STANDARD OPERATING PROCEDURES
for
PLUS TREE SELECTION

Indian Council of Forestry Research & Education

(An autonomous body under Ministry of Environment, Forest and Climate Change)
P. O. New Forest, Dehradun - 248006 (Uttarakhand)

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Submitted To:
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Message

I am delighted to introduce this comprehensive guide on Standard Operation Procedures (SOPs) for Plus Tree Selection, which represents a significant milestone in the field of forestry and tree breeding. In today's ever-changing world, where sustainable resource management is crucial, this manual serves as a vital resource for professionals seeking to enhance the quality and productivity of our forests.

This SOP manual represents the culmination of extensive research, practical experience and collaborative efforts of numerous experts in the field. It provides a standardized framework for the identification, evaluation and selection of plus trees, ensuring accuracy, reliability and consistency in the process.

The manual begins by outlining the fundamental principles and objectives of plus tree selection, emphasizing the significance of genetic diversity, adaptability and sustainability in forest management. It then proceeds to detail the step-by-step procedures for identifying potential plus trees, including field observations, measurements and data collection.

I congratulate the team of scientists and contributors of ICFRE for putting in their expertise and time in bringing out this manual on Standard Operating Procedures for Plus Tree Selection. This manual will be helpful to the officers and frontline staffs of the State Forest Department of Odisha to carry out the selection of plus trees of important plantation species for quality seed collection.

Dated: 10 July, 2023

(Arun Singh Rawat)

पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय, भारत सरकार की एक स्वायत्त परिषद
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Foreword

The selection of superior plus trees plays a pivotal role in the genetic improvement of tree populations. Plus trees, distinguished by their exceptional growth, disease resistance and desirable traits, serve as the foundation for future generations of trees. The proper identification and selection of these exceptional individuals are crucial for enhancing the productivity and quality of our forests. In today’s world, where sustainable and efficient management of natural resources is of paramount importance, this manual serves as a valuable resource for professionals in the field of forestry and tree breeding.

These exceptional individuals, hold the potential to shape the future of our forests. The identification and careful selection of these trees are critical for sustainable forest management.

I congratulate the Indian Council of Forestry Research and Education, ICFRE for formulating the manual of Standard Operating Procedures for Plus Tree Selection to serve as a guiding light in our collective mission to unlock the genetic potential of our forests and secure a greener, more resilient future.

Dated: 10 July, 2023

(Debidutta Biswal)

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Preface

Tree improvement is being emphasized as the top priority by Forest Departments all over the world which is based on the practical applications and principles of genetics and tree breeding. Selection of genetically superior individuals from the genetically variable population is the base for any tree improvement programme. All the methods of selection in an applied tree improvement programme is based on the general principle that chooses the most desirable individuals for the use as parents in breeding and production programmes.

On the initiative and support of the State Forest Department, Odisha, the Standard Operating Procedures of Plus Tree Selection of target species was formulated/developed by the Indian Council of Forestry Research and Education. This manual serves as a definitive guide, offering comprehensive procedures and guidelines to streamline the process of selecting exceptional plus trees for the genetic improvement of tree populations.

By delineating the fundamental principles and objectives of plus tree selection, this manual emphasizes the significance of genetic diversity, adaptability and long-term forest management strategies. It outlines the step-by-step procedures for identifying potential plus trees, encompassing various field observations, meticulous measurements, data collection techniques and analysis.

I would like to extend my heartfelt appreciation to all the scientist and officers of Institute of Forest Productivity, Ranchi who have dedicated their time, expertise and unwavering commitment to developing this comprehensive resource. Their collective efforts have culminated in a manual that will undoubtedly pave the way for a more sustainable and prosperous future for our forests.

Dated: 10, July, 2023

(Sanjeev Kumar)

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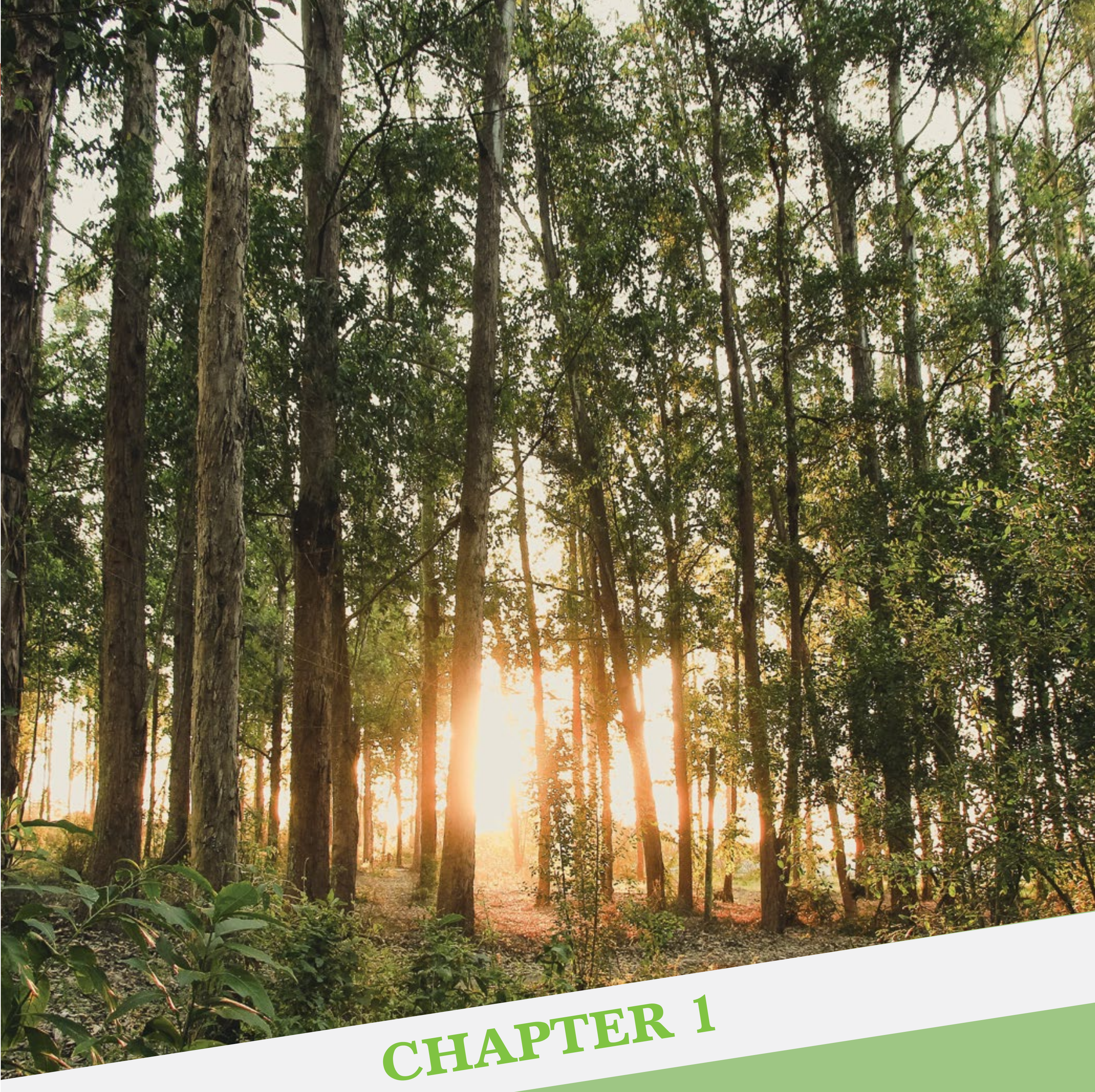


CHAPTER 1

Introduction

1. Steps Involved in Indentification and Selection of Plus Trees
2. Importance of Selection in Tree Improvement Programmes
3. General Guidelines for Selecting Individuals

Forest tree breeding can be explained as activities that are geared to solve some specific problem or to produce a especially desired product.

In any plant or animal breeding program, there are a series of activities that will ultimately determine the amount of genetic improvement. One of the most important activities is choosing those individuals which will serve as parents for the next generation. The process is known as selection and may be formally defined as "the non-random differential reproduction of genotypes" or alternately, "the actual procedure by which discrimination between individuals with respect to their reproductive rate is arrived at". The result is that selection dictates that only certain individuals are allowed to transmit genetic material to the next generation.

In breeding or improvement programs, the reproductive contribution of each individual is the result of a conscious decision of the breeder. Thus, in improvement programs, the selection is more accurately referred to as artificial selection. By contrast, organs whose reproductive success is not determined by human choice, are considered to be subject of natural selection. For the purpose of the parents by convenience, the choosing of the breeder in an improvement program is usually called only "selection", with the understanding that deliberate choices are to be made. The use of selection in forest tree crops is certainly not a new or unique idea.

Selection is usually the first step in any improvement program and determines how much genetic gain can be obtained, as it provides the basis for the first and, through a recurrent system, succeeding generations. The gains can be no greater than the quality of the parents used (Zobel and Talbert, 1984). The importance of selection for forest trees is certainly no less than for other crops. Several biological characteristics increase the importance of selection in forest trees above that of annual or biennial crop species.

First, trees live much longer than many other plants. Thus trees are exposed to a wide variety of environmental conditions (insects, disease, weather, etc.) during their lifetime. Selected individuals must produce offspring which are adapted to the various conditions which may be encountered. Trees also have a relatively long generation interval (defined as the time from seed collection until an individual is selected and produces seed) of several years, whereas many crops have a one-year generation interval. Once chosen, an individual remains in the breeding population for a considerable length of time. The longevity and extended generation interval are but two factors that necessitate the efficient selection of individuals early in a tree breeding program to maximize genetic gain.

An effective selection program is based on both sound genetic theory and the implementation of the proper procedures.

All beginning tree improvement programs rely on and consist of the following:

1. A determination of the species, or geographic sources within a species, that should be used in a given area.
2. A determination of the amount, kind and causes of variability within the species.

3. A packaging of the desired qualities into improved individuals, such as to develop trees with combinations of desired characteristics.

4. Mass producing improved individuals for reforestation purposes.

5. Developing and maintaining a genetic base population broad enough for the needs in advanced generations.

Forest tree breeding programme is emerging very fast due to the need of rejuvenating degraded forests. In India per capita, forest area is only 0.064 hectares, against the world average of 0.64 hectares (FAO). The productivity of Indian forests is only 1.34 cubic meters per hectare per year, against the world average of 2.1 cubic meters per hectare per year. While 78% of the forest area is subjected to heavy grazing and other unregulated uses, adversely affecting forest productivity.

In the present scenario, there is a need of integrating the tree breeding component with afforestation/reforestation programmes to enhance the productivity of Indian forests. The selection of superior trees in natural stands is the first and one of the most important step to start a tree breeding programme. The objective of the selection programme is to obtain a significant amount of genetic gain, while at the same time maintaining a broad genetic base to ensure future gains. Selection is the key part of all applied tree improvement programmes. All method of selection in an applied tree improvement programme is based on the general principle that chooses the most desirable individuals for use as parents in breeding and production programmes.

1.1 Step Involved in identification and Selection of Plus Trees

1. Stand Selection

In a typical breeding programme, plus-trees are selected from across the entire zone and are recorded by region of provenance and seed zone. The first step is to identify suitable stands. Typically, a stand should have a minimum of 30 individuals of good form, but it is more desirable to select a female tree. Having determined that the stand is suitable for plus-tree selection, it is then necessary to assess each tree to ensure that the best individual is chosen.

2. Tree Selection

The tree’s dominance within the stand, indicated by its superior height and diameter, are the first attributes to be assessed. Timber height (the amount of clear stem to the first fork or major branch) is very important. Timber is usually required in 2m sections. A minimum of three such sections (6 m) of the clear stem is desirable for a plus tree and obviously, more is better. The degree of clean self-pruning and the shape of the bole are good indicators of the quality of the timber. A large healthy crown is essential for good growth potential. The best tree may be the most dominant in a stand, but factors affecting form are also considered such as branch angle and thickness which are also useful indicators of timber quality. The height of the first fork and the deepness of the fork should be considered. Hardwood species fork naturally, although some individuals show a greater predisposition to do this than others. Forking can occur as a single instance or it can be persistent throughout the crown. Where it occurs as a single fork it is likely to be due to environmental factors and the tree need not be discarded on this account.

However, where forking is persistent throughout the crown, it is much more likely to be genetic in origin and such tree should be avoided. Selected trees should be free from diseases and pests. A final consideration is the presence of any seeds or flowers. In those trees that are dioecious, it is more desirable to select a female tree (if the objective is to collect seed) although males may be selected if graft wood is to be collected for clonal propagation. It is to be known that for each species, the selection strategy is a little different.

3. Recording the Tree

Having decided which tree is to be selected on a visual basis, it is then necessary to make notes on the tree using a standard data form (Table 1). Detailed and accurate notes are essential as they will be valuable over decades. Designation of breeding orchards under tree breeding requires details of the parent trees and their locations. Some general observations on the stand are useful to note such as species composition, what component the selected species plays and any statutory designations that the woodland may have.

Tree characteristics such as total height, timber height, estimated branch diameter of the lowest branch and diameter at breast height (taken at 1.37m above ground level) are recorded. Factors that contribute to the form of the tree are also scored. These include the circularity of the bole, the bark grain (which may be spiral and thus undesirable), the presence of any basal sweep, fluting and stem straightness. Any bark defects should also be noted, including slight mechanical damage.

Other more serious bark defects such as cavities or cankers will prevent the tree from being selected in the first place. Once selected, it is helpful to identify the tree with tree marking paint. This ensures that in future visits, the right tree is located. In some cases, a global positioning system (GPS) reading may be obtained, although this is not always possible under dense tree canopies.

1.2 Importance of Selection in Tree Improvement Programmes

Selection is normally the first step in a tree improvement program and it determines how much gain can be obtained, both in the first and succeeding generations.

Any breeding programme for the improvement of timber quality relies on the identification of the best parents. These will form the genetic base from which all subsequent improvements can be formed and vigor can be obtained.

Selection methods can be used for trees from stands where there is no pedigree information.

In most species, a considerable improvement in bole straightness, disease resistance, wood quality and adaptability to adverse environment conditions or tolerance to pests can be rapidly obtained by selecting and allowing cross fertilization among the very best trees.

Selection methods are used in seed orchards, allowing favourable genic combinations to interact and produce progeny with a larger proportion of the desired characteristics.

Any breeding programme for the improvement of timber quality relies on the selection of the best parents. These will form the genetic base from which all subsequent improvements can be formed and vigor can be obtained.

1.3 General Guidelines for Selecting Individuals

There are general guidelines for selecting individuals in even-aged natural stands and plantations. These guidelines have been very useful in choosing superior trees in first–generation tree improvement programs. These are given below-

1. The search should be concentrated on stands and plantations that are average or better in growth, pruning, straightness, branch angle and other characteristics of interest. An occasionally acceptable tree may be found in a poor stand but this is rare and search efforts are more efficient when they are carried out in good stands. Outstanding trees of stands are referred to as plus trees.

2. Stands and plantations in which candidate trees are sought should be located on the same variety of sites where plantations from improved seed will ultimately be established. This is true unless there is evidence that sites do not affect the performance of the genotype. There should never be a concentration of selections from the very highest site lands if the plantations are to be established on average or poor sites.

3. When selections are made from plantations, information about the suitability of the seed source used in the planting should be obtained. Selections should not be made from stands planted with seeds and areas known to be poorly adapted to the area where planting will be done.

