

EVALUATION OF PROVENANCES OF
***Dalbergia sissoo* Roxb.**

M.Sc. (FORESTRY) Thesis

by

FATTE LAL PATEL

DEPARTMENT OF FORESTRY

COLLEGE OF AGRICULTURE

INDIRA GANDHI AGRICULTURAL UNIVERSITY

RAIPUR, 492006 (C.G.)

2006

EVALUATION OF PROVENANCES OF
***Dalbergia sissoo* Roxb.**

Thesis
Submitted to the
Indira Gandhi Agricultural University,
Raipur

by
FATTE LAL PATEL

In partial fulfilment of the
requirements for the
degree of

Master of Science
in
Forestry

Roll No. 3258

ID No.PG/AG/2003/51

OCTOBER, 2006
CERTIFICATE – I

This is to certify that the thesis entitled “**EVALUATION OF PROVENANCES *Dalbergia sissoo* Roxb.**” submitted in partial fulfilment of the requirements for the degree of “**MASTER OF SCIENCE IN FORESTRY**” of the Indira Gandhi Agricultural University, Raipur, is a record of the bonafide research work carried out by **FATTE LAL PATEL** under my guidance and supervision. The subject of the thesis has been approved by student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

Dr. M. N. NAUGRAIYA
Chairman
Advisory Committee

Date:

THESIS APPROVED BY STUDENT’S ADVISORY COMMITTEE

Chairman	Dr. M. N. Naugraiya	-----
Member	Dr. Lalji Singh	-----
Member	Dr. A. K. Sarawagi	-----
Member	Dr. R. K. Yadav	-----
Member	Dr. Ravi R. Saxena	-----

CERTIFICATE - II

This is to certify that the thesis entitled “**EVALUATION OF PROVENANCES OF *Dalbergia sissoo* Roxb.**” submitted by **FATTE LAL PATEL** to the Indira Gandhi Agricultural University, Raipur in partial fulfilment of the requirements for the degree of **M.Sc. (FORESTRY)** in the **DEPARTMENT OF FORESTRY** has been approved by the Student's Advisory Committee and the external examiner.

Date :

EXTERNAL EXAMINER

MAJOR ADVISOR

HEAD OF THE DEPARTMENT

DEAN / DEAN FACULTY

DIRECTOR OF INSTRUCTIONS

ACKNOWLEDGEMENT

*I feel elated in expressing my deepest sense of gratitude to **Dr.M.N. Naugraiya**, Senior Scientist, Department of Forestry, IGAU, Raipur and Chairman of my Advisory Committee for his valuable guidance, unique supervision, constant encouragement and constructive creativity throughout the tenure of this investigation. His hard work for preparation of this manuscript along with photography will be the remembered till the last.*

I wish to record my sincere thanks to members of Advisory Committee Dr.Lalji Singh, Associate Professor & Head (Forestry), Dr. A. K. Sarawagi, Associate Professor (Plant Breeding & Genetics), Dr. R. K. Yadav, Associate Professor (Plant Breeding & Genetics) and Dr. Ravi R. Saxena, Associate Professor (Statistics) for their excellent guidance and suggestions during the course of this study.

I profoundly express my grateful thanks to Dr. C.R. Hazara, Hon'ble Vice Chancellor, IGAU, Raipur, Dr. A. S. R. A. S. Shastri, Director of Research Services, Dr B. S. Thakur, Dean College of Agriculture, Dr. R. B. Sharma, Director of Extension Services, , Dr. V. S. Thrimuty, Director Instructions IGAU, Raipur for providing necessary facilities and constants encouragement during the course of investigation.

I am deeply indebted to Dr.S.R. Patel, Associate Professor& Head (Agriculture Meteorology), Dr.R.K.Prajapati, Associate Professors (Forestry) and Dr. S.L. Swamy Senior Scientists (Forestry) and Smt. Shilpa Chandravanshi (Sr.Tech.Asst.) and Shri U. D. Manikpuri, FEO (Forestry) for their kind help and time to time cooperation.

I am highly grateful to Shri U. S. Singh, Shri M. L. Sahu for generous help and cooperation during entire course of research work.

I am extend my most cordial thanks and affectionate appreciation to seniors Santosh Dhruw, Anwar Singh Sisodia, Jayant Kasture, Ravi Shankar Singh, Rajiv Umrao, and Nidhi Singh for their kind help and co-operation during my post graduation study.

