from the clonal number (Fig 8.9; after, Freeman 1969.

Directional Cyclic Balanced Incomplete Block A special modification of the balahced incomplete-block design was developed, which aimed at perpetuating all the upwind neighbours. An example of such a lay-out for 13 clones (after Freeman 1967) is illustrated in Fig 8.10 in which only central rows are considered as seed parents (when t -13, k 3, r 12, b $2 and n 20).

Balanced Lattice A special case of the balanced incomplete-block design, known as the balanced lattice, arises when t-kA2. In it the following relationships hold (Fig 8.11): b-k (k+1, r-k+1, n-1. It can be used only when the number of clones is a square of a whole number (after Cochran and Cox 1950, when t-25; k-5; r-6; b-30 and n-1).

ermutated Neighbourhood La Bastide (1967) had developed a computer programme that provides a design, if feasible, for a set of number of clones, ramets per clone, and ratio of rows to columns. The production of the design by computer is very expensive on computer time, but already several designs have been obtained for small blocks; e.g. composed of30 clones and having 10 ramets per clone, which can then be replicated over the seed-orchard area. The constraints in this design are: (i) there is a double ring of different clones to isolate each ramet of the same clone (which are planted in staggered rows), and (ii) any combination of two adjacent clones should occur in specific direction only once (Fig 8.12; after La Bastide 1967).

Sstematic Desigus The first systematic design was proposed by Langner (1974) for 10 clones, and is based on a maximumt distance of separation between the ramets of each clone equal to square-root of 10, mailtiphiof by the planting distance. This method simply involves running the clones consecutively by pumbers down a row and repeating the process in each suceeding row but always restarting the process under a given clone in the preceding row (Fig 8.13). The design is unsuitable for systematic thin sitg, but even so it is still occationally used in its original form (van Buijtenen, 1971). Thisdesign is suitable for expansion in all directions and for any number of systematic thinning. The only major disadvantages of the design are that by having fixed neighbourhoods, it does not favour panmixis; and that it produces more full-sibs in the progeny than most other designs, but less than from a general collection of seed from a stand based on the number of trees equal to the number of clones in the orchard Evaluation of Design Various authors have stressed different aims as being of primary importance in the preparation of a seed-orchard design. The two most commonly mentioned are: (i) minimising self-fertilisation risks; and (ii) a provision for the maximum number of cross-fertilisation combinations. There are, however other considerations, as listed in Table 8.3 (MaciejGiertych, 1977). which summarise the advantages and disadvantages of various designs A good seed-orchard design must have flexibility for the improvement of the genetic quality of the orchard by roguing as well as for minimizing the potential for inbreeding. Enough trees must be established in the orchard to permit several roguing and still leave enough trees for seed production. Each clone should be represented by approximately equal frequencies per unit area. Also of importance

is to avoid repetitive neighbourhoods', in which the same clonal pattem is repeated several time When this is not done, clusters of good or poor clones can be located together, thus making it most difficult to do a good job of roguing. Also, when repetitive neighbourhoods are used, some coe tend to pollinate their neighbours, and the proper within-orchard mixture is not achleved The following criteria were used to develop a design for second-generation loblolly pine.scod Wits recommended to start with 338 trec « Ma (145 trees / acre) removing 35 % of the remaining trees at each of four rogung , and ultimately to rogue 60 o 70 % of the cloncs and to maintain a distance of 28 m (90 ft) between ramets of the some clone or related individuals. To nchicve the fore-going situation not less than 30 and not more than 40 clones are recommended for use. Roguing, as recommended results in 10 to 12 clones left with a stocking of 80 to 150 trecs/ha (36 to 60 trecs/acre). In actuality about 63 trees per ha (25 trees/acre) would probably mako up the final orchard. Although the recommendations are for one species, loblolly pine, they do give an indication of the methods used in designing a seed orchard. It is impossible to list and describo all the varied designs that have been suggested for establishing seed orchards, but a few differing types are listed as follows: (i) Gerdes (1959) covered the possible methods to use for Douglas fir, a species that has several difficult problems, especially with graft incompatibility; (ii) Goddard (1964) described some ideas about the genetic distribution in a seedling orchard following selection both within and among families; (ii). Giertych (1965) developed a systematic lay-out for orchards; (iv) Burrows (1966) developed a theoretical l of clonal dispersion to give the greatest possible gains; (v) van Buijtenen (1971) described the theory and practice of orchard designs for the southem pines; (vi) Klein (1974) developed a special design for a jack pine seedling-seed orchard; and (vii) Hatcher and Weir (1981) discussed the advanced orchards in the Industry Tree Improvement Co-operative, North Carolina State Univensity. It w generation design used by the Tree Improvement Cooperative, North Carolina State-Industry No matter what design is chosen, it must assure that related matings are minimized, and it should enhance random pollination. An orchard that is established incorrectly or carelessly becomes a horror to rogue. Instead of upgrading the genetic quality of the trees in the seed orchard, all that the roguingplishes is to remove the related individuals that are too closely spaced. Much genetic gain is lost by poor orchard designs or sloppy planting in which a reasonably good design is not followed. Advantages of Seed-Orchard Design The main advantages are: () it ensures separation of related clones; (ii) it uses information on provenance, compatibility, flowering and general combining ability; and (ii) it provides score to enable the breeder to assess the level of panmixis and inbreeding expected in the orchard. SEED-ORCHARD MANAGEMENT Much of the advantage of a tree-improvement programme is lost if the seed seed to their maximum potential. It is certainly bencficial to use geneticully superior genotypes orchards do not produco that henologically synchronized to assure cross-pollination and to use those that are inherently h are p seed producers to obtain maximum seed production. It is of equal importance, however, to unders the environmental factors and management practices that enhance seed production. An orcl is suffering from a soil-nutrient deficiency, soil compaction, or overcrowding will not produco to its potential, regardless of the inherent superiority of the stock contained therein. Seed management is extremely complex. Proper procedures will vary according to the species, locationol the orchard, and conditions encountered from one year to another within the same orchard.