4. In older stands, the search effort should be confined to trees that have an age range of number more than 10 to 15 years younger or older than the projected rotation age of the plantations that are to be established. For species that are harvested at an early age, the trees must be old enough to have shown their potential. For tropical pines, the stands need to be a minimum of 10 to 12 years old before they exhibit development that enables efficient selection.

5. Selections should be made from stands that are as pure in species composition as possible. Differential growth rates among species can severely complicate selection through differential competition if the stand has a sizable component of two or more species.

6. Stands must be avoided that have been logged for poles or piling or that have been otherwise high-graded or thinned from above. If the stand has been thinned from below, or if it has suffered fire damage, allow crown competition to be re-established before selections are made. Stands that are mechanically thinned or thinned in a truly silvicultural manner are suitable for an individual selection program.

7. The minimum size of a stand or plantation in which a candidate can be located is immaterial. If the stand is large enough to locate a good candidate tree and to allow choosing comparison trees, then it is large enough to search for a trait that is superior as compared to the surrounding.

8. Preferably only one select tree should be accepted from any one small natural stand to reduce the possibility of obtaining candidate trees that are close relatives. This restriction does not apply to selecting plantations.

9. Although candidate trees should exhibit a heavy flower or cone crop, these characteristics are generally not given much emphasis. This is particularly true in young and dense stands where many trees show no sign of flowering because of insufficient light on their crowns to stimulate flower production. Usually, these will flower heavily in the seed orchard environment.

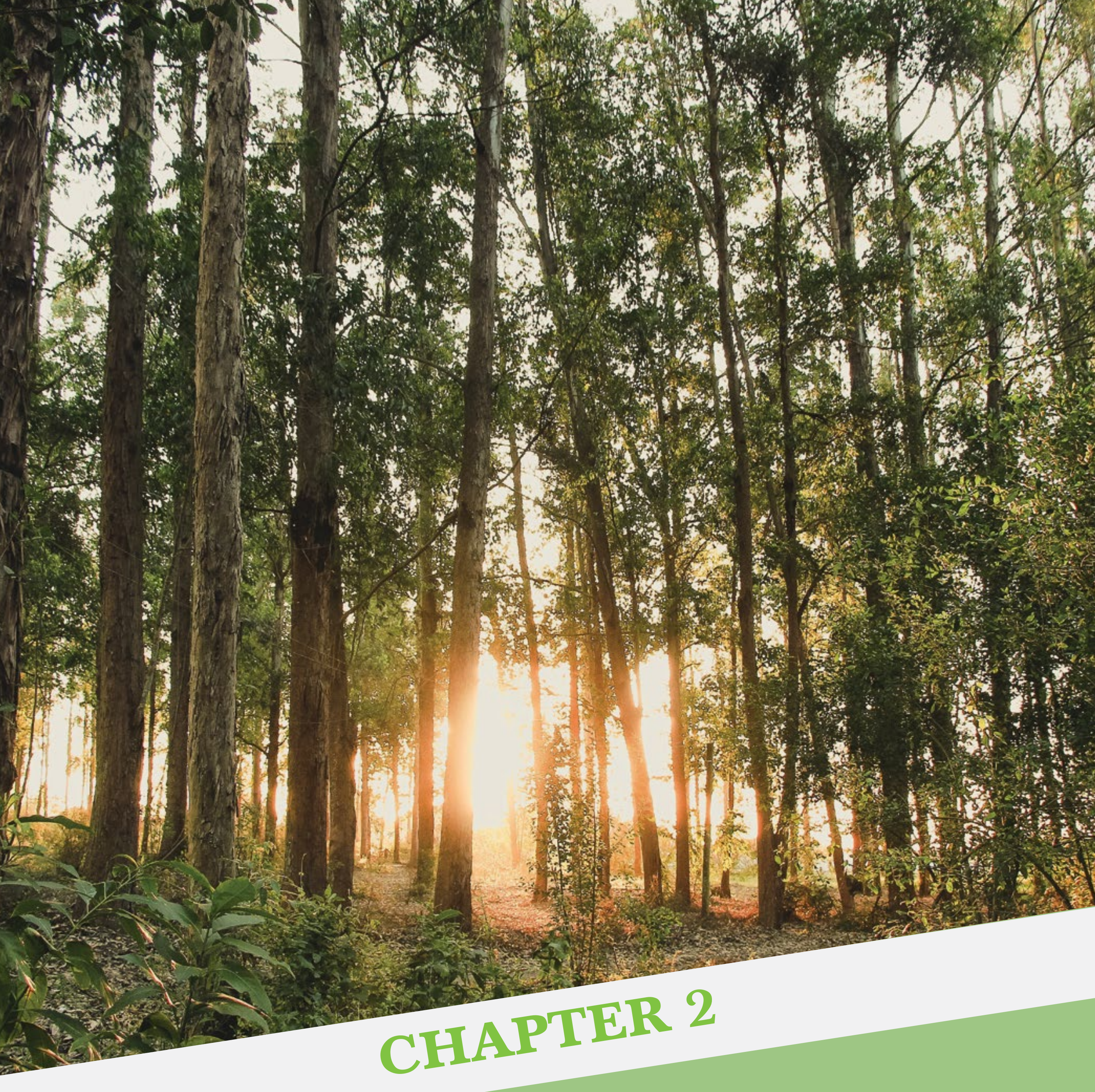
10. A comparison or check tree selection system should be used when feasible. This helps to account for environmental differences within stands and permits a more efficient and objective selection of superior trees. A method of evaluating candidate trees without the use of check trees was suggested by Robinson and Van Buijtenen (1971), but usually, the use of check trees is desirable.

11. At the time of selection, the candidate tree should be reproductively matured. In other words, the tree should be in the flowering and fruiting stage. However, in dense stands because of insufficient light, many trees show no sign of flowering. But such trees are found to flower in seed orchard conditions.

12. The probability of locating a good tree is always higher in a good even-aged stand than in an uneven-aged poor stand.

13. Trees should be selected which are reproductively matured. Generally, trees that have attended half-rotation age, are considered for selection. However, care should be taken to avoid over-matured trees or trees which have crossed the rotation age. In some species with small rotations like eucalypts and casuarinas, selection can also be equally effective at the age of 2-3 years.

14. Once stands with the above-noted criteria are found, a systematic survey should be made to locate a candidate tree with a desirable character combination.



CHAPTER 2

Selection Methods

1. Selection in Even-aged Stands
2. Selection in Uneven-aged, Mixed Species, or Stands of Sprouts Origins

Irrespective of the breeding techniques used, the largest, cheapest and fastest gains in most forestry improvement programme within species is assured with the appropriate use of suitable species and seed sources (Zobel and Talbert, 1984). Selection helps to change the genetic properties of a population, by choosing individuals to produce next-generation offspring. The procedures used for the selection of plus trees depend upon several factors like stand structure, number of traits considered, selection intensity, etc. The selection of plus tree is based on the phenotypic assessment of the characters of the economic interest. Systemic surveys are done over the maximum possible area of the species distribution. The tree is selected after thorough research of the stand. Observations are recorded on the characters of economic interest.

A determination of the best selection technique depends upon several factors, including species characteristics, history, the present condition of the forest, the variability and inheritance pattern of important characteristics and objectives of a particular tree improvement programme. There are two major kinds of forest stands, each of which require different first generation selection system:

1. Even-aged wild stands or plantations.
2. Uneven-aged and scattered stands.

Advantages of selection from even-aged stands as compared to uneven-aged stands

Individual selection works best when good even-aged stands of the proper age are available. This allows efficient comparisons to be made among selected trees and checks.

There are several advantages to selecting in even-aged stands rather than in uneven-aged or mixed stands when practicing individual tree selection. First, the breeder can be sure that age will not differ greatly among trees and that relative of growth, form, disease tolerance and adaptability will not be confounded with age effects. Second, it is in these types of stands where the "comparison tree" system of selection can be used in which trees considered for selection are graded against the best trees in the stand. All of these factors work to increase selection differential and thus it results in greater gain.

WHICH IS BETTER FOR SELECTION OF PLUS TREES?

PLANTATION NATURAL STAND

Source: *pollution.blogspot.com, 2015*

1 Generally, plantations are preferable to natural stands in selection efforts if plantations of suitable seed source are available.

2 In plantations, all trees are exactly of the same age. In natural stands, even slight differences in age cause differential competition that can result in large differences in volume and form within the stand.

3 It is known, for instance, that in densely stocked pine stands, a difference of one or two years in age among neighbouring trees will usually result in the younger trees' never becoming dominant or co-dominant trees in the stand.

4

An additional advantage of selection in plantations is that spacing among trees is more uniform.

5

The plantations where the age, spacing and cultural practices are same are the most useful base population for selection of individual trees and the relative expression of trait will not be confounded with age and cultural conditions. In view of less or uniform competition, the genetic effects (heritabilities) will be more pronounced.

In addition to choosing among several objectives when tree breeding projects are established, decisions have to be made in regard to specific traits to be improved and what is equally important, the method of selection. Selection in trees may be achieved in many different ways but all methods of selection do not apply equally to all types of stand and the advantages of each method have to be balanced against the disadvantages. Methods of selection must be evaluated on the total marks allotted to candidate trees.

2.1 Selection in Even-Aged Stands

The even-aged or regular forest is defined as a forest composed of even-aged woods. The term even-aged is applied to a stand consisting of trees approximately of the same age. Differences up to 25% of the rotation age may be allowed in cases where a stand is not harvested for 100 years or more.

According to Van Buijtenen (1969) Zobel and Talbert (1984), following methods can be used for the selection of superior trees in even-aged forests:

2.1.1 Comparison Tree Method

2.1.2 Total Score Method

2.1.3 Independent Culling Method

2.1.4 Selection Indices Method

2.1.1 Comparison Tree Method / Point Grading Method

This method is most suitable in plantations and natural stands of uniform age. A candidate tree that is phenotypically superior in chosen traits is compared with its nearest neighbors, or average or best trees in the stand.

The comparison or check tree method is most in vogue and preferred for species growing in relatively uniform,even-aged stands of a single dominant species or, at most, only a few species. Such conditions are most commonly met in species of early Successional or pioneer status like southern pines. In practice, after a superior tree candidate is located, it is scored for traits of interest in relation to a number of surrounding trees, the comparison trees. If the candidate exceeds the comparison trees by a certain arbitrary amount, it is selected for incorporation into the breeding program, often by grafting scion into a seed orchard.

The object of using comparison trees is to adjust or correct the phenotype value of the candidate tree for environmental effects common to that stand but distinguishing it from other stands. It is feared that environmental differences between stands or areas that vary in soil, climate, or stand history would make it difficult to evaluate 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 individuals with good genotypes as contrasted to merely good phenotypes.

General guidelines to be followed in comparison tree method

1. In this method, observations on the characters of economic interest on candidate tree and comparison trees are recorded on the candidate tree report performa.
2. The comparison tree should be the best five trees from the candidate trees.
3. The distance reported for comparison trees in the immediate vicinity of a candidate tree is 25 to 50 m.
4. The superiority of a candidate tree over the average of comparison trees is worked out for each trait. The candidate tree is designated as plus tree, if it proves superior to comparison trees, otherwise it is rejected.

5

A few characters like total height, clear bole height and diameter at breast height, volume and wood specific gravity are measured actually for candidate and comparison trees (objective grading). Bole straightness, disease and insect resistance, pruning ability, flowering and fruiting, crown conformation, etc. are subjectively scored. For evaluation and scoring of candidate trees, appropriate grading sheet should be developed.

6

Candidate trees can also be scored for important quantitative characters on the basis of their percent superiority over average of check trees. All the records and results of evaluation (scoring) should be carefully recorded on plus tree record form.

7

Superiority of the candidate tree over the average of the comparison tree is worked out for each trait.

8

Comparison tree should be selected from dominant or co-dominant crown with similar age and site conditions, approximately within 100 m range from the candidate tree.

9

Objective is to adjust or connect the phenotypic value of the candidate tree for the environmental effects common to that particular stand.

10

Search should be concentrated on stands and plantations that are average or better in growth and other characters of interest.

11

Stands in which candidate trees are sought should be located on the same variety of sites where plantations from improved seed will ultimately be established.

12

When selection is made from plantations, information about the suitability of the seed source used in the planting should be obtained.

13 In older stands, the search effort should be confined to trees that have an age range of no more than 10 to 15 years younger or older than the projected rotation age of the plantation that are to be established.

14 Stands must be avoided that have been logged for poles or pilings or that have been high graded or thinned from above.

15 Once decision has been made to look over an area for candidate trees, a through systematic search should be made.

EXAMPLES OF COMPARISON TREE METHOD

Conservation and selection of plus trees of *Pongamia pinnata* in Bali, Indonesia

Plus trees are trees that have superior morphological characteristics and have advantages over similar trees, such as growth, height, stem diameter, yields, resistance to disease and oil content of the seeds. Oil content is one of the most important selection criteria in *Pongamia pinnata* because oil is used as raw material for biodiesel. The research aimed at:

(i) Mapping growth sites of *Pongamia pinnata* in Bali.

(ii) Counting the number of trees.

(iii) Selecting plus trees based on growth parameters and oil content.

The selection of plus trees was conducted using the comparison trees method. For each village with a minimum of 6 trees, one candidate tree and 5 check trees were selected. The number of *Pongamia pinnata* trees in each village varied greatly, ranging from 1 to 30 trees. Some villages were not represented in the selection of candidate trees because they had fewer than 4 trees. With respect to the candidate and check trees, the following measurements were made: total height, clear bole height, diameter at breast height, canopy width and pest and diseases.

Growth parameters

Total height (TH) was measured from the base to the tip of the tree. Clear bole height(CBH) was measured from the base to just under the first branch of a tree. The diameter at breast height (DBH) was measured at 137 cm from the base using a meter tape around the main stem. Canopy width (CW) was measured from the widest distance between two ends of the canopy. Pests and diseases were observed on each tree.

Scoring CPTs by Comparison Tree Method in *Pongamia pinnata*

Characters	Value	Ranges	Score
Total Height (TH)	15	<100%	3
		100-115%	6
		116-131%	9
		132-147%	12
		>147%	15
Clear Bole Height (CBH)	20	<100%	4
		100-140%	8
		141-181%	12
		182-222%	16
		>222	20
Diameterat Breast Height (DBH)	15	<60%	3
		60-85%	6
		86-111%	9
		112-137%	12
		>137%	15
Canopy Width (CW)	15	<69%	3
		69-99%	6
		100-130%	9
		131-161%	12
		>161%	15
Oil Content (OC)	30	<103%	5
		103-105%	10
		106-108%	15
		109-111%	20
		112-114%	25
		>114%	30
Pestsand diseases		Absent	5
			0

The growth parameters of the 17 candidate trees were ranked from the lowest to the highest. Total height was 7.50-13.60 m, clear bole height was 1.40-6.13 m, diameter at breast height was 20.70-63.69 cm, crown width was 6.00-20.00 m and oil content was

26.00-32.00%. Scores of candidate trees are presented in the above table. Candidate trees with scores more than 60% were selected as plus trees.

2.1.2 Total Score Method

In this method, the selection is made for all the traits simultaneously by using some kind of a total score or index of the net merit of an individual constructed by combining the scores for each component character.