Words run short to express my feeling towards colleagues Dinesh, Pranav, Ugrash, Manleshwar, Kalu, Ranjeet, Narendra, Bilal, Sarita, Archana, Deepak, Mohan and juniors Sanjivan, Dhiraj, Satish, Gadekar, Funde, Veena, Bardani, Swati, Shailendra, Gunjan, Priyeta, Vijay, Vinod, Vidya, Sunil, Akhilesh, Ritesh, Pravin and Golu for their affectionate help appreciation endurance and co-operation.

I express my thanks to Shri Ghanshayam, Baronda Research Farm and Sobharam, Tiwari and Patel department of Forestry who gave their kind co-operation. This study would not have been possible without their active support and co-operation.

I am also thankful to Mr. Shailendra Patel for his painstaking effort in typing the manuscript magnificently. His patience and efficiency deserve economics.

Diction is not enough to express my gratitude to my respected grand fathers Lakchhaman Patel, Shri Piladau Patel and grand mother Late Smt. Jhulmati Patel, Smt. Ghurai bai Patel and my beloved parents father Shri S.R. Patel, mother Smt. Jamati Patel, and Brother Dhaneshwar Patel, and jija Shri Ishwar Patel and sister Smt.Chanchla Patel for their ever–showering blessing and encouragement accordingly.

Above all my honorable and whole hearted prostrations before god for sprinkling his unprecedented favours upon me.

Department of Forestry,
College of Agriculture,
IGAU, Raipur (C.G.)

(Fatte Lal Patel)

CONTENTS

CHAPTER	TITLE	PAGE NO.
---------	-------	-------------

I	INTRODUCTION	
II	REVIEW OF LETERATURE	
2.1	Genetic variability and heritability	
2.2	Variation in pod and seed traits	
2.3	Correlation and association analysis	
2.4	Genetic divergence	
III	MATERIALS AND METHODS	
3.1	Experimental site	
3.2	Climate and weather	
3..3	Geology	
3.4	Physiography	
3.4.1	Soils	
3.4.2	Physio-chemical characteristics of the soil	
3.5	Experimental details	
3.6	Measurement of growth parameters	
3.6.1	Tree height	
3.6.2	Clear bole height	
3.6.3	Straight bole height	
3.6.4	Diameter at breast height	
3.7	Morphological characteristics of pod and seeds	
i)	Pod size (cm)	
ii)	Number of seed	
iii)	Seed size (cm)	
iv)	Seed thickness (mm)	
v)	Pod and seed weight (g)	
3.8	Phenological observations	
CHAPTER	TITLE	PAGE NO.
3.9	Ranking of provenance	
3.10	Statistical analysis	

3.11 Photography

IV

RESULTS AND DISCUSSION

4.1 Genetic variability

4.1.1 Co-efficient of variation for tree growth and pod-seed characters

4.1.2 Mean performance for tree growth and pod-seed characters

4.1.3 Phenotypic, genotypic and environmental coefficient of variation for tree growth and pod-seed characters

4.2 Heritability for tree growth and pod-seed characters

4.3 Genetic advance for tree growth and pod-seed characters

4.4 Genetic gain for tree growth and pod-seed characters

4.5 Phenological observations

4.5.1 Colour of bark

4.5.2 Branching pattern

4.5.3 Leaf fall

4.5.4 Leaf initiation

4.5.5 Flowering

CHAPTER	TITLE	PAGE NO
4.5.6	Fruiting	

4.6 Growth performance and ranking of different entries

4.7 Estimation of heritability (broad sense) for different entries

**V SUMMARY, CONCLUSION AND
SUGGESTION FOR FUTURE WORK**

ABSTRACT

REFERENCES

APPENDIX

LIST OF TABLES

TABLE NO.	PARTICULARS	PAGE NO.
3.1	Initial physico-chemical properties of experimental	

	soil
3.2	List of entries of CPTs from different location
3.3	Location, soil characteristics and morphological feature of selected Candidate Plus Trees in Chhattisgarh
3.4	Table-points/scores awarded for different entries of <i>Dalbergia sissoo</i>
4.1	Co-efficient of variance for tree growth characteristics of different entries of <i>Dalbergia sissoo</i>
4.2	Co-efficient of variance for pod-seed characteristics of different entries of <i>Dalbergia sissoo</i>
4.3	Estimation of genetic parameters for tree growth characteristics of <i>Dalbergia sissoo</i>
4.4	Estimation of genetic parameters for pod and seed characteristics of different entries of <i>Dalbergia sissoo</i>
4.5	Phenological characteristics of different entries of Candidate Plus Trees of <i>Dalbergia sissoo</i>
4.6	Growth performance and ranking of different entries in Seedling Seed Orchard of <i>Dalbergia sissoo</i>
4.7	Heritability (broad sense) estimates for different entries of <i>Dalbergia sissoo</i>