Soll Management Soil texture (i.e, the proportion of sand, silt and clay) is essentially unchangeable through manipulation, and as a result, the quality of the soil is one of the most important considerations in the establishment of the orchard. Soil texture has an influence on the moisture and nutrient-holding capacity, compatibility, crodability, and other soil characteristics. The soil texture most desired will vary with the species, although most species are similar to loblolly pine, where there is evidence that' a sandy loam overlying a friable subsoil, such as sandy clay, is conducive to flowering (Gallegos, 1978). Regardless of the soil texture, normal operating traffic in the seed orchards may change the soil structure (i.e. how the sand, silt, and clay are aggregated), usually in an undesirable direction Such activities cause formation of compaction layers ('hard pans') (compaction is worse in the clays). These pans are frequently responsible for a general decline in the vigour and seed production of the orchard and, if left uncorrected, they can result in outright death of the trees from root penetration drainage problems and from excess concentration of salts on the pan where the roots are concentrate The most obvious symptoms of decline in the health of orchard trees that are caused by a pan are a rounding and thinning of the crowns, shortening and poor colouration of foliage, a flattening or fluting' of the bole of the rootstock portion of the grafts, and the emergence of the tops of largse on the soil surface. Some of these symptoms are also indicators of graft incompatibility and may misinterpreted as such. Incompatibility is strongly clonal, whereas general decline, because of hard pan problems, usually affects all clones to some extent. However, both can be related, and symptoms of incompatibility will appear much more rapidly under the stress conditions that result from soil compaction. Orchard Surface Much attention must be given to the surface of the seed orchard. Efficiency and speed of operation are increased with well-prepared smooth surfaces. In some instances, the requirement for a good orchard surface will necessitate filling and levelling, and the establishment of a cover prior to orchard establishment. However, it is essential that good soil characteristics are maintained or restored in areas that have been altered. The orchard floor should be protected from wind and water erosion, and the organic matter of the soil should be maintained at adequate levels for proper nutrient supply to the seed orchards. One most common treatment is sub soiling, which can be met through the establishment and maintenance of a good sod cover, that will reduce soil compaction resulting from traffic in the orchard. It will also greatly enhance traffic ability during inclement weather. Sometimes a sod cover is disadvantageous when mice are prevalent Under such circumstances, should be kept away from the immediate vicinity of the tree (about I m). Although native or naturalized grasses will eventually colonize a new seed orchard, it is usually preferable to sow a sod cover to protect the soil from crosion and compaction (Schuulz et al. 1975). Orchard Fertilization Based on soil analyses or in some instances foliar analyses, soil amendments are applied when needed to maintain plant vigour and to promote flowering. Fertilization, particularly application of nitrogen and phosphorus, has promoted flowering for nearly every species for which the trials have been established, especially for various hardwoods (Hattemer et al. 1977). Soil acidity (pH) is of key importance and has a direct effect on many reactions in the soil as well as on the behaviour of the soil organisms and plant roots. The optimum pH will vary with the species; for most conifers the desired * 137