It is the most effective method of selection. The selection index is a single numerical value within the total scores given for each trait considered in the selection. Each trait is weighted, by giving a score and an individual trait score is summed up to the total score for each trait. The individual specification for a number of traits can vary greatly and is combined into one value for the tree called a **Total score or an Index.** The high merit in one trait can certainly be used to compensate for the deficiencies in other traits. An index is simply a means of putting a whole lot of different information into one value. The information and the score should be fixed based only:

- ✓ Variation is seen in each trait – The phenotypic standard deviation
- ✓ Heritability of the traits
- ✓ Phenotypic and genetic relationships (correlation) between the traits
- ✓ The relative economic value of the traits

The aim of computing an index is to derive an estimate in which the various traits are approximately weighted to give the best prediction of the tree's breeding value. An advantage of this index is suppose if one component is missing then benefit can be obtained by predicting the missing one from the others that are present.

The greater the number of traits involved, the index becomes more reliable than the independent culling method.

Trees are arranged based on index values and those with the highest scores are kept for breeding purposes and the trees with lower index values are eliminated from the breeding population. The net value of a tree is dependent upon several traits that may not be equal to the economic value or that may be independent of each other. Hence, it is necessary to select more than one trait at a time. The desired traits will depend upon their economic value.

The selection index includes all the advantages and disadvantages of a tree for those traits which are considered for selection. The amount of weightage given to each trait depends on their relative economic value, the heritability of the character and the genetic correlation between characters. A highly heritable trait can be given a greater score than a trait, which has a low heritability. The selection index method is the most efficient (best method) among the three (Tandem, Independent culling and Selection Index) methods because it results in better genetic improvement. The only disadvantage is that the traits vary in importance from time to time and the index built at one time will not be applicable for all times. Hence, it has to be constructed and modified from time to time.

2.1.3 Independent Culling Method

This method is based on the establishment of a level of merit for each trait for selection. This is similar to the minimum selection standards used in the comparison method. The candidate tree is selected as a plus tree if meets minimum fixed standards for each trait. If the score for any trait of a candidate tree falls below the fixed level, the candidate tree is rejected regardless of its superiority in other traits.

In this method, selection may be practiced for two or more traits at a time. But for each trait, a minimum standard (culling level) is set, so that every tree must meet the minimum standards to be selected for breeding purposes. The failure to meet the minimum standard for any one trait makes the tree to be rejected. Therefore, in actual practice, it is possible to cull some genetically very superior trees when this method is used. The properties selected for each trait will depend upon the total number of trees screened for breeding.

This method reduces the selection intensity of the traits to be selected. The negative correlation among the traits will make a further reduction in selection intensity. Selection based on the independent culling method is easy to perform but becomes complicated when more traits are considered and if there is a negative correlation between traits. Therefore, only a few important traits should be considered in this method.

EXAMPLE OF INDEPENDENT CULLING METHOD

Selection of Candidate Plus Trees (CPTs) of Malabar Neem (*Melia dubia* Cav.) for Enhancement of Farm Productivity in South Gujarat using independent culling method

Twenty Candidate Plus Trees (CPTs) of *Melia dubia* were selected from different places covering Valsad, Narmada and the Dangs districts of the South Gujarat region of India. The selection was made through independent culling method by considering qualitative and quantitative traits of economic interest like stem straightness, roundness, tree height, clear bole height, girth at breast height and disease resistance. The selected candidate plus trees will be useful in the development of superior quality planting material for mass propagation and future tree improvement programmes.

Out of the trees visited, twenty CPTs were selected with an age of more than half of the rotation age of the species. An individual tree selection approach with independent culling method was followed for the selection of superior phenotype. Candidates qualifying for minimum selection standards were selected and marked with a yellow band with the number. In case, many trees were available nearby for comparison, judgment was taken to select the trees having high phenotypic value. The CPTs were not selected too close to each other to avoid narrowing down the genetic base due to relatedness or inbreeding. The aerial distance of at least one kilometer between individuals was maintained.

The selection criteria for CPTs vary from species to species but many of the basic characteristics are quite considerable. The objective was that the selected individual should have good stem form, good growth characteristics, a well-formed crown, natural pruning ability and be free from pests and diseases. The individuals having diseases, dead branches, or were attacked by any pathogen and pests were rejected in the initial stage of selection. Major economic characteristics considered for the CPT selection were the stem straightness, cylindrical clear bole, Girth at breast Height (GBH), tree height and branch angle. Trees with average or better traits of interest were preliminary screened based on bole straightness and roundness by assigning visual scores. No tree was selected having a clear bole height below 5 m and GBH 100 cm despite superiority in other traits. No tree was accepted with forking or excess crookedness up to 5 meters from the ground. Tree height was recorded by using a Ravi Altimeter from the base of the tree to the tip of the tree. Girth at Brest Height (GBH) was measured at 1.37 m height from the base of the tree using standard measuring tape and expressed in the nearest centimeter. Clear bole height was recorded with Ravi's altimeter from the tree base to the first live branch on the main stem and expressed in meters. Trees were not accepted with a branch angle of more than 90^0. The degree of branch angle was judged subjectively by considering the upper stem portion as a base. The ability of the candidate tree to shed its lower limbs (dead or alive) as compared to other trees was also judged subjectively.

The analysis of variance revealed significant variation among twenty selected CPTs. among all selected plus trees, girth at breast height (GBH) ranged from 101.80 to 170.20 cm. The highest GBH (170.2) was observed in NAU-20 whereas the lowest value was recorded in NAU-12 (101.80 cm). Among all selected plus trees, six CPTs were within the range of 151-175 cm girth class, however, seven trees each were found within the girth class 126.00-150.00 cm and 100.00-125.00 cm. In this study, the range of clear bole height (CBH) varied between 5.10-10.80 m. Maximum CBH was observed for NAU-13 (10.80 m) while the minimum was recorded in NAU-19 (5.10 m). Range class distribution suggested that nine CPTs fall in the 5.00-7.00 m, seven in 7.10-9.00 m and rest four CPTs in the 9.10-11.00 m CBH class. Tree height, from ground to tip, of the selected CPTs ranged from 14.20 to 26.20m. NAU-11 was found to be the tallest (26.20 m) whereas; the shortest (14.20 m) was NAU-10. CBH: TH ratio was found to be varied from 0.25 to 0.61. Maximum CBH: TH ratio was recorded in NAU-5 whereas, the minimum CBH: TH ratio was recorded in NAU-3. Out of the selected CPTs, one fell in the range of 0.56-0.65 class, two in 0.46-0.55, seven in 0.36-0.45 and ten occupied the place in 0.25-0.35 class. Moreover, visual scores (on a scale of 1-5) for quantitative traits like stem straightness and roundness were found to vary from 3-5 in all the selected CPTs.

CPT No.	Girth at breast height (GBH in cm)	Clear bole height (CBH in m)	Tree height (TH in m)	CBH:TH (m)	Straightness (Visualscore) 1-5	Roundness (Visualscore) 1-5
NAU-01	108.20	7.75	15.30	0.51	4	3
NAU-02	129.10	5.50	17.50	0.31	3	3
NAU-03	151.40	5.20	20.70	0.25	3	4
NAU-04	141.10	6.80	18.50	0.37	4	4
NAU-05	148.60	10.10	16.50	0.61	4	4
NAU-06	132.20	7.40	20.10	0.37	3	4
NAU-07	131.30	8.40	25.60	0.33	5	4
NAU-08	120.70	6.60	18.20	0.36	4	3
NAU-09	136.30	5.60	18.50	0.30	4	3
NAU-10	104.20	5.80	14.20	0.41	4	4
NAU-11	165.10	8.10	26.20	0.31	3	3
NAU-12	101.80	6.80	18.80	0.36	4	4
NAU-13	106.70	10.80	20.00	0.54	4	4
NAU-14	156.20	7.50	22.20	0.34	4	3
NAU-15	155.10	10.50	25.40	0.41	5	4
NAU-16	105.30	10.10	24.20	0.42	4	4
NAU-17	166.10	7.10	24.80	0.29	4	4
NAU-18	129.60	7.40	26.10	0.28	4	4
NAU-19	103.90	5.10	20.00	0.26	4	4
NAU-20	170.20	5.30	17.20	0.31	4	4
Min.	101.8	5.10	14.2	0.25	3	3

CPT No.	Girth at breast height (GBH in cm)	Clear bole height (CBH in m)	Tree height (TH in m)	CBH:TH (m)	Straightness (Visualscore) 1-5	Roundness (Visualscore) 1-5
Max.	170.2	10.8	26.2	0.61	5	4
Mean	133.15	7.39	20.5	0.367	3.9	3.7
SE±	5.16	0.41	0.84	0.02	0.12	0.11
CV%	17.31	24.59	18.34	25.85	14.17	12.71

2.1.4 Selection Indices Method

Selection indices for each trait are developed for the selection of plus trees. The development of selection indices is a difficult process and requires information on the economic value of traits of interest, genotype, phenotypic variance and co-variance for these traits. It is difficult to ascertain the economic value of a trait, which fluctuates over the period. If the information on these aspects is available, selection indices can be developed for the selection of plus trees. The component characters are combined into a score or index. Selection is then applied to the index as if the index is a single character. The index is derived by multiple regression equation.

For two characters X and Y, the index will look like I = Px + WPy. Where I is the index by means of which individuals are to be chosen, W is a factor by which the phenotypic value of character y is to be multiplied and Px and Py are phenotypic values measured as deviations from the population mean. For detailed methods, any standard book on quantitative genetics may be consulted. Though it is a difficult method, the selection of a plus tree by this method is very effective as it is based on both genetic information and the economic value of a trait. However, the use of a selection index where economic weights are not properly assigned can lead to the erroneous selection of individuals. This method is used rarely in the selection of plus trees.

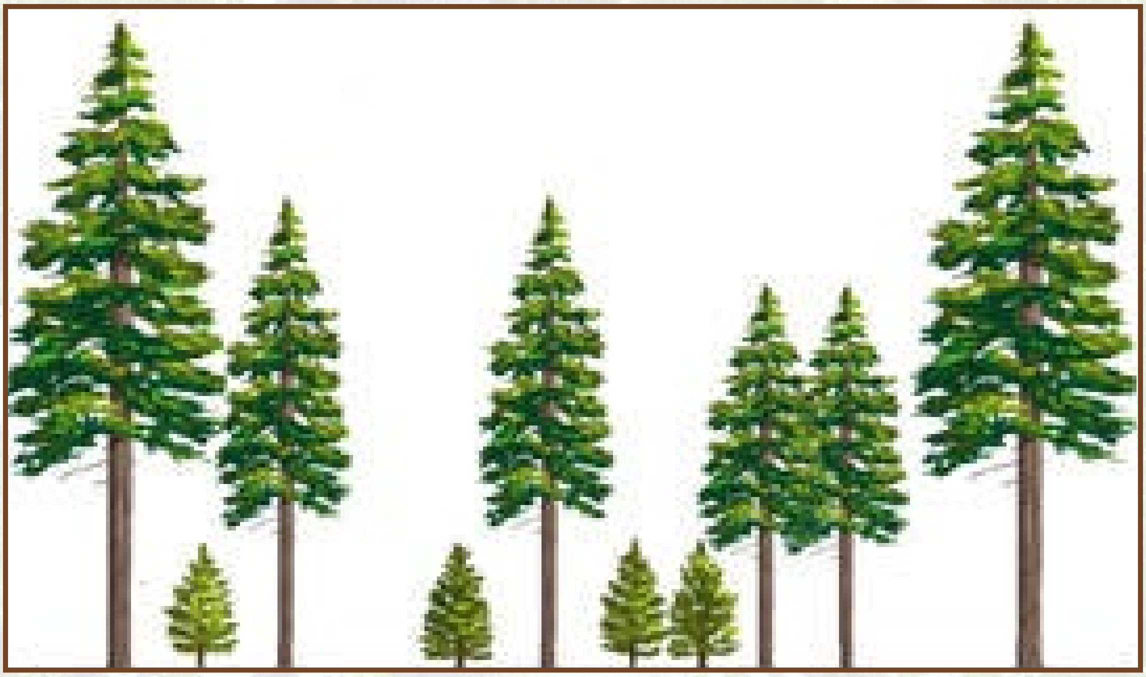
2.2 Selection in Uneven-Aged, Mixed Species, or Stands of Sprout Origin

Forest stands are quite often not even aged, trees are scattered and desired species are unavailable to be checked. This condition is most common for hardwood trees. A comparison tree selection system will not work in this case. This is by far the most common situation that requires a grading system other than the comparison tree method.

The comparison tree system does not work when trees are growing in all-aged stands. Since growth curves within a species vary with age, it is not suitable to use ratios such as height or diameter growth per unit of time for comparison purposes. In addition, the form of the tree often changes drastically with age. Therefore, even quality characteristics cannot be compared among trees of different ages from uneven-aged stands. Many foresters make the mistake of assuming that stands containing trees of varied sizes are all aged. The major exception to this generalization that forests are usually even-aged is when stands have been manipulated by humans into an all-aged condition by selective cutting. Even within the true uneven-aged stands, there is a tendency for a storied age class to be present.

Trees sometimes grow in mixed stands with relatively few individuals of a given species found in a specific area. This condition is most common for hardwoods. A comparison tree selection system will not work in this case because the scattered individuals of a species are growing under different environments.

This is by far the most common situation that requires a grading system other than the standard comparison tree method.



Uneven-aged stand.

Source: *forestypedia.com*, 2018

The importance and frequency of relatedness among trees from stands of sprout origin are often not understood. Usually, sprouts from a single tree are limited to those individuals that are adjacent to the tree, but, sometimes, sprouts from a common root system can be quite extensive. When stands of sprout origin are large enough and of sufficient genetic diversity to enable the use of a comparison tree system, the check trees must be carefully chosen so that they will not be related to the candidate tree. This is sometimes difficult to do accurately.

Stands composed partially of sprouts and partially of seedlings also pose the problem of growth differential between trees from sprout and seedling origin. Initially, sprouts usually grow much faster than seedlings because of the established root system and stored food. However, sprouts often culminate in growth at a younger age than seedlings. After a few years, it commonly becomes impossible to distinguish sprouts from seedlings, but selection results will not be good if the two types of trees are mixed.

Different selection methods used in uneven-aged stands are:

2.2.1 Regression selection method

2.2.2 The mother tree system

2.2.3 The subjective grading system

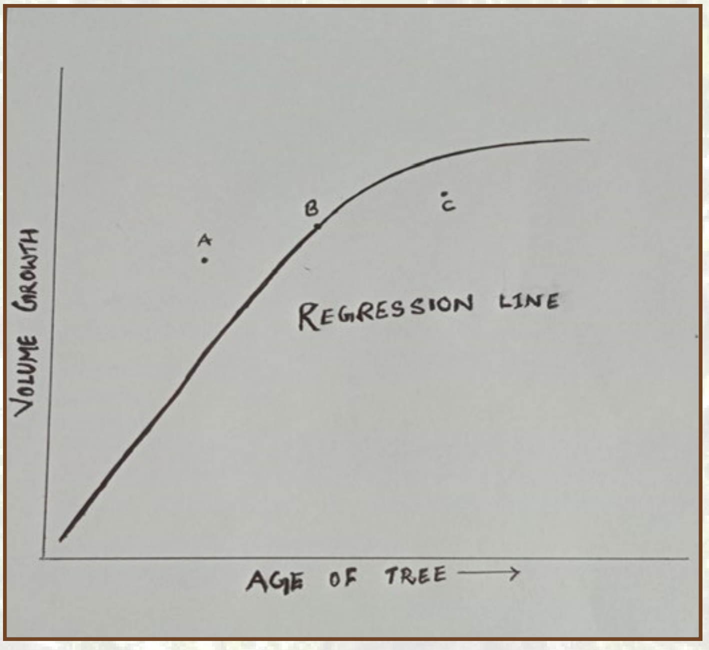
2.2.4 Baseline selection method

2.2.1 The Regression Selection Method

The most useful method of tree grading for the uneven-aged or mixed species type stands described previously is the regression system. This requires the development of tables relating the characteristic of interest to tree age. A regression selection system is built by sampling a number of trees for desired characteristics, such as volume growth on a given site and then plotting them against age.