LIST OF FIGURES

TABL E NO.	PARTICULARS	BETWEEN PAGE
---------------	-------------	-----------------

3.1	Meteorological features of study area among 10 years
4.1	Co-efficient of variance for different tree growth characteristics of different entries of <i>Dalbergia sissoo</i>
4.2	Co-efficient of variance for pod-seed characteristics of different entries of <i>Dalbergia sissoo</i>
4.3	Estimation of genetic parameters for tree growth characteristics
4.4	Estimation of genetic parameters for pod and seed characteristics

LIST OF PLATES

TABLE NO.	PARTICULARS	BETWEEN PAGE
--------------	-------------	-----------------

-
- 1 Morphological variations of pod and seed of different entries of *Dalbergia sissoo* collected from Pantnagar (U.A.)
 - 2 Morphological variations of pod and seed of different entries of *Dalbergia Sissoo* collected from Solan (H.P.)
 - 3 Morphological variations of pod and seed of different entries of *Dalbergia sissoo* collected from Chhattisgarh
 - 4 Morphological variations of pod and seed of different entries of *Dalbergia sissoo* collected from Faijabad (U.P.)
 - 5 Morphological variations of pod and seed of different entries of *Dalbergia sissoo* collected from Garwal (U.A.) hills
 - 6 View of growth performance of different entries of *Dalbergia sissoo*
 - 7 View of most promising entries of *Dalbergia sissoo*
-

LIST OF ABBREVIATIONS

Notations used	Description
-------------------	-------------

%	Per cent
&	And
±	Standard deviation
<	Less than
>	More than
°C	Degree centigrade
CBH	Clear bole height
CG	Chhattisgarh
cm	Centimetre
DBH	Diameter at breast height
<i>et al.</i>	And co-workers/or others
Fig.	Figure
i.e.	That is
HP	Himanchal Pradesh
HT	Height
pH	Pusine of hydrogen ion
m	metre
mm	Millimeter
g	Gram
SEm	Standarad error of means
S. No.	Serial number
U.P.	Uttar Pradesh
U.A.	Uttaranchal
<i>viz.,</i>	That is to say / in other words

CHAPTER-I

INTRODUCTION

Forest trees are integral parts of human society. They provided fuel, fibre, construction and building material, food, medicines, among other things. The forest itself is an ecosystem, and as ecosystems, forests stabilize environments and are essential components of the global ecology.

The requirement of various woods in India by the year 2010 has been projected to be 344 million tones of fuel wood and charcoal, 37million m³ of industrial wood, 33 million m³ sawn timbers, 5.7million m³ pulp and paper wood and 1.3 million tones of wood-based panels (FAO, 1993). However, the annual total productivity of the forests in India is only 15 million m³ of industrial timber and 195 million m³ of firewood (Chadha *et al.* 1992). There are limited options to meet the ever growing wood demand, i.e. either by increasing the total forest cover or increasing the productivity of man-made forests substantially. Unlike the former, the latter is a viable option. Therefore; reforestation must be carried out only with genetically improved planting material coupled with improved technical inputs, scientific management and effective protection measures (Kumar *et al.*, 2003).

The knowledge of genetic variability and association among seed quality and traits are considered to provide considerable help in genetic improvement of the species. It has been realized that the use of quality seeds increases the productivity and seed quality measured by a number

of parameters viz. length, breadth, thickness, shape index, seed weight, viability and germination capacity etc . Hence there is need to evaluate the source variation in different parameters of the seed collected from various seed zones (genotypes) of India

The genus *Dalbergia sissoo* (Leguminosae) is the major genus of woody legumes in the sub-family Papilionaceae. It includes some of the more valuable tropical heartwoods commonly grouped as rosewoods but ranging from rose to black heart wood colour. The genus *Dalbergia* is named after the late 18th centuries Swedish Botanist Nils and Carl Gustav Dalberg (Parrota, 1989; Lapido, 1994). The genus *Dalbergia* comprises trees, shrubs and woody climbers of the 150 *Dalbergia* species distributed throughout the tropics, 42 including 20 tree species are known to occur in India and Burma (Bhat, 1994). There are at least seven highly valued timber species of *Dalbergia* in Asia, most of them indigenous to India and Burma. *Dalbergia sissoo* Roxb. (Shisham) and *Dalbergia latifolia* (Indian Rose wood) are among the most important Indian timber trees. *Dalbergia sissoo* (Shisham) is among the most important Indian timber yielding species having a wide range of distribution and is widely planted, it is one of the few species which has been tested outside Asia.