range is S.5 to 6S. When the acidity drops below 5.2 or rises above 65 for the pines action should be taken. For some hardwoods the desired pH is higher, and for a few conifers madh lower values can be tolerated. In seed orchards, the objective is to have the pH at the desired not at just what can be tolerated. Lime is commonly used to raise a low pH and an acid-f Irrigation evelorming The installation of an irrigation system is expensive. On the basis of increased seed alone, irrigation now appears to be a good investment for some species (Grigsby.1966). In one loblo pine orchard , mgation as well as fertilization were responsible for approximate 30 % increase in seed production over the area receiving fertilizer only , and 100 % increase over the area that did receive irrigation or fertilizer (Harcharik. 1981). In droughty years,. irrigation may mean the difference a poor and a good seed crop (Long et al 1976). It has been found from experience that pollen production gation sometimes delays flower and fruit as well as cone maturity, and increases It has been used effectively to prevent freezing of flowers during critical periods. It has also been used in Douglas fir orchards to delay maximum strobilus recepivity until after maximum fight of the pollen in the surrounding stands (Fashler and Devit, 1980). Like fertilization, irmi at young stages in seed orchards to maintain optimal growth and vigour. To is used at any time during the year when the soil is dry enough to warrant it The actual timing of stress and irrigation is still not clear for most species. 1980). Like fertilization, irrigation is accomplish this, irrigation Pest Problem When seed orchards are established, pests in one or another form will become evident. Pests are different for each species and in each geographic area, so there is no point in listing and discussing them in more than a general way. Pests in seed orchards can be divided into those attacking the flowers, fruits, cones, and seeds; those attacking the tree foliage, bark and limbs; and those attacking he roots. They vary from insects to diseases to animals, birds, and even to human beings. Since pess often attack after an orchard has been established for some years, their most important effect is often overlooked. As Bergman (1968) and others have emphasized so strongly, that the economic returns from tree improvement are closely tied to the amount of seed produced per unit area of the seed orchard. In southern pine orchards, for example, DeBarr (1971) and others have shown a dramatie increase in the value of seed orchards when seed losses were reduced through the use of effective systemic insecticides. The value of pest control was explained by Weir (1975), who showed that the sizes of the potential losses from pests destroying seed-orchard seed were greater than the economic value of the timber destroyed by the very destructive southern pine beetle. A major factor determining whether a seed orchard is cconomically feasible or not depends upon the success of control of the orchard pests. Many methods have been developed to control pests in seed orchards, varying from manual removal shooting or trapping, spraying, and using chemicals, By far the greatest damage to seed orchards is done by insects; as their control is not easy. They vary from small insects and diseases that amck flowers, fruits and cones, to those that kill and destroy the whole tree. Insects can often be controlled by systemic, i.e. chemicals that are taken into the plant that repels or kills the insect when it eats the foliage, cambium, or reproductive structures. They can become of major importance in seed orchards. and their control can spell the difference between success and failure. To the seed-orchard manage and for the efficiency of a tree-improvement programme, they are a key problem. When losses from 138

adverse or unusual environments are added to the losses from pests, keeping the orchards healthy and fully productive is indeed a challenge. Other Management Methods to Increase Flowering There are numerous actions that can be taken to speed up or improve seed production, out of which two are detailed here. Partial girdling of the stem will often result in increased flower cone crops. Aldhou not usually recommended for orchards meant to be kept for long periods. It is will be useful to obtain I and gh partial girdling works, cither as a girdle or a band, it is a severe method that is lated trees that will be used only temporarily. Top pruning to keep tree on easier has been widely discussed and tried, but with indifferent height down and to make seed collecti success. It is also used in the hope of keeping the trees low for case of control in pollination. Generally seed crops from top pruned trees, compared to normal trees, vary from little or no reduction to as much as one half on pines and to much more for genera like Abies that bear most cones at the top of the tree. Aldhoughsul being tied, lop pruning is not a generally accepted method of seed-orchard management for most of the species. A problem is that the limbs below the severed portion tend to curve up to make a new top or a multiple top. This can be partially prevented by intensive measures such as tying down the upturning branch. Seed-Orchard Records The importance of maintaining good records on the seed orchard cannot be over-emphasized. The records provide a history of the orchard, upon which present and future recommendations are based. They identify the genetic material contained therein, and they reduce the possibility of errors. Of great importance is the fact that they provide a record of what environments and management practices have influenced the orchard, how these were handled, and what the results were. Basically, two types of records are needed: (i) those related to the orchard as a unit and (ii) those related to individual trees or clones within the orchard. A minimal set of information for the orchard as a unit would include the following: G) fertilization and liming; (ii) formulation type; (ii) rates; (v) date of application; and (v) method of application-broadcast or single tree, ground or acrial etc. Management Requirements The most important management requirements are: (G), accessibility; (ii) labour availability;) closeness to administration; (iv) closeness to nursery: and (v). gentle topography. The seed orchard should be established as strategic for rational management as possible. Since the seed orchard is labour intensive both in terms of operation (establishment, maintenance and seed collection) and administration (record management, organization of labour etc.) a central place is preferable for it, e.g. near to a local forest administration office and nursery. Such areas may also be easier to protect. A flat or slightly hilly area, for example abandoned agricultural land, is preferred because it permits mechanical operation by tractors and other machines. Protection Seed orchards must be protected from: (i) strong winds, typhoons etc.; (ii) fire; (iii)illegal logging or fuel-wood collection; and (iv) destroying animals. The site of seed o far from places where natural It should be placed as little exposed as possible, i.e. sheltered by hills or mountains. Fire is disasters are frequent, in areas where strong winds and typhoons occur 139