Once the curve has been made, the regression is as follows:

- ✓ A candidate tree is chosen, based on the judgment of the selector and measured for the characteristics desired, such as height or volume.
- ✓ The trait is plotted on the regression graph using the proper age and site. If the candidate tree falls at some defined distance above the regression line, it is acceptable and the higher above, the more desirable it becomes. When the value of the characteristics falls below the acceptable level, the tree is rejected.
- ✓ The regression line should be based on at least 50 trees if the age spread is considerable.
- ✓ The regression selection system is more difficult to use than the comparison tree method, but there is no doubt that it will become more commonly employed as hardwood tree improvement becomes more widely practiced.



It is observed that species A lies above the regression line which suggests it to be chosen as candidate plus tree.

Species B also lies in the regression line which also suggests it to be considered as candidate plus tree.

Species C lies below the regression line which makes it clear that it cannot be selected as candidate plus tree.

Figure 1. Volume growth of species A, B and C against the age of the trees

EXAMPLE OF REGRESSION SELECTION METHOD

Diversity assessment and selection of candidate plus trees of *Ailanthus triphysa* in Kerala using regression line method

Plus trees of *Ailanthus triphysa* trees were selected from the natural populations of the different panchayat of Kerela. The trees were enumerated and the location was marked using Global Positioning System (GPS). Trees above 45 cm girth at breast height were surveyed at the selected panchayats. The tree height was measured using Laser Hypsometer and expressed in meters (m). The girth at breast height (GBH) was measured using tape at 1.37 m. The diameter of the crown was measured as the average of the two diameters. The first axis was measured at the broadest portion of the crown and the diameter perpendicular to this was measured as the second axis. The average of these two diameters was considered as the crown diameter. The length of the bole was measured from the ground level to the point of first branching, *i.e.*, the first living branch that forms part of the crown of the tree. The crown length was estimated as the total height of the tree minus the crown base height. Crown volume was estimated as:

$$\textit{Crown Volume} = CD^2 \times l$$

where CD represents the crown diameter of the tree and l, crown length.

$$\textit{Crown Volume} = \left(\frac{0}{2}\right)^2 x\, l$$

Trunk volume was calculated as Quarter's girth formula,

Where g is the girth of the tree at breast height and l is the height of the tree.

Clean bole straightness, cross-section, swellings, branching habit, branch angle, apical dominance, forking, self-pruning ability, foliar and stem damage were recorded. The variations in the qualitative traits were determined using the scoring method developed. A total of 255 trees were identified for assessing the variability.

Thirty plus trees were selected using the baseline regression method. For this, the regression of trunk volume vs crown volume was determined. Trees above the regression lines were initially selected as plus trees and below were rejected. Among the trees falling above the regression line, those having the highest score of qualitative characteristics were selected following the scorecard.

Variation in morphological characters of *Ailanthus triphysa* trees from selected panchayaths

No. of panchayat	No. of trees	Height (m)			GBH (m)			Crown width (m)			Clean bole height (m)			Score		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
I	24	14	26	20.5	0.5	1.1	0.7	2	8.0	4.9	4	17	10.6	27	46	33.3
II	25	16	28	21.0	0.6	0.9	0.6	2.5	8.5	4.3	8	18	13.3	23	48	33.7
III	26	16	37	26.5	0.5	1.3	0.9	3.5	8.5	6	7	24	16.7	21	48	33.8
IV	30	13	37	28.7	0.5	2.0	1.0	2.5	11	6.6	6	24	15.2	21	47	32.1
V	25	15	33	25.2	0.5	1.7	1.0	2.5	9.5	5.1	4	21	14.2	22	48	32.3
VI	26	15	28	20.2	0.5	1.3	0.7	1.8	9.9	3.7	3	18	8.1	18	46	31.5
VII	22	17	27	23.1	0.5	1.1	0.8	2.2	7.5	4.2	6	19	13.0	23	48	34.1
VIII	25	21	34	27.1	0.6	1.9	1.2	2.5	9.5	6	13	23	18.3	20	48	32.3
IX	26	16	35	25.3	0.5	1.1	0.8	2.5	7.5	4.5	7	24	16.4	20	48	33.0
X	26	10	23	17.9	0.5	2.2	0.9	1.5	10.5	4.7	3	18	10.2	24	45	31.4

In this investigation, thirty candidate plus trees were selected from selected different panchayat of Kerala using a baseline regression system combined with a scoring of qualitative traits. Details of thirty selected CPTs are given in the above table. The variation in tree height was in the range of 21 m to 37 m. The average tree height measured for the plus trees was 28.7 m. The standard deviation for tree height was 4.76 m and, the coefficient of variation was 16.89 percent. The variation in girth at breast height was in the range of 0.5 m to 2.2 m. The average girth estimated was 1.20 m. The standard deviation and coefficient of variation of GBH were 0.36 m and 29.84 percent, respectively.

The average crown width for CPTs was 6.6 m and, the variation ranged from 3.5 m to 9.9 m. The standard deviation for crown width was 1.93 m and, the coefficient of variation was 30.34 percent. A wide range of variation is observed in clean bole height, i.e., 3 m to 24 m. The average clean bole height for all the CPTs was 18.3 m. The standard deviation and coefficient of variation of clean bole height were 4.20 m and 24.19 percent, respectively. The selection of plus trees is an essential tool for the genetic improvement of a tree.

2.2.2 The Mother Tree System

When there is no immediate urgency to obtain large amounts of improved seed, the mother tree system of selection may be best. It consists of locating "good" trees that are usually not as good as select trees in the comparison tree or regression systems. Then, one must obtain seeds from these and establish seedlings in the genetic tests. After this, either the best parent trees or the best trees of the best families can be used in a vegetative orchard. If suitably laid out, the progeny test may be thinned to create a seedling seed orchard.

The main disadvantage of the mother tree system is that time is lost before commercial quantities of seed are needed for planting programmes. However, this can be used for hardwoods for which planting programmes are small and seeds are not immediately needed.

How to Select Good Mother Trees

Prior to seed collection, there is a need to select and mark good mother trees. These are the trees you will use as sources of high-quality seed. Here are the major characteristics that determine a good mother tree:

1. Healthy and free of diseases and insects
2. Nearly mature
3. Good producers of the desired product
4. Growing in the midst of a healthy stand of the same species.

A tree's off-spring will usually resemble its mother therefore

- If you want straight trunks, choose a straight-trunked mother tree.
- For a multi-trunk fodder tree, select multi-trunk mother trees.
- For trees which tolerate drought, or flooding, select good looking mother trees from dry or flooded sites, etc.

For timber trees:

- Mother trees should be fast-growing, very straight and have few thin branches

For fodder, good mother trees should:

- Be fast-growing.
- Have many branches.
- Have several trunks.
- Grow new leaves quickly after fodder harvesting.

Note: *Trees that have leaves all year round produce more fodder than those which lose their leaves part of the year.*

The most important factors in selecting mother trees for fodder are:

- Fast production of leaf matter and pods is preferred by local animals.
- The ability of the tree to recover after cutting.

For fruit trees:

- Collect seeds from trees of local varieties producing good quantities of tasty, healthy fruit of marketable size.
- Low-branching trees may be preferable as mother trees. It is easy to pick fruits from low branches.

2.2.3 The Subjective Grading System

The subjective grading system is possible if the grader must know what constitutes a good tree. The subjective grading system is frequently used for hardwoods but is successful only if the grader is experienced and dedicated to find the best trees possible.

This subjective grading system is frequently used for hardwoods but is successful only if the grader is experienced and dedicated to finding the best tree possible. To minimize the problem of deviation caused by technical errors or prejudices when selecting candidates, the survey team is composed of experienced researchers who standardized the research method before starting work.

EXAMPLES OF SUBJECTIVE GRADING METHOD

The study was conducted to select plus trees of two evergreen oaks, *Quercus salicina* and *Q. glauca*, in Korea. Evergreen oaks are distributed in subtropical regions in Korea and have recently emerged as one of the alternative tree species against climate change. Accordingly, a tree breeding program is underway to foster evergreen oaks as a reforestation species for the future. Through an intensive survey of the distribution range, 15 stands (8 for *Q. salicina*, 3 for *Q. glauca*, and 4 for both species) were selected as base populations. To select candidate trees, we developed a subjective grading system with six characteristics in three categories and introduced a weighted generalized value (GVIw) to compare the superiority of candidate trees. The candidate trees were screened using baseline value '0', i.e., if GVIw > 0, then accepted and if GVIw < 0, then rejected. After then, adjustment was conducted to avoid biasing the selection of plus trees for a particular location. Through this process, 44 candidate trees in *Q. salicina* and 41 candidate trees in *Q. glauca* were selected as plus trees. Finally, the results and implications were discussed in relation to evergreen oak breeding in Korea.

To select candidate trees, we developed a subjective grading system with six characteristics in three categories. Each characteristic was rated and scored as 5 grades, i.e., 5 - very good, 4 - good, 3 - moderate, 2 - poor and 1 - very poor. The grade was given by relative superiority or degree compared to the average of the stand.

For the selection of the base population, priority was given to whether there were enough individuals to perform selection and whether there were candidate trees that met the selection criteria. For example, a stand with a small size and no available candidate trees was excluded.

Although the primary goal of this study was to select plus trees, the conservation aspect was also considered. Nevertheless, we cannot be sure that enough genetic diversity will be included in a breeding population. Thus, additional studies are required to evaluate genetic diversity, i.e., a comparison of genetic diversity between natural stands and candidate trees including rejected trees. If genetic diversity is lower than expected, adding some rejected trees to the breeding population may be an option.

Through the adjustment process, 44 candidate trees in *Q. salicina* and 41 candidate trees in *Q. glauca* were finally selected as plus trees. In order to compare the selection effect of the plus tree, the mean values of six characteristics, height and diameter growth between the accepted group (plus trees) and the rejected group were compared. On average, the accepted group was excellent in all characteristics in both species, i.e., 103.2~112.9% *in Q. salicina* and 105.0~112.8% in *Q. glauca*.

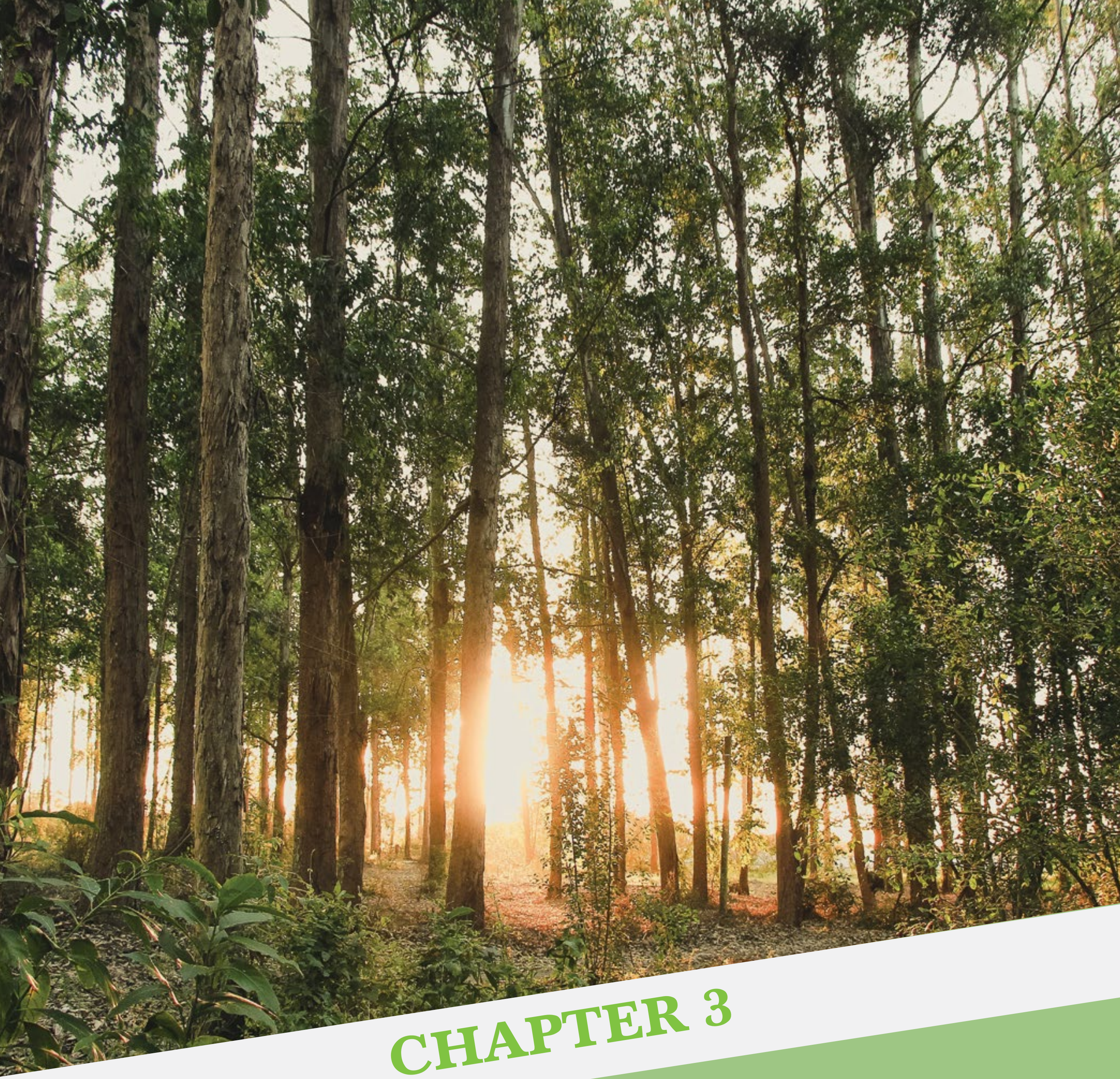
2.2.4 Base Line Selection Method

Base line selection method - Scores are allotted based on the measurement of a dependent and independent variable (e.g. height and age) on 20 - 25 dominant and co-dominant trees in a particular stand. Trees with higher scores as compared to the neighboring trees are considered as CPTs.

The base value method is used in uneven - aged stands for those traits, which are not much affected by the environment including age difference among the trees because of strong genetic control of the characters such as stem straightness, branching habit, disease resistance, wood density, etc.

A base value (average value) for such traits is prepared for each stand. The values of candidate trees for different traits are compared and a candidate tree is either selected as plus tree or rejected.

In its most simply applied form, individuals are located and their value for traits of interest is compared to the average for the region in which the selection is made. The average is a "base-line," giving the system its more common name, base-line selection. If the candidate exceeds the baseline by an arbitrary amount, it is selected and incorporated into the breeding population. The baseline may take the form of a regression equation relating height or diameter to age but it could even be a multiple regression equation that takes into account physical factors of the site such as soil texture and drainage. The candidate tree is not compared directly to surrounding trees of the same species.