Dalbergia latifolia is a large deciduous or nearly evergreen tree with cylindrical, fairly straight bole and full rounded crown, found in the sub-Himalayan tract and central, western and southern India. *Dalbergia latifolia* occurs naturally in moist deciduous forests

and sometimes in semi-evergreen or dry deciduous forests of the tropics, at elevations upto 1500 m.

Dalbergia sissoo Roxb. (Shisham) is best known internationally as a premier timber species of rosewood genus. Shisham is found in many parts of India up to 900m in the sub-Himalayan tract, and occasionally ascending to 1500 m between latitude 21° 17' N and longitude 74° 8' E to 93° 43' E. In the sub-Himalayan tract, it occurs along rivers and streams, gregariously growing on alluvial soil. Outside India the species is found in Nepal, Bhutan, Bangladesh, Myanmar, Malaysia, Pakistan and Afghanistan.

In *Dalbergia sissoo*, straight bole form is most important for production of large quantities of high grade wood. The stem straightness further increases the suitability of the species for agroforestry plantation.

Dalbergia sissoo Roxb. has been recognized for centuries as a high value timber species and enjoys world wide fame. When building a new palace at Susa about 2500 years ago, Darius-I sent his admiral, Seylax, to bring *Dalbergia sissoo* logs from the Punjab to use as pillars (Fox, 1973). This may be the first recorded long haul of long timber. *D. sissoo* timber is classified as heavy, strong, tough, steady and very hard (Limaye, 1936). The wood is easy to saw and work. Rawat and Rajput (1975) found it about 20% faster to plane, bore, mortise, turn and shape than teak (*Tectona grandis*). Its natural hardness, fast growth and the high value of its timber *Dalbergia sissoo* is an ideal species for afforestation. It is also an

medicinal species and the decoction of the leaves is said to be useful in gonorrhoea. The roots are astringent and the wood is useful in cutaneous affections (Ann., 1952).

Dalbergia sissoo is also an important as fuel wood, shade, shelter and fodder tree. It has been planted in tropical countries, especially arid and semi-arid regions for timber, fuel wood, fodder, shade and stabilization of eroding landscape. It is very important raw material for a wide variety of wood based industries, especially furniture and building construction. The wood is a very hard, heavy, strong, double elastic, seasons well and decay resistant. Its timber is prized for finest cabinet, furniture, veneer and structural works etc. It is also suitable for marine and air-craft grade plywood. It enriches soil through atmospheric nitrogen fixation and rich leaf fall. Its pruned branches are the cheap source of firewood as it has good combustion with calorific value ranging from 4900-5200 cal/kg.

Dalbergia sissoo Roxb. is one of the most important commercial timber producing species of northern India. Where it is being promoted as a multipurpose nitrogen-fixing tree, but its major end use is as wood, with grower and market appeal as a quality cabinet timber. Any breeding programme to improve wood quality must focus primarily on vigour and form. This is particularly important in case of *Dalbergia sissoo*, which is characterized by crookedness, forking and ramification was branching. Stem form is under strong genetic control. Early trials have shown that the crooked stem form of *Dalbergia sissoo* has a high heritability 42-65

% (Vidakovic and Ahsan, 1970). Straight stem forms are available for selection, but many centuries of planting non selected trees from degraded stands or unimproved seed sources have had serious affects on stem quality. So there is an urgent a need to develop trees with a clean and straight bole, compact crown, low branch angle, required wood colour properties and of course not forgetting resistance to disease and other defects. This species is one of great importance from various points of views viz. agro-forestry, social forestry, energy and industrial uses.

Vidakovic and Siddiqui (1968) find out of heritability of *Dalbergia sissoo* for diameter, height and crookedness by using regression for parent-progeny test. Heritability for height and diameter was very low, whereas for crookedness, the heritability was high.

Shiv Kumar (1988) suggested the desirable characteristics viz; vigorous growth, dominant or co dominant, straight stem with more clear bole, free of forking, persistent branches and good seed production potential.