mainly by man, and it is prudent that the orchard site is placed where, for example, grass fires are rare. In areas with severe food shortage and consequent cutting and fuelwood collection, the orchards may be in danger unless the area has been negotiated with local authoriues. Both wild and domestic animals can be destnuctive to seed orchards. Location close to national parks or close to villa where for example goats and cattle graze freely, may be avoided. In general, remote places should be avoided, since they may be difficult to protect ages, ESTABLISHMENT The plants (either vegetative propagules or seedlings) are vulnerable to competition from weeds, fire, diseases, browsing, termites etc. during the first year of establishment. The site should be prepared well before planting, for ease of future management. Clearing The cost of producing the seed-orchard planting stock is high, and it is therefore essential to achieve high standard of general site preparation and planting. Basic sites work, including tree and scrub clearance and drainage, should be conducted at least I year ahead of planting. This is particularly important for drainage work, since checks can be made on its effectiveness before planting. Leaf and woody material may attract pests and diseases, increase the risk of fire and impede mechanical management. The ideal one is a completely cleared area, free from trees, shrubs, stumps and big stones That will case the access to the area and mechanical operations. If the seed orchard is established on forest land, all trees and shrubs should be cut and removed or burned on the site. Soil Preparation Proper soil preparation improves the growth of the tree plants and promotes their competition with other plants. The site should be completely weeded before planting, e.g. by ploughing and harrowing. Mechanical cultivation improves the soil structure, and consequently water-holding capacity and drainage. A hard pan impedes draining. It can be caused by tractors or if the soil has podzol profile. Hard pan is broken by deep ploughing or subsoiling. It is generaily agreed that soil cultivated by ploughing and harrowing in the initial phase is essential for a good start. If there is hard pan and where no other area is available, deep ripping is required. The soil cultivation increases the effect of fertilizer application and improving the water balance. Experiments in the USA showed an increase in seed harvest of Pinustaeda by 4.5 times after deep ploughing (46 cm), and 1.5 times after ordinary ploughing (15 cm) compared with the control (Jens Granhof 1991). The soil should have the optimal acidity and nutrient level for the tree species to be planted. Soil tests are carried out before planting, and possibly lime and fertülizer are also applied. Vegetative Propagation for Clonal Orchards Very often there is a variation in the success of preparing the grats due to variation of skill in grafting and clonal variation or due to stock or scion incompatibility etc. This may spread the establishment for several years. It leads to variation in age, sex and the individual orchard trees causing problems with competition, thinning, nlowering etc. A recommended procedure is to concentrate on a few blocks at a time and make sure that all clones are represented in some blocks rather than trying to fill as many blocks as possible, resulting in blocks with a large variation in the number of clones represent ed. 140

Nursery Ys Field Granting A distinction is made between the following two propagation methods: (0) nursery grafting on rooted containers, which are grown on stock; and (i)fild grafting on established usually ol stock From a physiological point of view, field grafting is preferable because of () adequate availability of planting shock, (ii) faster growth of ramets. (ii) root development in containers avoided, (iv) disease problems (fungi) frequently experienced in ercen house or grafting sheds avoided; (v) early flowering. A major problem with field grafüng is to der fieled problems with restricted growth in keep a control on the identity of the scions. It should be realised that grafting must to a pre-arranged field plan. Mistakes casily occur. Another problem is that the vegetative m be done according as to te brought into the field, requirning cooling and protection. Protection in the field after grafting is also essential, c g against wind, strong sunshine and evaporation during the initial sensitive stago. Protective covers may simply be damaged or even stolen. Spacing Spacing must be wide enough to ensure that flowering is possible several years before thinning is required. A closer initial spacing than the final allows for initial losses. The trees in the seed orchard will have a much wider spacing than those in normal plantations. For most species a final spacing, ie. after roguing, of 10 m is preferred, which corresponds to 100 treesha. The initial spacing should be designed with the expected thinning in mind. If the trees are initially planted in 4 trees per family per plot , with expected 3 of them plus may be 50 % of the families to be culled then a planting stock of 800 trees/ha should be used, i.e. a spacing of 25 mx5 m Demarcation It is another important criterion to be considered while establishing a seed orchard. Plots and rows with replication should be clearly demarcated Planting It usually involves several clones or families, and it is important that the planting is done according to the prescribed plant, to have a clear identity of the individual in the orchard. To avoid confusion or mixing up of the plants, the following measures should be taken: (i). a plan of the orchard design should be brought to the field and used when the planting spots are demarcated, and the concerned plant should be distinguished, providing the identity of the plant to be planted on the spot (clone/ family leiter/number); (i), the plants (or scions in field graftings) should be distinetly marked and kept separately; and (i) the plants should be marked with a tag when planted. The tag carrics a number or symbol of the plant similar to that of the map Thinning Flowering and seed production can also be stimulated by thinning and crown development. In particular, the first thinning is important especially for light-demanding species, where the loss of lower-line crow progressively from 50 % sunlight and disappearing completely by 15 % sunlight . Once the flowering material is recognised from the progeny of the clonal test, inferior familics or clones removed n is often permanent Shade experiments in pines have shown that flowering decreased 141