CHAPTER 3

Selection of Candidate Plus Trees

1. Desired Characters for Timber Species and/or Bark as an Economic Part
2. Desired Characters for Fruit and Fodder Species and/or Species Having Seed or Leaf as a Commercial Part
3. Data Collection of Candidate Plus Trees

For the selection of plus trees, mainly four steps have to be followed in this method:

1. Selection and data recording of Candidate Plus Trees.
2. Convergence of all quantifiable and scored traits in one scale.
3. The weighted score of CPTs according to their commercial use.
4. Screening and marking of plus trees.

The basis for the selection of a plus tree depends on phenotypic superiority. As per the requirement of selection, there are certain desired characters for trees and accordingly, the trees are selected.

3.1 Desired Characters for Timber Species and/or Bark as an Economic Part

While selection in the field has to be made for any timber species, the following points should be taken into consideration:

- ✓ The tree must have straight, cylindrical, non-forking, non-twisting bole.
- ✓ The stem should have a circular cross-section without excessive taper.
- ✓ The tree need not be infected by any pests and diseases.
- ✓ The tree must have a long clear bole and small crown height.
- ✓ The age must be more than half of the rotation age.
- ✓ It should be free from pronounced buttress and fluting.
- ✓ The tree should be vigorous, healthy and show superiority in height and diameter compared to other trees of the same species in the surroundings.
- ✓ There should be an absence of spiral grain.
- ✓ It must have good natural pruning, none or few epicormic branches.
- ✓ It is not suppressed either from the top or from the sides.
- ✓ There should be moderate to good flowering and fruiting.

Table 1: Datasheet for Timber Species

CANDIDATE PLUS TREE DATASHEET

Species Name: ……………………………… **CPTID: ………………………**

Location

State	Division
Range	**Beat**
Compartment/ Mauja/ Plot No.	**Altitude**
Latitude	**Longitude**

Stand and Site Characteristics

Stand Type	Terrain
Vegetation	

Tree Characteristics

Quantifiable	Scored
Total Height (m)	<u>Stem Straightness</u>
Clear Bole Height (m)	>4/5 of total height – 10
Girth at Breast Height (m)	>3/5 of total height – 08
	2.5/5 - 3/5 of total height = 6
Crown Height (m)	<u>Stem Form</u> (Circularity)
Crown Width (m)	Circular and less taper – 10
	Moderate circular and less taper – 08
	Moderate circular and more taper - 06
Number of Branches	<u>Branching Habits</u>
	Branch angle of 75^0-90^0– 10
	Branch angle of 60^0-75^0– 8
	Branch angle of 45^0-60^0– 6
	Disease and Insect Pest Symptoms
	Nil – 10
	Slightly infected (<10 %) – 08
	Moderately infected (10 - 20 %) - 06
App. Age	Data Collection Date
Data Collected By	

Figure 2: Shorea robusta as timber species having straight, long clear bole

Table 2: Major Timber Species of Odisha State

Sl. No.	Botanical Name	Local Name	Family
1	*Careya arborea*	Kumbhi	Barringtoniaceae
2	*Mitragyna parvifolia*	Mundi	Rubiaceae
3	*Terminalia alata*	Asana	Combretaceae
4	*Terminalia arjuna*	Arjuna	Combretaceae
5	*Bridelia retusa*	Kasi	Euphorbiaceae
6	*Dalbergia sissoo*	Bali sissoo	Fabaceae (Papilionaceae)
7	*Pterocarpus marsupium*	Bija Sal	Fabaceae (Papilionaceae)
8	*Lagerstroemia parviflora*	Sidha	Lythraceae
9	*Xylia xylocarpa*	Kangada	Mimosaceae
10	*Acacia catechu*	Khaira	Mimosaceae
11	*Adina cordifolia*	Kurum	Rubiaceae
12	*Gmelina arborea*	Gambhari	Verbenaceae
13	*Anogeissus acuminata*	Phasi	Combretaceae
14	*Anogeissus latifolia*	Dhaura	Combretaceae
15	*Pterocarpus santalinus*	Rakta chandan	Fabaceae
16	*Michelia champaca*	Champa	Magnoliaceae
17	*Pterospermum heyneanum*	Giringa	Sterculiaceae

3.2 Desired Characters for Fruit and Fodder Species and/or Species Having Seed or Leaf as a Commercial Part

- ✓ The tree should be vigorous, healthy and show superiority in height and diameter compared to other trees of the same species in the surroundings.
- ✓ The tree need not be infected by any pests and diseases.
- ✓ It must have a large and wide crown with a dense mass of healthy foliage.
- ✓ The age must be more than half of the rotation age.
- ✓ It should be free from pronounced buttress and fluting.
- ✓ It is not suppressed either from the top or from the sides.
- ✓ There should be moderate to good flowering and fruiting.

Table 3: Datasheet for fruiting, Flowering and Fodder Trees

CANDIDATE PLUS TREE DATASHEET

Species Name: ……………………………… **CPT ID: ……………………….**

Location

State	Division
Range	Beat
Compartment/ Mauja/ Plot No.	Altitude
Latitude	Longitude

Stand and Site Characteristics

Stand Type	Terrain
Vegetation	

Tree Characteristics

Quantifiable	Scored
Total Height (m)	***Crown***
Clear Bole Height (m)	Dense -10
Girth at Breast Height (m)	Moderately dense-08 Less dense - 06
Crown Height (m)	***Flowering***
Crown Width (m)	More than 90% - 10 75%-90% - 08 60%-75% - 06
Number of Branches	***Branching Habits*** Branch angle of 75^0-90^0– 10 Branch angle of 60^0-75^0– 8 Branch angle of 45^0-60^0– 6 ***Disease and Insect Pest Symptoms*** Nil – 10 Slightly infected (<10 %) – 08 Moderately infected (10 - 20 %) - 06
App. age	Data Collection Date
Data Collected By	

Table 4: Major Fruit/Fodder Tree Species of Odisha State

S. No.	Botanical name	Local Name	Family
1	*Buchanania cochinchinensis*	Chara	Anacardiaceae
2	*Terminalia bellirica*	Bahada	Combretaceae
3	*Terminalia chebula*	Harida	Combretaceae
4	*Phyllanthus emblica*	Amla	Euphorbiaceae
5	*Pongamia pinnata*	Karanja	Fabaceae (Papilionaceae)
6	*Artocarpus heterophyllus*	Panasa	Moraceae
7	*Syzygium cumini*	Jamun	Myrtaceae
8	*Aegle marmelos*	Bela	Rutaceae
9	*Madhuca indica*	Mahula	Sapotaceae
10	*Mesua ferrea*	Nageswar	Clusiaceae
11	*Cleistanthus collinus*	Karada	Euphorbiaceae
12	*Morinda tinctoria*	Achhu	Rubiaceae
13	*Grewia tiliifolia*	Dhaman	Tiliaceae

There are certain trees that are useful for specific purposes such as lac cultivation, dye, gum, resin, flosses, medicinal value, etc. For such trees selection criteria also depends on the production of valuable products.

Table 5: Datasheet for Trees having Commercial Value for Gum, Dye, Resin, etc.

CANDIDATE PLUS TREE DATASHEET

Species Name: ………………………… **CPT ID: ……………………**

Location

State	Division
Range	Beat
Compartment/ Mauja/ Plot No.	Altitude
Latitude	Longitude

Stand and Site Characteristics

Stand Type	Terrain
Vegetation	

Tree Characteristics

Quantifiable	Scored
Total Height (m)	***Crown*** **Dense -10** **Moderately dense-08** **Less dense - 06**
Clear Bole Height (m)	
Girth at Breast Height (m)	
Crown Height (m)	***Production of gum, resin, lac, etc.*** **High - 10** **Medium -08** **Low -06**
Crown Width (m)	
Number of Branches	***Branching Habits*** **Branch angle of 75^{0}-90^{0}– 10** **Branch angle of 60^{0}-75^{0}– 8** **Branch angle of 45^{0}-60^{0}– 6**
	Disease and Insect Pest Symptoms **Nil – 10** **Slightly infected (<10 %) – 08** **Moderately infected (10 - 20 %) - 06**
App. Age	**Data Collection Date**
Data Collected By	

3.3 Data Collection of Candidate Plus Trees

Data on phenotypic characters has to be collected for each candidate plus tree along with the location details. These characters may also be changed as per the requirement of selection.

Data on the following traits will be collected:

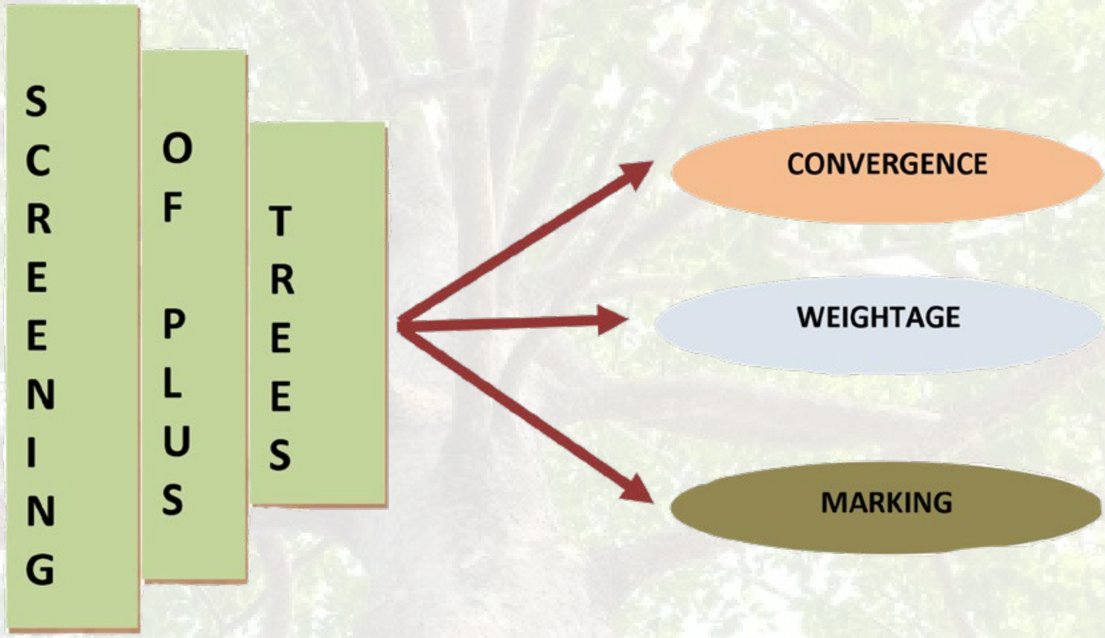
1. Quantifiable Traits
   - I. Total height
   - II. Clear Bole Height
   - III. Girth at Breast Height
   - IV. Crown Width
   - V. Crown Height
   - VI. Number of Branches
2. Scored Traits
   - I. Stem Straightness
   - II. Crown
   - III. Flowering
   - IV. Branching habit

CHAPTER 4

Screening of Plus Trees

1. Convergence of All Quantifiable and Scored Traits in One Scale
2. Weighted Score of CPTs According to its Commercial Use
3. Screening and Marking of Plus trees

After selection and data recording, screening of trees is important for the final selection of plus trees. Screening is done by converging quantifiable and non-quantifiable data in one scale and further giving them a weighted score. This weighted score decides the final marks allotted to each candidate tress.



4.1. Convergence of All Quantifiable and Scored Traits in One Scale

Data collected is of two types, quantifiable and non-quantifiable. For analysis, the data must be on one scale. It can be done by two methods:

1. By taking class intervals of traits.
2. By taking the average of traits.

1. By Taking Class Intervals of Traits

Method to find out class interval

$$\text{Number of Classes} = \frac{\text{Range of Scores}}{\text{Length of class-interval}} = \frac{R}{h}$$

- The formula can also be used to decide about the length of class interval or h if we know the range of scores and number of classes used in grouping.

$$\text{Length of class interval or } h = \frac{R}{\text{No. of classes}}$$

- Having determined the length of the class interval and No. of classes, one must decide where to start the classes.
- After writing the class intervals in ascending order from bottom to top and putting tallies against the concerned class interval, scores are given for each class interval.

  As non-quantifiable traits are scored out of 10, hence quantifiable traits will also be converted into scores that will be out of 10. 5 class intervals will be made for each trait and a corresponding score will be given.

  For example, the tree having a height from 16 to 16.9 will be scored as 6 and the tree with a height from 17 to 17.9 will be scored as 7. In the same way, a tree consisting of a crown width between 3 to 4 cm will be scored 6 while a tree having a crown width between 4.1 to 5 will be scored as 7.

Table 6: Example of Class Interval for Different Traits with Given Scores

Height Interval	Score	Clear Bole Height Interval	Score	Girth at Breast Height Interval	Score	Crown Height (m)	Score	Crown Width	Score
16-16.9	6	11-12.2	6	0.6 - 0.7	6	2.0– 3.0	6	3.0 -4.0	6
17-17.9	7	12.3-13.5	7	0.71-0.8	7	3.1– 4.0	7	4.1– 5.0	7
18-18.9	8	13.6–14.8	8	0.81-0.9	8	4.1-5.0	8	5.1– 6.0	8
19-19.9	9	14.9–16.1	9	0.91-1.0	9	5.1-6.0	9	6.1– 7.0	9
20-21	10	16.2–17.4	10	1.1-1.2	10	6.1- 7.0	10	7.1– 8.0	10

2. By taking the average of traits

Following are the traits that are considered for evaluating candidate plus trees and the results of the evaluation should be recorded in plus tree recording form.

1. VIGOUR (25 points possible)

Height and diameter are considered under vigour. Measurements of these characters are taken both on the candidate and comparison trees. The comparison tree average is then used to score the candidate tree.

a. Height (15 points)

Take measurements of the candidate tree. Take measurements of all the check trees and calculate the mean or average. Score the candidate tree based on this average in the following way:

- ✓ 0-4 points for less than average.
- ✓ 5-10 points for more than average.
- ✓ 11-12 points for more than average but shorter than the tallest check tree.
- ✓ 13-15 points for taller than the tallest check tree.

b. Diameter (10 points)

Diameter or girth at breast height be measured as in case of height and point be awarded as follows:

- ✓ 0 - 2 points for smaller than average.
- ✓ 3 - 5 points for equal to average.
- ✓ 6 - 8 points for between the average and largest check.
- ✓ 9 - 10 points for more than the largest check tree.

2. BOLE FORMS (20 points possible)

The candidate tree is scored subjectively based on ocular observation with reference to check trees. Maximum points are given if a tree is perfectly straight and less taper. The appropriate point should be deducted for abnormality in stem form as follows:

- ✓ Deduct 1 - 3 for basal sweep.
- ✓ Deduct 1 - 5 for trunk bends, spiral.
- ✓ Deduct 1 - 5 for trunk curves.
- ✓ Deduct 1 - 3 for cross-section not circular.
- ✓ Deduct 1 - 3 for detectable bole swelling.

3. BRANCHING HABITS (25 points possible)

a. Branch angle (15 points)

Trees with flat angles are preferred. The angle between the main stem and the third branch is measured and points are given :

- ✓ 15 points for a branch angle of 80°- 90°
- ✓ 13 points for a branch angle of 70° - 80°
- ✓ 10 points for a branch angle of 60° - 70°
- ✓ 06 points for branch angle of 50° - 60°
- ✓ 02 points for branch angle of 40° - 50°
- ✓ 00 points for a branch angle of < 40°

b. Branch thickness (10 points)

Trees with thinner branches for average branch thickness and subjectively scored as under:

- ✓ 10 points for less than 1/4 of the main stem
- ✓ 7-9 points for 1/4 to 1/3 of main stem
- ✓ 4-6 points for 1/3 to 1/2 of main stem
- ✓ 0-3 points for more than 1/2 of the main stem

4. CROWN (5 points possible)

Trees with well-formed and balanced crowns should be selected. Generally, trees with narrow crowns are preferred; however, in certain species, a wide crown is preferred. Maximum points may be awarded if the crown is balanced. 1 to 2 points may be deducted if the crown is not balanced due to excessive branch length.