Bangarwa *et al.* (1990) described the characteristics of superior sissoo tree for agroforestry purposes such as narrow crown, clear straight bole, self-pruning habit and low crown diameter to bole diameter.

Gupta *et al.* (1992) also selected plus trees of sissoo from natural and plantation forests of U.P. based on stem straightness, height and diameter.

Tewari (1994) suggested the plus tree selection criteria requirements as good height, diameter, clean bole, compact crown, low branch angle, heartwood and sapwood ratio and resistance to specific pests and disease.

Thomson (1994) in selection criteria places emphasis on individual trees evaluation scored against the average of the five nearest dominant trees on the basis of dominance stem straightness, branch angle, natural pruning, pest resistance and seed production.

Similarly provenances trial for evaluating the 45 provenances of *Dalbergia sissoo* Roxb. has been conducted at Indira Gandhi Agricultural University, Raipur under ICFRE project. (Naugraiya, 2000).

Due to the biggest drawback of Shisham in it's extremely crooked and low forked bole both quality and quantity of converted timber is affected. Straight trees, on the other hand, provide good quality timber and more amount of converted wood. The species, because of its wide geographic distribution, shows variation in stem form characteristics. Such phenotypic variation provides an indication for the possibility of genetic improvement in stem form through selection along with systematic study on genetic improvement. (Sidhu, 1997).

The present study was undertaken to evaluate the best performing CPTs of *Dalbergia sissoo* collected from different part of country, grown in Baronda Research farm of Indira Gandhi Agriculture University, Raipur.

The present study entitled “**Evaluation of provenances of *Dalbergia sissoo* Roxb.**” has following specific objectives:

1. To evaluate of Candidate Plus Trees collected from different provenance.
2. To study the performance of different genotype of *Dalbergia sissoo* for selection of plus tree.

CHAPTER –II

REVIEW OF LITERATURE

Variations the rule of nature. It does exist among species, races and individuals within species due to their genetic make up, environment in which they grow and interaction between genetic and environmental factors. Study of natural variation is important for any breeding or improvement programmes as it helps in detection of relative performance of various traits of economic value. Among the total variation genetic variation is important from the breeders' point of view. Determination of that portion of variation which is genetically controlled in economically important traits is useful in tree improvement programmes. The estimate of heritability can further help in formulations effective and efficient selection and breeding strategies. The relevant literature on variation studies is being reviewed under the following heads:

2.1 Genetic variability and heritability

2.2 Variation in pod and seed traits

2.3 Correlation and association analysis

2.4 Genetic divergence

2.1 Genetic variability and heritability

In natural population of a species the presence of land masses, water bodies and mountains cause variation. High genetic variation within and among populations has been demonstrated and this distribution of

variation and evolutionary histories can lead to the recommendations of future breeding programmes (Namkoong, 1984).

Hanover and Barnes (1969) from a study of heritability of height growth in western pine seedlings demonstrated that choice of individual parent or parental population could greatly influence heritability estimated from progeny analysis.

Brewbaker *et al.* (1972) observed the varietal variation in 104 strains of *Leucaena sp.* and showed that genetic variation was quantitative and prominent for leaf character, pod length, seed number, size and mimosine content.

The morphological and physiological traits exhibit significant amount of genetic variation both within and between plant populations (Stebbins, 1950, Stern and Roche, 1974).

Significant variation in various phenotypic characters such as needles and seed dimension of *Pinus densiflora* was recorded with respect to altitude and similar variations were observed for *Pinus thunbergii* (Bab, 1976: Hayashi and Mural, 1976).

Kedarnath and Vakashasya (1977) have reported decreasing heritability of *Eucalyptus tereticornis* seedling height from $h^2 = 0.42$ to 0.25 at 4 year age.

Surendran and Chandrasekharan (1984) recorded height, number of leaves, number of branches, collar diameter, leaf length, breadth, length/breadth ration and internodes length of seedlings grown from seeds of thirty five *Eucalyptus tereucornis* plus trees selected from different parts of TamilNadu. Heritability and genetic advance were found

to be high for number of branches. They, therefore, recommended that this could be useful in selection programme for high biomass production.

Rehfeldt (1985) reported genotypic covariances between different characters under study for *Pinus contorta*. Maximum was found between branches and whorls, whereas, minimum was found between whorls and branch lengths. The degree correlated responses depend on the genetic variance, covariances and correlations.