Crown Pruning and Shaping Pruning is done mostly to facilitate colloction. Its effect on flowering is very much dependant of the species In conifers, however, top pruning leads to the loxs of many future potential flowering plants and increase in the proportion of male to female flowers within a zone of the crown, where selfing is likely to occur, with a negative effect on seed yield and quality A standard pracice in South African pinc-orchand management is to artificially bend both the main stem and branches n the a hey an seedlin rather (Sijde 1969), a method shown to be more effective than pruning alone Stem and Root Treatments The objective of these treatments is to create a higher carbohydrate level, believed to promcle flowering Such treatments may be root pruning (by deep ploughing), stem girdling or banding, mosdy reported for horticultural species. The general consensus indicates that such treatments can be very effoctive in the short term, in particular which are applied at the right time of flower development (Swect 1975). However there may be severe long-term cffects on the general health and conditions of the trees, especially if used over an extended period. Physiological stress situation likes drought (stopping of irrigation) and confinement of roots are known to provide increased Howcring. The possible explanation, according to Lec (1979) is that, if the balance between photosynthesis and nutrient uptake is disturbed, the intemal mechanism that regulates the secual reproduction is also disturbed. This causes a change in bud diffcrentiation, from vegetative teo reproductive, as a defense for survival. Protection is one of the major managerial aspects of seed orchards. It includes possible measures against mammals, including humans (particularly encroachment on seed-orchard arcas, man-lit fires etc.). Prevention or treatment of insect atack diseases on roo, stem, leaves as well as flowers and fruits, or damage by birds are, however, equally Accal love Hano important 5 amiurJuvenlity and Maturation in Seed Orchards Juvenility and maturity demonstrate that the shoots of an individual tree can exist in more than one relatively stable state Phase change in forest trees is a complex subject, prone to misunderstanding and confusion of terminology (Longman, 1987). Morcover, much confusion and misundenstanding exist about the nature of the juvenile period, the terminology of phase change and the relationship between the onset of maturity and the induction of flowering Some biological and concepcualprobiems In concerning phase change in trees are given below: chan General There are often no clear-cut morphological differences between juvenile and mature material h leads to problems such as: (0) identification of the phase is uncertain: () every juvenile characterissic y not be lost, nor each mature feature gained at the same time, (ii), maturation could oocur ally instead of abruply, and (iv) no all changes, that occur with age are examples of maturaticon. some just reflect the increased size and complexity of the tree. Flowering The problems relating to phase change during fowering are: (0) the time at which a treogais the ability to nower (ripenessto-flower) is subject to pronounced genctic and environmental influescesideoce and and is affected by tree size; (i) genetic and environmental factors also control the ic 142 heaviness of nowering in the mature phase (and thus the 'Opportunity-to-flower'), but nok necessarily in the same way; (ii) when a tree is not flowering, it is difficult to know whether maturation has occurred, (iv) mature propagules sometimes show a period of several years without flowering when they are still small (sometimes called 'secondary juvenility), and (v) nowering can be stimulated in secdlings of some species while they are apparently still in the juvenile phase, suggesting a quanútative rather than an absolute change in the capacity to flower. With forest trees, it is particularly important to recognise two general types of ugc related alterations in shoot morphology and physiology: () ageing (or physiological agcing), which includes the losses in vigour, and (i) maturation (or cyclophysis, or ontogencticalngcing), which may occur concurrentdy Acceleration of Maturation The most promising treatment for hastening the change from the juvenile to the mature phase is to grow seedlings as fast as possible to a certain minimum size, and then (if necessary) place them in flower inducing conditions. In several correlated forest and fruit-tree species, such 'acce growth' substantially reduces the number of years to first flowering. Methods used to promote growh have included higher temperature, increased photoperiod. growing in large-sized containers with plentiful water and mineral nutrient supplies, and extending the growh season under lights in controlled environments. The onset of flowering has been hastened by rapid growh in Larix, Picea (Young and Hanover 1976), Pinus and Betual (Longman 1984). The possible reason suggested for this earficr flowering in rapidly grown trees is that distance from the root allows maturation to occur. It could be that gibberellins, produced in the roots, act to preserve the juvenility in the adjacent tissues, and that this effect fals off with distance (Hackett, 1980). An alternative explanation is that the shoot apex has to produce a certain minimum number of nodes, or undergo a given number of cell divisions, in order to become mature. The observation that mature apices are often larger than juvenile ones raises the possibility that a threshold apical dome diameter may have to be achieved during maturation. lerated optimal Effect of Maturation on Flowering In loblolly pine both precocity and fruitfulness are in part genetically controlled, and grafted material from mature ortets flowers better than seedlings from the same ortets planted at the same time (Schmidting, 1981, 1982). Therefore, any assessment of age on flowering must also take genetic variation into account. In order to assess the effects of scion age on flowering and other mature characteristics, Greenwood (1984) grafted loblolly pine scions from ortets representing four different ages (1, 4, 8 and 12 years) from 5 half-sib families into uniform 2-year old rootstock in June 1978 Consequently, the results of strobilus counts done in 1979 and 1981, estimate the potential for female production on the potted orchard, but do show the effects of maturation of flowering.

SEED ORCHARDS AND SEED PRODUCTION

Flowering Phenology

Frequent and abundant flowering of a large proportion of the clones is a programme of clonal seed orchard. The flowering phenology varies among population among the trees within a population, within the crown of individual tree, among flowers on a given branch and even amon developmental period from flowering to early seedfall can vary by more than 3 weeks when early-essential for the success of g different ovules within a single strobilus. In Douglas fir seed orchards,

and late-lowering parent trees are grown together in the same orchard. In Douglas fir, flowering phenology (early, intermediate or late) had no discernible effect on seed maturation. Higher germinaion and yields of filled seeds were obtained from cones collected in mid-August, approximately 2 weeks prior to cone opening, than from cones collected just as they began to open. Seeds extracted immediately following harvest germinated better than those from cones stored for 2 months. Seeds from all the treatments were dormant and responded to pre-chilling by showing increased germination rates.

Skroppa and Tuttusen (1984) studied the location and characteristics of 6 seed orchards and the clonal archive Norway spruce which includes annual variation in flowering and frequency distribution. A large variation in flowering was obscrved between sites, between years within the site, between provenances and between clones of the same provenances within the orchard. Depending on the environmental conditions for flowering, a certain percentage of the clones in each orchard can be expected to have none, or very modest flowering for most of the years.