5. APICAL DOMINANCE (10 points possible)

Measure the length to the first live branch i.e. clear bare length. Record as a percentage of total height.

- ✓ 10 points for over 70 %
- ✓ 7-9 points for 55 - 70 %
- ✓ 4-6 points for 40 - 54 %
- ✓ 1-3 points for 25 - 39%
- ✓ 0 points for below 25%

6. FORKING (5 points possible)

- ✓ 5 points for forking above 10 meters from the ground
- ✓ 3-4 points for forking from 5 - 10 meters from the ground
- ✓ 1-2 points for forking below 5 meters from the ground.

7. HEALTH (10 points possible)

Candidate trees are expected to be healthy and free from disease or insect attack. Points should be deducted for evidence of pests, dead-top, insect boring, rotten knots, etc.

8. WOOD PROPERTIES (30 points possible)

Candidate trees are expected to have higher specific gravity and longer fiber length than the average for a certain geographic location. Core wood property analysis may be done as described in the main text. Candidate trees are scored as given below:

(The assessment of wood properties is optional as it relates to the end-user objectives of the organization. However, these are important traits for pulpwood and timber production).

9. SPECIFIC GRAVITY (20 points)

- ✓ 15-20 points for above average
- ✓ 10-14 points for average
- ✓ 5-9 points for light
- ✓ 0-4 points for very light

10. FIBER LENGTH (10 points)

- ✓ 5-10 points for above average
- ✓ 3-4 points for average
- ✓ 0-2 points for short

4.2. Weighted Score of CPTs According to its Commercial Use

After converging all the data weights are given to each trait according to its commercial use.

Two conditions are taken here:

a. X species as a timber species OR

b. X species is a fruit-yielding species

In the case of timber species, tree traits like Girth at Breast height, clear bole height along with total height, straightness and tree form are of interest and weightage will be given accordingly as follow (out of 10):

Table 7: Example of Different Timber Tree Traits Allotted with Varying Weightage

Sl. No.	Tree Trait	Weightage
1	Total height	1.5
2	Clear Bole Height	2
3	Girth at Breast Height	2
4	Crown Height	0.25
5	Crown Width	0.25
6	Number of Branches	0.25
7	Stem Straightness	1.5
8	Stem Form	1.5
9	Infection	0.75

If a species is a fruit-yielding or fuel wood or fodder species, the weightage criteria will be changed. Fruit yield will depend on the crown characteristics and number of branches. Hence accordingly weightage has been provided as follows:

Table 8: Example of Different Fruit/ Fodder Tree Traits Allotted with Varying Weightage

Sl.No.	TreeTrait	Weightage*
1	Total Height	1.0
2	Clear Bole Height	0.5
3	Girth at Breast Height	1.0
4	Crown Width	1.5
5	Crown Height	1.75
6	Number of Branches	1.75
7	Stem Straightness	0.5
8	Crown	1.0
9	Infection	1.0

For unbiased selection, weightage is given to different traits as per the requirement. For example, branch angle has more weightage if the selection of plus tree is for fruit production whereas trunk straightness is allotted with more weightage if the selection is for timber production. Further, the allotted weightage for each trait is multiplied by the scored mark for obtaining an unbiased final score.

4.3. Screening and Marking of Plus trees

Marking of candidate plus trees:-

The selected trees are marked with yellow/red bands of 5cm width, 5 cm above the breast height and given a candidate tree number of the Division as the first set of two letters will indicate Division, the second set of two letters as Range, the third two letter genus and species and lastly the tree number in a division (DD/RR/GS-01).

Screening and Marking of plus trees:-

As we get the weightage score of each candidate tree, the tree whose score is more than the average score of the population can be screened as plus tree (only 1 plus tree per hectare). When a candidate tree is finally approved as plus tree, another yellow band/red band of 5 cm width, 5 cm below the breast height is marked. In between the yellow bands plus trees, the number is written. The Geo coordinates of the plus tree recorded earlier are checked and entered in the plus tree register for future reference and maintenance. However, geotagging is more preferred now a days due to its longevity when compared to the painted bands.

Figure 3: Marked candidate plus tree

CHAPTER 5

General Precautions for Candidate Plus Tree Selection

1. A systematic search for plus tree selection must concentrate on average or good stand.
2. Selection should be done from uniform age and site conditions, similar to where the plantation will be established.
3. Isolated trees or border trees in a stand should be excluded.
4. Age of tree should be more than half of the rotation age but less than the rotation age of the species.
5. No more than 3 to 4 selections per hectare should be preferred.
6. Candidate tree should be selected from upper crown in a stand.
7. Comparison tree should be selected from the near vicinity of the candidate tree.
8. The candidate free should be 5% superior in height and 20% in dbh.
9. The candidate tree must be free from apparent pest and disease damage.

10. Stem should not have crooked bole.

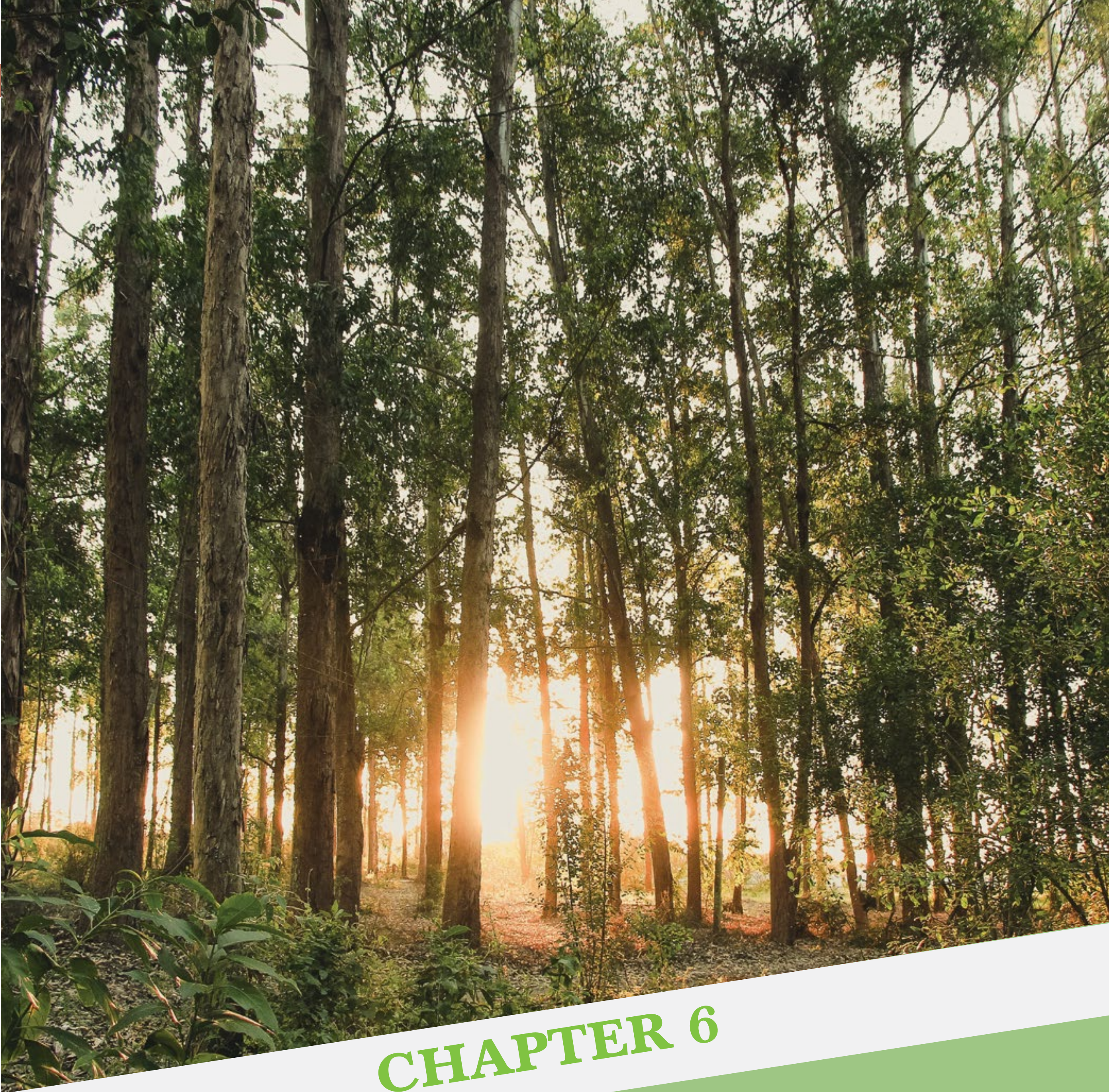
11. Trees should have good seed production capacity.

12. Select few trees (30-40) from large part of species-distribution range with utmost care to avoid the extra environmental advantage.

13. Traits of economic significance should be determined by the objective of plus tree selection.

14. Traits for selection should be arranged according to economic priority in descending order.

15. Record the ownership, geographical information and map of the area of plus tree selection.



CHAPTER 6

Methodology for Measurement of Quantitative Characters

1. Measurement of Girth and Diameter
2. Measurement of Height
3. Measurement of Branches and Crown Diameter

6.1. Measurement of Girth and Diameter

Linear measurement is a fundamental measurement for the selection of plus trees. It can be made either directly or indirectly by measuring the line joining two points. In forestry linear dimensions of a tree includes diameter and girth, height, crown width, length of the commercial bole and length of bole containing standard-timber. Breast height (B. H. or b.h.) is defined as an almost universally adopted standard height for measuring girth, diameters and basal area of standing trees. In India, Burma, America, the Union of South Africa, Malaya and some other former British Former colonies it is taken as 1.37 m (4 feet 6 inches) above ground level. There are certain reasons for considering breast height as the standard height for girth measurement such as:

- ✓ It is a convenient height for taking measurements and therefore avoids the fatigue unnecessarily caused by taking a large number of measurements at any other lower or higher point.
- ✓ The base of the tree is generally covered with grasses and shrubs and even thorns so the measurement of diameter or girth at the base is generally very difficult without incurring extra expenditure in clearing the base.
- ✓ The majority of the trees develop root swell near the base. This results in abnormal formation from ground level to a certain height along the bole. These abnormalities depend upon the species and the conditions of the ground on which the tree grows. However, in most cases, these abnormalities disappear below breast height.
- ✓ It gives a uniform point of measurement and therefore standardizes the diameter measurements of trees.

6.1.1 Method of Describing Diameter Measurements

The diameter or girth measurements are referred to as D.B.H (or d.b.h.) or G.B.H (or g.b.h) respectively. Unless otherwise stated, they are over bark (O.B. or o.b.) measurements. If nothing is mentioned, they are presumed to be over-bark measurements. The under bark (U.B. or u. b.) measurements of diameters or girths are made after removing the bark at places of contact in the case of the caliper and in a narrow strip 8 to 10 cm wide all around the log or tree at the place of measurement

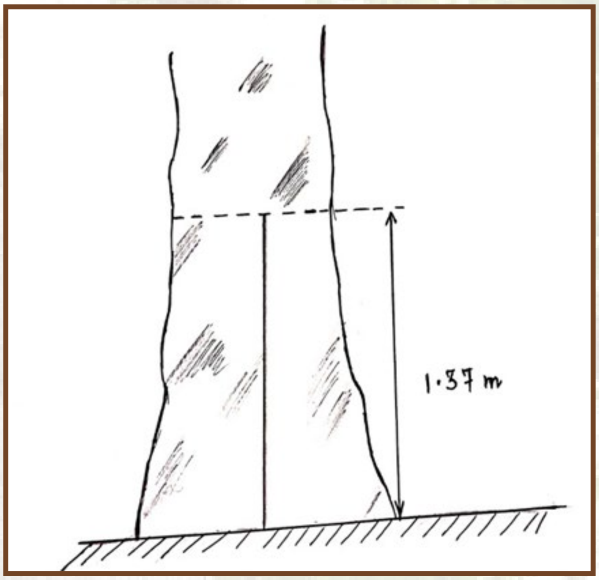


Figure 4: Measurement of diameter breast height at 1.37 m.

in case of tape and are referred to D.B.H. (U.B.) or d.b.h (u.b.) and G.B.H. (U.B.) or g.b.h. (u.b.) respectively.

6.1.2 Standard Rules Governing Breast-Height Measurements

For Statistical work in sample plots - The following are the standard rules governing breast-height measurements in a sample plot:

- ✓ Breast height should be marked through a measuring stick on standing trees at 1.37 m (4 ft 6 in) above the ground level.
- ✓ The breast-height point should be marked by intersecting vertical and horizontal lines 12 cm long, painted with white paint. This is referred to as a cross-mark.
- ✓ In case the tree is leaning, dbh is measured along the tree stem and not vertically, on the side of the lean for trees growing on flat ground (Fig. 5) and on the uphill side, for trees growing on sloping ground.
- ✓ On sloping ground, the diameter at breast height should be measured on the uphill side, after removing any dead leaves or needles lodged there. (fig.6)
- ✓ The dbh should not be measured at 1.37m (4 ft 6 in) if the stem is abnormal at the level. Breast-height mark should be shifted up or down as little as possible to a more normal position of the stem and then the diameter measured.

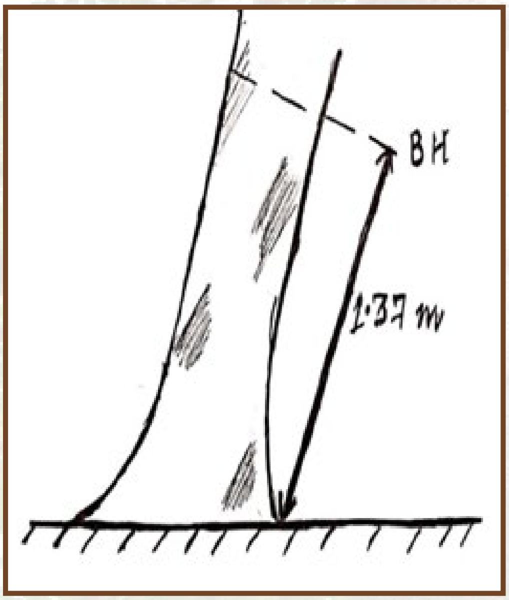


Figure 5: Measurement of breast height of leaning tree.

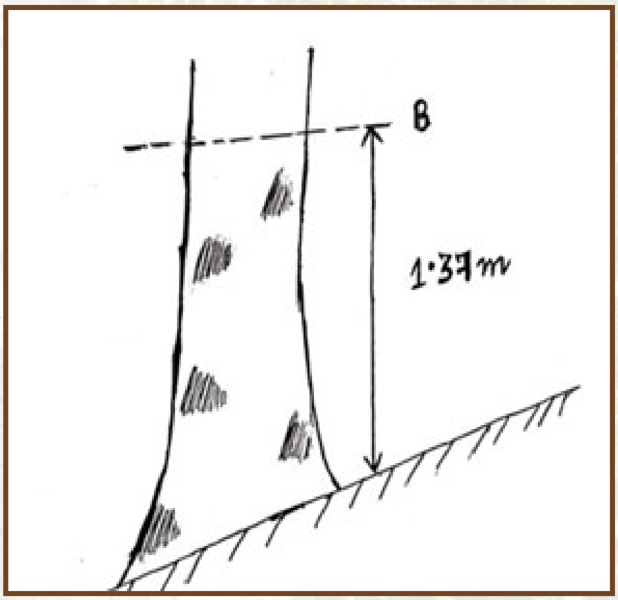


Figure 6: Measurement of breast height of tree on sloping ground.