Greham *et al.* (1985) reported significant effect of total height of the progeny within each plantation family and also between sites and family interactions in open-pollinated families of *Pinus ponderosa*. Narrow sense heritability estimates within and between plantations indicated substantial genetic variation and that selection practices can achieve good response.

Boyle and Morgestern (1987) in a study on black spruce (*Picea mariana*) estimated variation within population amounting to 99 per cent of total variation.

Jhonsen *et al.* (1988) observed significant difference for root growth potential among different provenances of white pine, where the heritability estimates have little genetic control over root growth potential in seedlings.

Kiss and Yeh (1988) estimated the narrow sense heritability after third, sixth and tenth growing season as 0.5, 0.36 and 0.20 respectively for height growth of *Picea glauca*. The corresponding family heritability was 0.81, 0.73 and 0.67 per cent, respectively.

Samarawira (1988) observed appreciable amount of variation in germination (57.6-95.2%) in date palm, where the heritability estimates for seed weight, length, leaf emergence and sprouting were low which varied between 58 per cent (seed weight) and 20 per cent (sprouting) in case of *Phoenix dactylifera* Linn.

Verma *et al.* (1988) studied the genetic variability, heritability, genetic advance and correlations for ten characters in sugarcane. The phenotypic and genotypic coefficient of variance indicated that selection may be done for kg-brix, millable cogs/clump, and invert sugar, ccs/cane, stalk weight and internode/cane.

Singh and Beniwal (1993) studied the variability, heritability and genetic advance in *Bambusa balcooa* in terms of culm height, culm girth and number of new shoots by recording data at four different ages on vegetative propagated six plus bamboo (culm/genotype) selected in different areas of Arunachal Pradesh and Assam. They reported significant variation in plant height and number of new shoots in all four successive ages. They concluded that high heritability accompanied with high genetic advance for plant height and number of shoots provided clear cut index of these characters in selection, improvement and multiplication for higher yield biomass.

Salazar (1989) reported considerable variation among provenances of *Acacia mangium* for seed dimension, plant growth and leaf dimension at nursery level further he reported that more than 93 per cent of variation in character was due to provenances.

Alvarez and Montalvo (1990) evaluated half-sib progeny trial with 26 families of *Pinus cubensis* at age of 10 years. The broad and narrow-sense estimates of heritability range from 0.842-0.964 and 0.551-0.85, respectively for total height, diameter at breast height and total volume.

Singh (1992) information on variability, heritability and expected genetic gain (genetic advance as per cent of mean) were obtained in 20 plus trees of Chilgoza pine for eight cone and characters. In general, heritability estimates were quite high for most of the characters, weight per cone provides lot of variability, high heritability and maximum genetic gain followed by seed length and number of seeds per cone. Seed weight per cone should be to priority for selecting the high yielding genotypes.

Chauhan and Verma (1993) evaluated the progeny performance of eight different provenances of *Acacia catechu* collected from different agro-climatic zones of Himachal Pradesh. The study revealed high heritability coupled with high genetic advance four seedlings height, collar diameter, number of leaves and branches per plant, thereby, indicating the importance of additive gene effects. Further, they suggested to give greater importance to the above characters while carrying out selection.

Dhillon (1995) calculated variability, heritability and expected genetic gain for seven growth characters studied in 30 superior phenotypes of Shisham collected from different agro-climatic zones of Haryana. Variability was recorded for all the growth characters. High heritability, coupled with high genetic advance (% of mean) was observed for number of branches, number of leaves and weight of leaves/seedling, suggesting them to be controlled by additive genetic effects.

Srivastava (1995) reported that high genetic coefficient of variability for *Bauhinia variegata* was accompanied by high heritability and genetic gain in seed weight, germination percentage, germination value, germination energy index, shoot and root dry weight thereby, depicting the scope for improvement of this character by direct selection.

Singh *et al.* (1995) derived information on genetic variability, heritability and genetic advance from data on total height, main stem height, basal diameter and straight bole height in the 3 years old progeny of 43 plus trees of *Dalbergia sissoo* from natural populations of Uttar Pradesh, Punjab, Haryana, Rajasthan and Bihar. High heritability estimates were recorded, ranging from 0.78 for total height to 0.85 for main stem height.

Singh and Bangarwa (1995) also studied the genetic variation of 43 trees of *Dalbergia sissoo* at the age of three year for total height, main stem height, basal diameter and straightness. They found significant variation/differences between progenies of different origin as well as among progenies of the same origin.