El-kassaby and Askew (1991) studied the relationship between reproductive phenology and reproductive output in a Douglas fir-seed orchard. The development of both male and female strobili was monitored throughout the flowering season, and the number of seed cones and production of male strobili were determined. The overall potential gametic contribution of each family was estimated in terms of proportional contributions to the seed crop and parental balance. Families varied greatly in both seed cone and pollen contributions. The top 5 contributors of cones were different from the top 5 pollen contributors. Assessing seed cone and pollen contributors prior to cone induction or supplemental mass pollination will be valuable for increasing the genetic value of orchard seed. Estimates of genetic value of the orchard crop should be calculated after assessing the remaining parents focused on the contributions of both seed and pollen and the timing of their reproductive phenology .

Analyses of the relationships between pollen-tube number and fertilization number, and between archegonium number and fertilization number in Douglas-fir indicate strong trends towards higher levels of simple polyembryony, as both pollen-tube number and archegonial number increase on per-seed basis. These relationships have a significant bearing on the management of conifer-seed orchards. Simple polyembryony has been proposed to be an effective means of increasing the competition on the seed basis in conifers and potentially the overall fitness of the e progeny.

Role of Hybrids in Tree Improvement

Hybridization is an effective tool in the hands of tree breeder, where artificially inter – or interspecies or genera are crossed with each other by hand-pollination to produce hybrids.

Similarly, in cross – pollinated species natural hybrids or spontaneous are also produced, where two species grow in close vicinity and are compatible.

Hybrids, due to their superiority, can be used for the improvement of tree species by further selection from the segregation populations (F_2) or progenies and also in relation to qualitative, quantitative and disease or pest-resistance traits, which are genetically controlled. Swarms of new recombinants are also produced and these can be selected from F_2, F_3, F_4 and so on populations, to have the maximum number of commercially or economically useful or superior traits in a single tree. The goal of higher productivity can be achieve by the hybrids.

Tailor- made need-based hybrid trees can also be produced with the advancement of bio techniques to match the site, including for edaphic conditioned prevailing in India and other countries like stress sited (saline, alkaline etc) and wastelands. Inter-and intra- specific or generic hybrids can be produced to meet the requirement of user agencies, who require specific properties in a tree for a particular end product. Hybrid-production programme in wheat carried out in India using local (tall) vis–a–vis Mexican (dwarf) varieties during the mid-sixties has been responsible to user the era of 'Green Revolution' and for attaining sufficiency in wheat. Similarly, hybrid- production programmes can be carried out in trees.

Nevertheless, the production of 'hybrids' in trees is a very difficult and a time- consuming task, due to their long span of life, big size and height, small size of flowers and exposure of the hybridized trees to the vagaries of the environment and biotic factor ,etc. However, there are important examples of the pioneer work carried out by the division of Genetics and Tree Propagation, forest Research Institute, Indian Council of Forestry Research and Education (ICFRE) Dehra Dun in producing the hybrids. Hybrids have been produced mainly in Eucalypts, 'FRI 4'and E. camaldulensis as female parents, respectively. Reciprocal hybrids have been produced in 'FRI 5' the species involved in these hybrids are Eucalyptud tereticornis and E. camaldulensis as female parents respectively. All these hybrids have shown heterosis and 3-5 times superiority over the parent species in wood volume per unit area and time. In addition, maternal effect has also been observed in these hybrids.

Tissue- culture protocols have also been developed for these hybrids for mass multiplication vegetatively. Hybrid seed was also produced in poplars and pines using Pinus, kesya, P. merkusii, P. taeda pollen on P.roxburghii female, on experimental basis. Hybridization was also attempted in Tectona, grandis and T. hamiltonia, where incompatibility was observed because the fertilizes embryo was abirtuve, Mostly the aim of producing hybrids has been to harness the benefits of hybrid vigour. The objective was also to incorporate resistance or improve the quality of wood in addition to the release of a wide range of spectrum of variability due to recombination for further selection and genetic improvement of species qualitatively and quantitatively.

Biotechnology, including tissue culture, can play a significant role in overcoming the problems like abortive embryo and segregation problem of the seed raised from $F_{2,}$ F_3 etc. populations after collecting the seed from F_1 etc. hybrids. Now F_1 hybrids can directly be multiplied vegetatively on mass scale through tissue culture (micro-propagation).the seedlings of F_1 hybrids raised through tissue culture are almost similar to their F_1 parents in expressing hybrid vigour and other characteristics. Protocols for these hybrids have also been developed for mass multiplication with very good survival rate and performance in the field. At present there is an acute shortage of quality planting material for raising plantations.

Therefore, micro-based macro-propagation technology or bio-technology would be a boon to the forestry sector in meeting the increasing demand of our country for production and utilization of improved planting stock from superior trees or selections for raising plantations having a great potential of improving the productivity in per unit area and time ,much earlier than the traditional tree –improvement programs prevailing , on the lines of crops like wheat in India or other countries.