- ✓ When the tree is forked above the breast height, it is counted as one tree (Fig. 7).
- ✓ When forking is below breast height, each fork should be treated as though it were a separate tree (Fig 8).

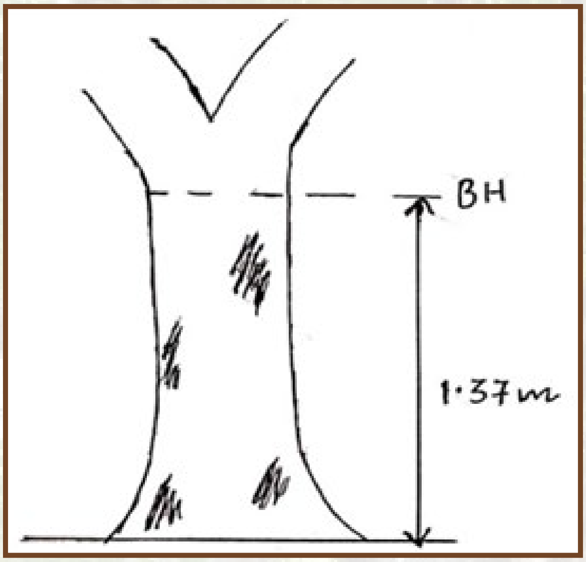


Figure 7: Measurement of breast height of tree having fork above 1.37 m.

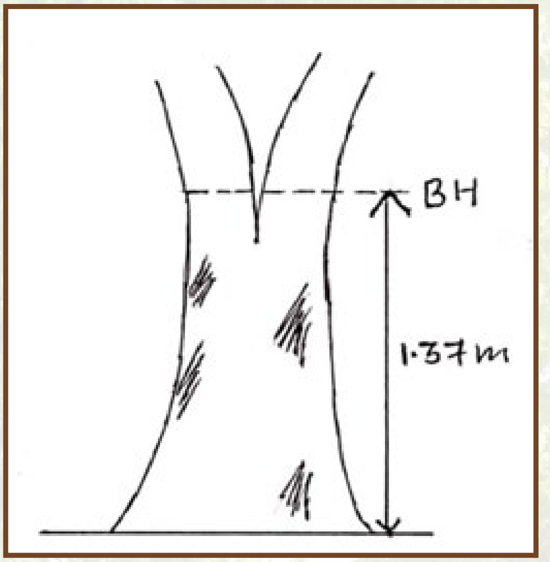


Figure 8: Measurement of breast height of tree having fork below 1.37 m.

- ✓ If forking renders the breast-height point abnormal, the foregoing rule should be applied and the tree counted as one or two depending on the place of measurement (Fig. 9).
- ✓ When buttress formation is characteristic of the species and is known or is likely to extend upwards with the development of the tree, the breast height should be taken at the lowest point above which the abnormal formation is not likely to extend. (Fig.10)

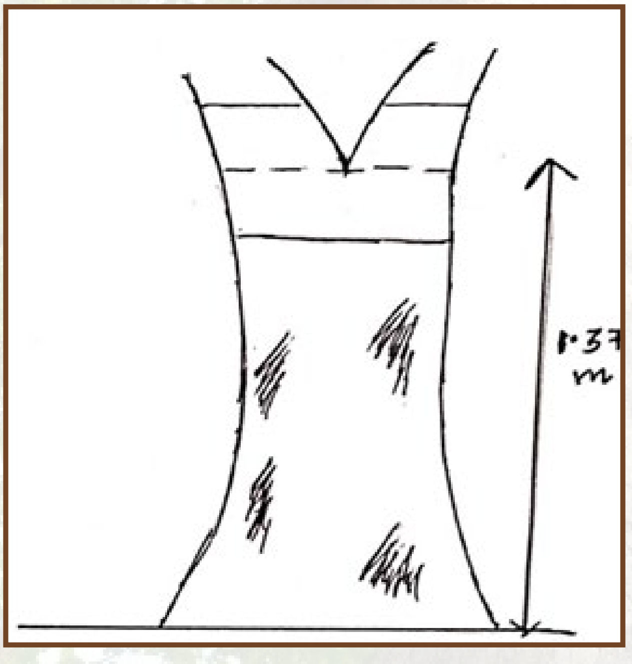


Figure 9: Measurement of tree breast height having fork at 1.37 m.

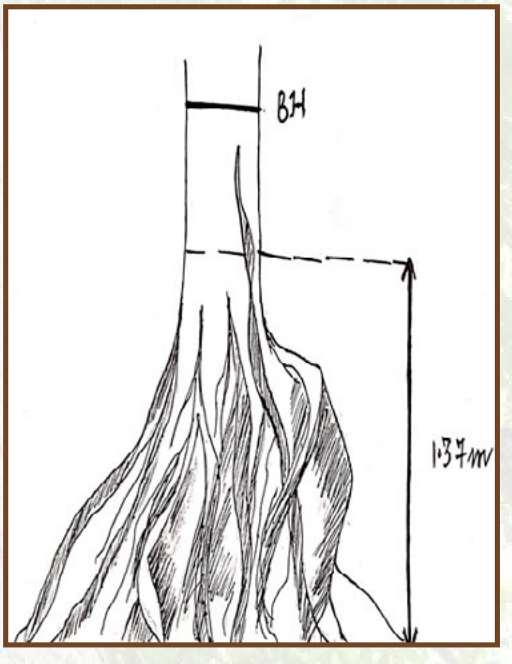


Figure 10: Measurement of breast height of buttressed tree.

- ✓ The height of the cross mark above ground level should always be recorded for each tree measured.
- ✓ Moss, creepers, lichens and loose bark found on the tree must be removed before measuring the diameter or girth of the bark.

Diameter measurements should be recorded in centimeters and to the nearest multiple of two millimeters. Girths should be measured in meters and to the nearest centimeter. The diameter or girth of each tree measured should be recorded separately.

6.1.3. Rules to be Followed During the Measurement of Diameter or Girth

- ✓ Diameters and girth are measured at breast height but a measuring stick is not used to mark that point.
- ✓ As the routine forest measurements are done for immediate use and not repeated periodically over the same tree, the diameter or girth is measured just above the buttress formation up to that year without making allowance for its future development upwards.
- ✓ Instead of recording diameter or girth separately for each tree and to the limits mentioned, the trees can be grouped in diameter or girth classes.

6.1.4. Instruments used in Diameter or Girth Measurement

There are different types of instruments used for diameter or girth measurements in the case of standing trees but the commonly used instruments in India are wooden scales, calipers and tape.

A. Method of using wooden scale:

- ✓ The diameter should be measured along the line passing through the pith. In the case of eccentric stumps or logs, two diameters, one along the major axis and the other at right angles to it, should be measured.
- ✓ As the end of the scale often gets worn off by continuous use, the measurement should be taken from the first centimeter and not from the zero mark because that may give an incorrect measurement.
- ✓ In such a case, care should be taken to deduct one centimeter from the reading to get the correct diameter. The scale should be placed on the edges so that the ends of the line to be measured coincide with the marks of the scale.
- ✓ While reading measurement, the eye should be just above the mark, i.e., the line joining the eye with the end of the line being measured, should be perpendicular to the line. If this is not done, some error will creep into the measurement and this is called an error of parallax.

A. Method of using caliper:

- ✓ To use calipers, the handles of the two arms of the calipers should be held in two hands.
- ✓ The movable arm should be titled inwards so that it can move freely and moved in such a position that the two arms can be separated enough to receive the tree between them without touching.
- ✓ When the tree touches the graduated rule, the movable arm should be shifted inwards in the tilted position so that the tree touches the fixed arm and movable arm.
- ✓ In this position, the movable arm should be slowly brought in a perpendicular position to the graduated scale and pressed to squeeze out any loose bark as well as ensure that there is no gap between the arms and the tree. The diameter is then read off on the rule.

6.2. Measurement of Height

After diameter or girth, the other important measurement of a tree is its height.

The total height of a standing tree is the straight line distance from the tip of the leading shoot (or from the highest point of the crown where there is no leader) to the ground level, usually measured on slopes from the uphill side of the tree. As some portion of the tree stem is lost as chips in felling and its length cannot be measured for inclusion in total height, it (i.e., the total height) is usually measured from the tip to breast height or any other point, height of which is determined before felling and added later to the measured length to give the total height of the felled tree. Total height is measured in meters correct to the first decimal place.

In the case of small trees, height can be directly measured with a pole or a rod. For taller trees, telescopic or sliding poles made of wood, light metal, or fiber glass can be used. Measurement of heights of standing trees particularly when their number may be large, requires some special considerations. Height measurement is a more time-consuming operation than diameter measurement because the measurement of the height of a standing tree with instruments takes about 10 times more, time than it takes to measure its diameter. Therefore, the heights of all trees are measured only in small permanent sample plots. For all other purposes, the heights of a few trees are measured with instruments and for the others, it is estimated by eye or by some other non-instrumental method. Thus, the methods of measurement of height may be classified into ocular, non-instrumental and instrumental methods.

Ocular estimate- In estimating the heights of trees by eye, a height scale has to be fixed in mind. This is easily done by measuring the heights of a few trees with some instruments before the start of the work and that of a few trees again in the middle of the work. With this standard in mind, the estimator judges the heights of trees to be measured and records them. To make it more reliable a pole of 3 m in length may be placed against the tree and then the tree is imagined to be divided into 3 m sections and the height is calculated. If the estimator has no practice in dividing the tree in imagination, he can make use of a pencil. A pencil may be held in a stretched-out hand in such a manner that a portion of the pencil sticking out of hand covers the 3 m pole placed against the tree. With that length of the pencil, he marks off sections on the stem in imagination and then the number of sections multiplied by 3 gives the height of the tree in meters. Ocular estimate is not very reliable and serious errors may result if the estimator has no previous experience of this work. Constant practice can, however, make foresters quite proficient in estimating heights correctly.

6.2.1. Non-instrumental Methods

No tree is truly vertical, most of them lean on one side or the other. If a leaning tree is assumed to be vertical, the calculated height does not give the actual height of the tree. All non-instrumental and instrumental methods are based on the assumption that the tree is vertical. But the heights of leaning trees can be calculated by any height measuring instrument if the angle of lean is also measured. Therefore, the methods of measurement of the heights of vertical and leaning trees will be described separately. The heights of vertical trees can be calculated either by instruments or without them. Since height measurement by instruments is slow and therefore expensive and by ocular estimate, not very reliable, several non-instrumental methods have been developed to meet the requirements of routine forest operation some of which are the shadow method and single pole method.

Single pole method- This is one of the most convenient methods for height measurement. In this method, the observer holds a pole of about 1.5 m length vertically at arm's length in one hand in such a way that the portion of the pole above the hand is equal in length to the distance of the pole from the eye. Without changing the position of the hand with reference to the eye, the observer moves slowly forward and backward till the line of

$$\frac{AB}{ab} = \frac{EB}{Eb}$$

$$\text{Therefore } AB = \frac{EB \times ab}{Eb}$$

$$\text{Since } ab = Eb, \qquad AB = EB.$$

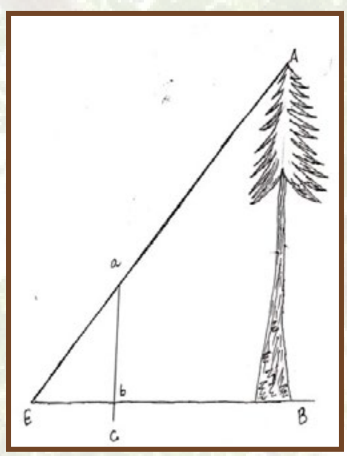


Figure 11: Measurement of tree height by single pole method.

sight to the tip of the tree passes through the tip of the pole and that to the base of the tree through the point where the pole is held by hand. This means that the portion of the pole above the hand covers the tree completely. The height of the tree is then equal to the distance of the observer's eye from the base of the tree.

6.2.2. Instrumental Methods

Instruments used in height measurements are hypsometers, altimeters and clinometers. Instrumental methods are based on trigonometric principles and principles of similar triangles

6.3. Measurement of Branches

The number of branches per tree is also a criterion for selecting candidate plus tree. Here, it is to be notified that only primary branches are to be counted. Primary branches are the one that remains intact on the main trunk of the tree.

6.4. Measurement of Crown Diameter

Measurement of crown diameter is done on the basis of shadow method. The length and breadth of the shadow of crown is measured with tape and the average is calculated and recorded as crown diameter.

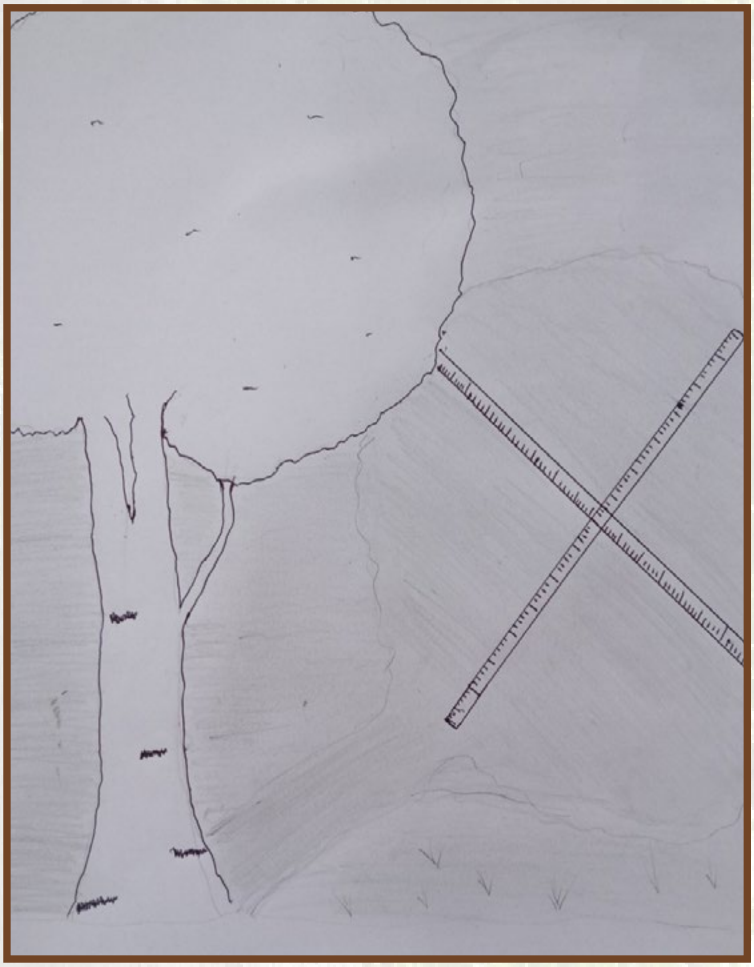


Figure 12: Measurement of crown diameter using shadow method.

CHAPTER 7

Past Studies Carried on the Selection of Plus Trees of Concerned Species

7.1 Title - Genetic variability and selection of candidate plus trees in chebulic myrobalan (*Terminalia chebula* retz.)

Objective - To study the genotypes of six morphological characters of trees and twelve physical parameters of fruits.