Yadav and Bangarwa (1997) studied the performance of ten clones of *Dalbergia sissoo* in a provenance trial for survival and the growth of circumference, height, branching pattern as well as volume yields. Result after 12 years of establishment indicated that provenances 11 from India and 6 from Bangladesh were the most promising for large scale plantations. However, other clones need special attention especially in genetic improvement programme.

Hosalli (1997) concluded moderate to high heritability and genetic gain for seedling height, collar diameter, internodal length, shoot and root fresh and dry weight among 49 species/ varieties of *Leucaena leucocephala*.

Gupta and Sehgal (2000) estimated the variability for phenotypic character of *Toona ciliata* among the altitudinal provenances and zones in Himachal Pradesh, where the heritability was found maximum (91.54%) under altitudinal provenances and relatively lower for zones (51.57%) with respect to leaf length among all other phenotypic parameters with genetic gain of 43.36 per cent and genetic advance of 14.08 per cent. In their study the wide ranges of genetic variabilities were observed for almost all the characters.

Kumar *et al.* (2005) studies the genetic variability and environmental variability of forty five Candidate Plus Trees (CPTs) of *Dalbergia sissoo* marked at different locations of Himachal Pradesh. The maximum heritability, genetic advance, genetic gain, phenotypic and genotypic coefficient of variability were recorded in the growth parameters as compared to wood extractives. It means that the growth parameters of trees are least influenced by environmental factors than genotypic factors.

Kumar *et al.* (2005) studies the variation in physico-chemical characteristics of wood of Candidate Plus Trees (CPTs) of *Dalbergia sissoo*. Among different CPTs of *Dalbergia sissoo*, significant differences were noticed for all the characters except for holocellulose contents. The maximum height and diameter were recorded in Khajjian-1 whereas, the minimum height was observed in Dhaulakkuan-1 and diameter in

Dhartatoh-3. The maximum bark percentage was noticed in Dhartyatoh-1 and minimum in Raja Ka Bagh-1. the maximum sapwood percentage and minimum heart wood percentage was found in Dhaulakuan-1, while the maximum heart wood percentage was noticed in Khajjian-1, Physico-chemical properties of sapwood viz., specific gravity, fiber length, cold water solubility, hot water solubility, alcohol-benzene solubility, lignin content and holocellulose content ranged between 0.5138, 0.6306, 0.93-1.22mm, 2.25% (1.50)-6.75% (2.60), 3.50% (1.87)-9.15% (3.02), 1.01% (1.00)-7.56% (2.75), 23.90-30.50% and 66.00-76.55%, respectively. Physico-chemical properties of heartwood of *Dalbergia sissoo* CPTs viz., specific gravity, cold water solubility, hot water solubility, alcohol-benzene solubility, lignin content and holocellulose content ranged between 0.5275-0.6905, 5.25% (2.29)-10.15% (3.19), 9.15% (3.02)-11.55% (3.40), 6.82% (2.61)-10.82% (3.29), 30.50-39.70% and 62.00-70.00%, respectively.

Dogra *et al.* (2006) evaluation trial was estimated for the identification of outstanding clones of *Dalbergia sissoo* for mass multiplication and field development of this species .The clones from Gonda,U.P.had overall better performance with an exception of clone 12 of pathri, Haridwar, Uttaranchal. Clone from Hanumanghar (Rajasthan) and Yamunanagar (Haryana) performed poorly. The clones 192,204, 232 and 66 (Gonda, U.P.) and 12 (Pathri, Haridwar, Uttaranchal) were not only high performers but also had better adoptability to this location and therefore, recommended for mass clonal multiplication for future plantation in panjab. On the basis of growth performance and heritability

estimates, height, GBH and clear bole were found to be genetically controlled traits.

2.2 Variation in pod and seed traits

Various researchers have stated that information on morphological variations in seed characteristics amongst natural population of a species is useful for tree improvement (FAO, 1985). Variation in pod and seed characteristics have been reported for *Acacia albida* (Snieszko and Stewart, 1984) and *Prosopis cineraria* (Arya *et al.*, 1992). The species having wide geographical distribution may display a wide spectrum of phenotypic variability (Khosla, 1984).

The most successful tree improvement programmes are those in which proper seed sources and provenances are used. The need to use the best-adopted seed sources was recognized in the early years as being important by researchers (Tozawa *et al.*, 1924).

Variation in seed and seedling traits and their significance in seed source studies have been documented in a number of tree species such as *Albizia lebbek* (Kumar and Toky, 1993), *Albizia procera* (Gera *et al.*, 1999), *Acacia nilotica* (Ginwal *et al.*, 1994 & 1998) and *Acacia spp.* (Bagchi and Dobriyal, 1990).