Disadvantages or problems of hybridization in forestry

It will be better to know the problems that exist in hybridizing the trees in comparison to annual crops:

1. The species are perennial, cross-pollinated and heterozygous in nature.
2. First flowering is quite late, which varies from 3 years to 90 years or so.
3. Homozygous or pure lines are not available in trees. The flowers are brittle and small in most of the species.
4. Synchronization of flowering time of two species, genera or provenances and of plus tree may always not be possible when flowering is in full bloom. Thus, matching of pre- or post- flowering between species or genera etc. may be needed.
5. The size of the flowering trees is very big in terms of height and diameter. Therefore special climbing equipment, movable trolley-mounted vehicles, ladders or scaffoldings etc. are the prior essential equipments needed. Alternatively, grafting techniques are required to be perfected to graft the flowering parent species on suitable rooted stock to reduce the height and promote flowering, to attempt crossings at convenient height.
6. Desiccation of hand- pollinated buds occurs in the ordinary bags are in the absence of proper aeration. To prevent this, special type of crossing or hybridizations bags are required, where aerations is possible and a transparent window is present to observe receptivity of stigma or withering of stigma and style as a sign of fertilization etc., without opening the bag to prevent out- crossing . Such bags are not available in India and are to be imported.

7. Before controlled crossing is attempted, knowledge is to be gathered on timing of an thesis, fertility of pollen and receptivity of stigma for better and successful results.
8. Once the flowering period is missed, complete 1-year is lost. Thus floral biology of the species and genera needs to be studied beforehand.
9. More time is required for harvesting the crosses; therefore care is to be taken for using durable metal or aluminum labels having all details with date of controlled crossing, identity with sketch etc. to avoid mistakes or confusion. As for example, in Pinus species it takes 2 years to harvest the seed cones after crossing.

Advantages of hybridization in forestry:

In most of the tree species or genera, provenances or individual plus trees in which controlled crossing hybridization by hand or nature is done, hybrid vigour or heterosis has been observed. As this phenomenon is present in trees, it can be utilized or harnessed for the following conditions:

1. Early or precocious flowering, which can help in reducing the total time required for releasing the hybrids.
2. Heterosis can help in improving the productivity in comparison with parent species and also in reducing the rotation age.
3. With the advancement of biotechnology (tissue culture), hybrids (F_1's) can be multiplied vegetatively on mass scale, ensuring uniform populations with potential of higher productivity. Large or wider areas of plantations can be raised and harvested much earlier than their parent species due to hybrid vigour. Financial gains can be increased manifolds by adopting this technology.
4. Expressions of maternity can be observed based on morphological traits in the field ,facilitating alternate row planting of 2 species side by side, avoiding cumbersome methodology of controlled crossing, and thus saving time, money and efforts. These morphological markers can be utilized to pick up hybrids at seedling stage raised through seed collected from 2 different species planted in alternate rows.
5. Production of triploids or haploids by taking aid of induced polyploidy.

PRE – REQUISITES FOR HYBRIDIZATION AND PRECAUTIONS

Before attempting hybridization, information on the following aspects is essential:

1. Whether the species (where applicable) belong to the crossable series, classes or genotypic or chromosomal acceptability or not.
2. Species or genera are cross-pollinated or self-pollinated.
3. Near relatives should not be crossed to avoid inbreeding depression.

4. Proper selection of female and male parents should be made, which are healthy, disease free and have all genetically plus traits, to participate in crossing programme. More the number, the better it will be.
5. Identification of the source and location of female and male parents is essentially preferred (if available) in inter- or intra-specific or provenances or crossing work.
6. To keep the genetic base wide, more number of parents need to be marked and utilized for making diallel crosses to find out general and specific combining abilities.
7. Information on heritability for genotypic improvement is an essential ingredient of the programme of hybridization.
8. Knowledge of the floral biology of the female and male parents, if inter-provenances or specific or genera crosses are being attempted.
9. Availability of grafting techniques and tissue- culture protocol.
10. Information on ploidy level of the female and male parents.
11. Survey, collection and establishment of germplasm.

TYPES OF HYBRIDS

Interspecific

Interspecific hybrids are produced when crosses are attempted between different species of a genus, if two species 'A' and 'B' are to be crossed , each species is used simultaneously as female and male, it will provide information on better combination as well as on maternal effect.

Intraspecific

Intraspecific hybrids are produced when crosses are attempted within different individuals of the same species, i.e. between two superior selected trees, between plus trees, between provenances, between individuals of different ploidy levels to produce triploids or teraploids etc.

Intergeneric

Intergeneric hybrids are produced when crosses are attempted between individuals belonging to different genera like wheat and rye, radish and turnip, tomato and potato etc. , though it is difficult to get success through conventional methods but 'Biotechnology'. Has made it possible through 'Somatic hybridization'.

PROCEDURE OF HYBRIDIZATION IN HERMAPHRODITE AGIOSPERMOUS SPECIES

If one plans to use hybridization as a method for tree-improvement (genetic) programme, and has all the preliminary knowledge on different aspects, as mentioned in the proceeding paragraphs, the following procedure is usually adopted step-wise:

Labeling and Bagging

After planning the schedule for the species or genera to b hand pollinated or crossed or hybridized during a particular period of the year, when the trees flower abundantly, the female and male trees should be labeled properly. If crossing is to be done in situ, the labels should be durable and ink used should be waterproof; however, use of good pencil and aluminum levels is preferred, knowing well that the trees in situ have to face the vagaries of weather and other environmental and biotic disturbances. Hence utmost care needs to be taken before and after crossing of the trees.