Traits targeted - diameter at base, diameter at breast, girth at base and girth at breast. Preference was also given to the physical parameters like non-reducing sugar percent, weight of fresh fruit, weight of seed, weight of fruit pulp, moisture percent and weight of dry fruit as these characters were under genotypic control.

Achievement - An experiment was conducted by Navhale *et al.* to find out the genetic variability and selection of candidate plus trees in chebulic myrobalan (*Terminalia chebula* retz.). A total of forty genotypes of chebulic myrobalan were selected from January to December for the study of variability. The analysis of variance revealed significant variation among the genotypes for all the characters. This indicated a greater scope for making selections in these genotypes. The maximum range of variability was observed for morphological characters viz., diameter at base, diameter at breast, girth at base and girth at breast. The estimates of the genotypic mean sum of squares indicated a comparatively wide range of variation for the character's moisture percent, TSS and weight of fresh fruits. The estimates of phenotypic variances were found higher than the genotypic variances for most of the characters indicating that these characters were influenced by environmental factors. The heritability was high for total soluble solids followed by weight of dry fruit, weight of fruit pulp, total sugars and acidity percent. The genetic advance as percent of mean was highest for non-reducing sugar followed by weight of fruit pulp, weight of dry fruit, weight of seed and acidity percent. For the selection of candidate plus trees, preference was given to the physical parameters like non-reducing sugar percent, weight of fresh fruit, weight of seed, weight of fruit pulp, moisture percent and weight of dry fruit as these characters were under genotypic control.

7.2 Title - Selection of candidate plus trees of *Pterocarpus marsupium* Roxb. for seed germination and associated parameters.

Objective: A field survey was carried out by Mishra *et al.* to find out the variation in progeny in candidate plus trees of *Pterocarpus marsupium.*

Traits targeted: plant height, girth at breast height (GBH), clear bole, crown size and the number of branches.

Achievements: During an extensive survey for the selection and marking of candidate plus trees in Chhattisgarh, a sparse population of the species was found in three agro-climatic zones of the state. However, twenty-one candidate plus trees (CPTs) were selected based on their superiority with respect to plant height, girth at breast height (GBH), clear bole, crown size and number of branches. However, the performance of progenies of CPTs was evaluated at different stages from the seedling stage to at least one-third of the rotation of that crop for morphological characteristics like quality and quantity of timber yield.

Selection of CPTs and evaluation of their progenies are prerequisites for tree improvement programmes based on performance at the seedling stage by providing the same growing condition. Hence, such plus trees can be categorized as elite types based on their performance through progeny trials.

7.3 Title - Identification of Plus Trees and Seed Source Variability in *Pongamia pinnata* (L.) Pierre

Objective: A field survey was carried out by Raut et al. to identify the candidate plus tree and seed source variability in Pongamia pinnata.

Traits targeted: Seed production (on score high/medium/low), seed size, pod size, number of fruit per bunch, 100 seed weight and volume, girth, height, crown height, crown diameter, canopy cover.

Achievement: The study was conducted for the selection of Candidate Plus Tree (CPT's) in the Konkan region of Maharashtra. The survey for the selection of CPTs was carried out from Feb to May 2009 in different agro-climatic zones of the Konkan region. Trees growing at one location were considered to be one population. Twenty locations with 25-30 random trees from each location were scored for various morphological characters, fruiting behaviour namely seed production (on score high/ medium/ low), seed size, pod size, number of fruit per bunch, 100 seed weight and volume, girth, height, crown height, crown diameter, canopy cover. Among the population, one or two superior individuals based on the phenotypic character were selected as CPT. Almost 20 trees marked as CPT'swere collected.

Mature Pods of such selected trees were collected for analysis of the seed attributes/ characters. Pod and seed characters viz. length (mm), breadth (mm), thickness (mm) and weight (gm) were recorded for all the genotypes. A total of 100 pods of each CPT (four replications) were taken and the average was computed for the pod and seed characters. To study the variability in seed source the observations recorded were subjected to statistical methods to estimate the variability.

7.4. Title - Selection of plus tree of Jamun (*Syzygium cumini*) with respect to morphological and yield characters.

Objective: An extensive survey was undertaken across Pulney, Dindigul district, Tamil Nadu, India from June 2017 to May 2018 to identify elite types of jamun among its native population. Trees of seedling origin were selected for the study.

Traits targeted: Observation on morphological characters such as tree and leaf characters were studied. Tree characteristics such as tree age, tree height, trunk girth, trunk height, crown diameter, tree canopy shape and tree growth habits were observed. Leaf characters such as shape, colour, length and width were observed.

Achievement: The height of the tree was recorded from the base to the topmost branching site and expressed in meters (m). Trunk girth was recorded at 25 cm above ground level and expressed in centimeters (cm). Trunk height was recorded from the base of the tree to the point of the emergence of the first branch and expressed in meters (m). Tree spread was measured as the mean canopy diameter using two directions (North-South and East-West) and expressed in meters (m). The growth habit of trees under survey was observed visually and classified into three groups namely erect, semierect and spreading based on NBPGR descriptor (Mahajan et al., 2002).

Leaf shape was recorded on mature leaves and classified as broadly ovate, elliptic-oblong, elliptic and lanceolate based on NBPGR descriptor (Mahajan et al. 2002). Leaf colour was noted as per the Royal Horticultural Society Colour charts (Edition V). Leaf length was calculated by taking the average length of ten fully expanded leaves from each tree from the base to the tip of the leaf blade was taken and expressed in centimeters (cm). Leaf width was calculated by the average width often fully expanded leaves from each tree at the widest point were taken and expressed in centimeters (cm).

The yield of fruits from each plant was assessed by weighing the fruits harvested separately and expressed as kg per tree.

7.5. Title- Morphological characterization of *Terminalia chebula* Retz. and selection of Plus Tree from Kondagaon & Kanker Forest Stands of Chhattisgarh.

Objective: To select plus trees from Kondagaon and Kanker Forest stands of Chhattisgarh

Traits targeted: Eight characters taken of fruit were - Length of fruit in mm, breadth of the fruit in mm, fresh weight of fruits in gm, dry weight of fruit in gm, dry pulp weight in gm, dry seed weight in gm, the shape of the fruit, color of the fruit

The tree characters taken were Circumference of crown size, height, trunk straightness, crown width and number of branches.

Achievement: A prospective survey was carried out in October 2020 within two districts of Kanker & Kondagaon. These are 150 and 210 km away from Indira Gandhi Agricultural University, Raipur towards the Bastar region of Chhattisgarh. The time of sampling was selected in such a way that when fruits were mature and ready to fall from the tree, 10 -30 fruits were collected from each tree and kept in polybags to record the data of different parameters. The fruit samples brought to the laboratory were oven dried at 80°C then dry weight, extracted pulp and seed weight data were recorded for further computation and statistical analysis. The height and diameter of sampled tree was recorded and trees were marked with white paint and numbered simultaneously. The location of trees was recorded with the help of GPS so that the CPT would be easy to find out as and when needed for further observations for research work it could be easily distinguished. In natural populations, 10 trees were sampled from different forest stands in Kanker and Kondagaon districts in different blocks of Chhattisgarh. In order to identify the variations within and between populations, a tree cluster of 2-3 trees was selected within a population and a distance of at least 1 km was maintained between clusters.

7.6. Title - Plus tree Variation of Shisham (*Dalbergia sissoo*) in Different Agro - Ecological Regions of Haryana.

Objective: To select the best individuals and identify plus trees in different Agro-Ecological Regions of Haryana

Traits Targeted: Diameter at breast height, total height, clear bole height, crown spread and straightness.

Achievement: Forty-five plus trees of *Dalbergia sissoo* were selected from three agroecological regions based on their morphological characteristics viz. diameter at breast height, total height, clear bole height, crown spread and straightness. Correlation among the character was also studied. Seed sources from dry sub-humid regions were found more promising than the other two. Significant variations were observed among morphological traits and a significantly positive correlation was found among the traits.

Morphological characters viz, diameters at breast height (DBH), total height (TH), clear bole height (CBH), straightness and crown spread (CS) were measured and CBH: TH and TH: DBH were calculated for forty plus trees i. e. fifteen from each region. Mean, standard error, critical difference and coefficient of variation were calculated by using OPSTAT and correlation among different characters was also calculated.

7.7. Title - Selection of plus trees of *Acacia catechu* with respect to seed traits

Objective: To select plus trees of *Acacia catechu* with respect to its seed traits.

Traits targeted: Plus trees were selected based on different morphological traits viz. diameter, height, clean bole and crown spread.

Achievements: The investigation was carried out at Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.). An ecogeographical survey of the populations of *Acacia catechu* was undertaken in the entire range of its distribution in Himachal Pradesh to identify the sites. A total of 32 seed sources were selected. The geographical location of the seed sources is distributed in the districts of Bilaspur, Hamirpur, Kangra, Sirmaur, Solan and Una. The altitude of the entire range varies from 500 to 1250 m above mean sea level. The localities fall under tropical to subtropical (sub-temperate) climates. Plus trees were selected on the basis of different morphological traits viz. diameter, height, clean bole and crown spread. Five plus trees from each site were selected and seeds from these plus trees were collected during January-February. Observations on seed length, seed width, seed thickness, 100 seed weight, number of seeds per pod, pod length, pod width, percent pods infested and pod colour were taken for 25 randomly selected seeds/pods having four replications.

The variation observed for seed traits did not follow any particular trend with regard to different populations. This could be probably because of environmental factors which might have played a significant role in changing the composition of seed.

GLOSSARY

- **Advanced 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 advanced-generation selections.
- **Afforestation programme:** afforestation is the process of planting large numbers of trees on land which has few or no trees in it. The overall objective of the National Afforestation Programme scheme is the ecological restoration of degraded forests.
- **Bole:** The main wooden axis of a tree up to the point where the main branches come off.
- **Buttress:** Out growths formed usually vertically above the lateral roots and thus connect the base of the stem with roots.
- **Candidate plus tree:** A tree that has been selected for grading because of its desirable phenotypic qualities but that has not yet been graded or tested.
- **Bole height:** It is defined as the distance from the base of the tree to the base of the first living branch that forms a part of the tree crown.
- **Co-dominant**: Slightly shorter dominants or to be more precise, 5/6 of the predominants.
- **Comparison tree:** Trees chosen as comparison trees are the best in the stand, with characteristics similar to "crop" trees that would be chosen in silvicultural operations.
- **Crown height:** It is the height of the crown as measured vertically from the ground level to the point halfway between the lowest green branch and the green branches forming the green crown all around.
- **Crown width:** The average crown spread is called as average horizontal width of the crown.
- **Dioecious:** Trees that have separate male and female parts on completely different trees where one tree is strictly male and one strictly female.
- **Dominant:** The tallest trees in a stand form the uppermost leaf canopy and have their leading shoots free.
- **Even-aged:** Stand consisting of trees of approximately the same age. Differences up to 25% of the rotation age may be allowed in cases where a stand is not harvested for 100 years or more.
- **Epicormic branches:** Branches originating in clusters from dominant or adventitious buds on the trunk of a tree or on the older branch when exposed to adverse influences such as excessive light, fire, or suppression.
- **Families:** Individuals that are more closely related to each other than to other individuals in a population is called a family. Generally, the term is used to denote the group of individuals who have one or both parents in common.
- **Fluting:** Irregular involutions and swellings on the bole just above the basal swell.

- **Forking:** Bifurcation in the trunk of a tree giving rise to two roughly equal diameter branches.
- **Genetic gain:** Amount of increase in performance that is achieved annually through artificial selection. It is calculated as = Narrow –sense heritability × selection differential.
- **Girth breast height:** Height at which girth/diameter is to be recorded. In India, Burma, America, Union of South Africa, Malaya and some other British colonies it is taken as 1.37 m (4 feet 6 inches) above ground level.
- **Mixed stands:** Stand compromising of all aged trees. It is also called an irregular stand.
- **Phenotype:** The set of observable characteristics of an individual resulting from the interaction of its genotype with the environment.
- **Plus tree/ Superior trees:** A tree that has been recommended for production or breeding orchard. 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 genetic worth, although the chances of its having a good phenotype are high for characteristics with a reasonable heritability.
- **Provenance:** Original geographic area from which seed or other propagules were obtained.
- **Rotation age:** The age of the tree that gives maximum volume production when harvested is called rotation age.
- **Seedling:** A plant grown from seed till it attains a height of about one meter, i.e., before it reaches the sampling stage.
- **Selection differentials:** The average phenotypic value of the selected individuals, expressed as a deviation from the population mean.
- **Self-pruning:** Natural shedding of branches that are defected, dead, or damaged.
- **Silviculture:** Art and science of raising forest trees.
- **Species:** Individuals capable of exchanging genes or interbreeding.
- **Taper:** The decrease in the diameter of the stem of a tree or a log from the base upwards.
- **Total height:** It is the straight line distance from the tip of the leading shoot (or from the highest point of the crown where there is no leader) to the ground level, usually measured on slopes from the uphill side of the tree.
- **Traits:** Specific characteristics of an organism. It is determined by the genes, environment and their interactions.
- **Uneven aged:** Applied to crops in which individual stems vary widely in age, the range of difference being usually more than 20 years and in the case of long rotation trees, more than 25% of the rotation.
- **Vigour:** The capacity for survival or strong healthy growth in a plant.

REFERENCES

Chaturvedi, A.N. & Khanna L.S., (1994), Forest mensuration, International Book Distributors Dehradun, ISBN: 81-7089-203-1

Clark, J., & Wilson, T. (2005). The importance of plus-tree selection in the improvement of hardwoods. Quarterly Journal of Forestry, 99(1): 45-50.

https://www.yourarticlelibrary.com/education/statistics/frequency-distribution-and-class-interval -statistics/91739

Latheef, A., & Kavino, M. (2018). Variability in Genotypes of Jamun (*Syzygium cumini* Skeels) for Morphological and Yield Characters. Madras Agricultural Journal, 105.

Mandal, A.K., Chawhaan P.H., Sharma, R., (2001), Plus tree selection, 77 ICFRE BR- 18 TFRI BR-2/2001

Mishra, S., & Tiwari, S. Spatial Distribution of *Buchanania cochinchinensis* in Jharkhand

Mishra, Y., Naseer, M., & Mishra, J. P. (2019). Progeny variation in candidate plus trees of *Pterocarpus marsupium* Roxb. for seed germination and associated parameters. Tropical Plant Research, 6(2): 226-232.

Mother Earth and Environmental Pollution, 2015, pollution.blogspot.com

Navhale, V. C., Sonone, N. G., Jangam, P. S., Jadhav, S. T., & Bhave, S. G. (2011). Research Note Genetic variability and selection of candidate plus trees in chebulic myrobalan (*Terminalia chebula* Retz.). Electronic Journal of Plant Breeding, 2(1): 157-163.

Raut, S. S., Narkhede, S. S., Bhave, S. G., Rane, A. D., & Gunaga, R. P. (2010). Identification of candidate plus trees and seed source variability in *Pongamia pinnata* (L.) Pierre. Journal of Tree Sciences, 29(1&2): 1-6.

Selvan, T., & Guleria, V. (2012). Seed source variation on Seed Traits of *Acacia catechu* Willd. Journal of Tree Sciences, 31: 54-61.

Sharma, K. B., Kumari, B., Johar, V., & Bisht, V. (2017). Plus tree Variation of Shisham (*Dalbergia sissoo*) in Different Agro-Ecological Regions of Haryana. Environment & Ecology, 35(4A): 2996-2998.

Zobel, B. & Talbert, J., (1984). Applied Forest Tree Improvement, New York: Wiley

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