1. If crossing work is to be done ex situ (on grafted plants or plants already grown there, which are flowering) or in 'flowering tents', which are of quite large size,, better control is possible in creating environmental conditions suitable for the species and protection from biotic and other disturbances, which are also to be labeled properly as per plan and identity of the female and male trees.
2. Daily observation should be taken during the flowering period for bud-break of the trees included in the hybridization programme , because the buds are to be covered and tied with bags before an thesis takes place to check selfing.
3. When flowering buds have appeared, these should be covered with 'pollination bags' and tied, having transparent plastic window made of a material that allows aeration at appropriate time and observations are to be made o the receptivity of stigma etc, without opening the bag.

Emasculation

When flowering buds have not opened and stigma is not receptive, that is the stage when male portion (anthers with filament) are to be removed by giving a fine round cut with a blade if the are in a whorl (as in eucalyptus) or by the help of a fine forceps, this process is termed 'emasculation'. Care must be taken not to injure the young bud or the ovary, style and stigma. After removing the male portion of the young buds, again the bag should be tied carefully so that the emasculated bud is not damaged, the date of emasculation should be noted on the label as well as in a field note-book along with the number of total buds emasculated, and the slop should be tied with the pollination bag. Usually it takes 2-3 days for the stigma to become receptive if the emasculation has been done at proper time. This judgment of proper timing of emasculation comes only by experience.

Pollen collection

The pollen collection is a tedious process in the case of angiosperm us (e.g. Eucalyptus) tree species, as enough pollen is not available and , even if it is there, in most of the species it is sticky. Pollen should be collected when it is mature and fertility or viability tests conducted by staining (e.g. acetocarmine) test including germination test. If pollen is to be stored , pre-storage tests should already have been conducted. Storage is required only when there is no synchronization in the flowering time of the species, genera or individual trees including plus trees or provenances.

In gymnosperm us species a lot of pollen is available in powdery form in the male cones and clouds of pollen can be seen near the trees when anthesis takes place. Male cones can be well distinguished from the female cones. The female cones are required to be bagged at a very early stage when the buds are in the scales, sometimes it becomes difficult to distinguish the female cones from vegetative buds; this can be learnt with experience.

Application of pollen on receptive stigma

In angiosperm us species, after emasculation and bagging of female flowers, the pollen of the male parent is applied only when the stigma becomes receptive, which can be recognized after seeing the nectar or other droplets on the stigma. Pollen is collected in sterilized Petri-dishes and it is applied on the stigma with the help of a sterilizes camel-hair brush No.4,6 or 8 as required. After application of pollen, the bag should be immediately tied again. If pollen is more sticky and cannot be collected easily in sufficient quantities whole mature anthers can be smudged on the receptive stigma with the help of a hair brush. Pollen should be applied thrice a day on 3 alternate days.

Alcohol should be carried to sterilize the brush quite frequently, and dates should be recorded on label and in field note-book.

Fertilization

After the pollen has been applied, the pollen tube will grow through the style to reach the egg cell to fertilize it. This natural process is reflected by withering of the stigma and style. Thus daily observation through the plastic window of the bag is essential.

Removal of Bags

After fertilization the bag should be removed but labels should be updated and kept intact. As these labels have to stay for a longer period, they should preferably be of aluminum or hard thick drawing paper, which should be waxed properly.

Harvesting of crosses

Crosses should be harvested only when the seed is mature. Each cross should be harvested separately and stored under ideal conditions till the sowing season approaches.

Sowing

As the hybrid seed is very precious and small in quantity, is should be sown under ideal controlled conditions, and utmost care should be taken for its healthy growth, in laboratory, nursery and field etc. by adopting good seed-testing rules and cultural practices. Only regular data recording on defined time period gap will throw proper light on the superiority or inferiority of the hybrids. Therefore it is essential to collect and sow the normal seed of the female and male parents simultaneously under the same conditions to serve as control for comparison with the hybrid seed. To know the superiority of F_1 hybrids, the experiments and data recording should be well designed and replicated for validity of statistical analysis.

After sowing of crossed (hybrid seed), proper record should be maintained on germination, morphological features, growth parameters (height and diameter etc.), leaf characteristics, stomata etc.

Another alternative that has become a very powerful tool in the hands of breeders is to multiply the F_1 hybrid seed through tissue culture on mass scale, as already discussed in this chapter.

In eucalyptus, where the species like E. tereticornis, E. camaldulensis. E. grandis, E. citriodora and E. torelliana are highly cross- pollinated, it can be grown in the field in close alternate rows to get natural F_1 hybrid seed. Due to the ,orphological markers available in the 2 species, i.e. presence of ligno-tubers in E. citriodora and broader leaves with pungent some, in E. torelliana and some seedlings in the progeny show lingo-tubers or if seed is collected from E. citriodora and some of the seedlings in F_1 progeny show broader leaves with smell of citriodora, it can be derived that these F_1 seedlings are hybrid as a result of the natural intercrossing of the two species and can be multiplied on mass scale through tissue culture.