Yadav *et al.* (1998) studied the measurement of seed quality parameters namely, electrical conductivity (μ mhos/cm/seed), germination (%), variability (%), accelerated ageing (%) and vigour index. Highly significant variation was recorded for seed size and electrical conductivity among the eight girth classes studied. Seed size gave highly positive correlation with seed germination, viability, accelerated ageing and vigour

index. Whereas electrical conductivity was negatively correlated with all the seed quality parameters.

Srivastava *et al.* (2001) studied to evaluate different parameter viz., length, breadth, thickness, shape index (1/b ratio), seed weight, variability and germination percentage of seed samples of *Dalbergia sissoo* collected from 58 Candidate Plus Trees representing 7 seed sources of U.P., where the significant variation was observed between seed sources and studied parameters. On the basis of over all performance of the seed source can be grouped in descending order as Marheya > Etawah > Kanpur > Ramnagar > Lucknow > Haldwani > Mau. The performance of some Candidate Plus Trees was found poor however seed from better CPTs could be used for further genetic improvement programmes.

Singh *et al.* (2001) Studies to the pattern of variation in pods, seed characteristics and the germination behavior among the 6 seed sources of *Dalbergia sissoo*. All pod traits (except number of seeds per pod), seed characters, i.e. length, width, weight (except seed thickness) and germination parameters, i.e. germination percentage, germination value, germination period, etc., varied significantly among different seed sources. The variability observed among different seed sources may probably be influenced by different intensities of natural constraints acting upon these traits in the prevailing geographic/climatic conditions. Among the six different seed sources, Gonda showed the best performance followed by Kankai, Chiriyapur, Simblewala, Hissar and Sibsagar (the

poorest). Seed weight and seed thickness showed highly positive and seed length negative correlation with germination percentage.

Shekhar *et al.* (2002) studied to the pattern an extent of variation in seed morphology and germination. Statistically significant differences were observed among the seed sources for all the characters studied. The variation in germination percentage was large (34-91.33%) as compared to other characters studied. Germination percentage is positive and significantly correlated with 100 seed weight and viability and showed negative association with purity and number of seed in 100gm. the variation observed in seed morphology and germination characters were non-clinal type, except for significant positive relationship between longitudes and germination per cent and significant negative association with latitude and 100 seed weight.

Dhanai *et al.* (2003) recorded variability among 13 populations of *Albizia chinensis* for pod and seed morphology though altitude of seed source was found non-effective but among all the pod-seed characters, number of seeds/pod and seed weight were found most variable characters, and, number of seed/pod had higher genotypic, phenotypic and environmental co-efficient of variability. High broad sense heritability and genetic gains as obtained for pod length, seed thickness and number of seeds/pod indicate additive gene action. On average, the population of Manan, Augastyamuni, Joshiara and Tallimari were found to be the best on the basis of the pod-seed morphological characters.

2.3 Correlation and association analysis

Rathinam *et al.* (1982) applied path coefficient analysis technique to find out the inter-relationship of wood yield components in *Eucalyptus tereticornis* and concluded that girth at breast height was most closely related to stem wood weight and suggested its use as a selection index for biomass production.

Khosla *et al.* (1985) evaluated the correlation between shoot dry weight and other seedling characters in *Pinus roxburghii* and found that the root and shoot length, shoot and root fresh weight contributed directly to the shoot dry weight and were important for increase in the ultimate dry weight.

Gupta and Patil (1988) investigated variation in *Leucaena species* for fodder yield. Fuel wood yield, yield per plant, plant height, collar diameter length of leaf and seed traits and found significant positive association of five characters with fodder as well as fuel wood both at genotypic and phenotypic levels. Correlation coefficient at genotypic level of fodder yield, seedling weight, collar diameter and leaves per plant in all positive combinations were positive and highly significant. Further, forage yields indicated a high and direct effect in the above characters.

Gera *et al.* (1999) studied ten provenances/seed sources of *Dalbergia sissoo* Roxb. scattered over a wide range of its natural occurrences for germination, nursery and early field performance and observed significant variation among the provenances for germination per cent, seedling height, collar diameter and survival per cent. Variation for most of the traits studies was non-clinical type, except seed germination per cent, which showed significant negative correlation with altitude. Low

germination among the seeds of higher elevation populations was found to be due to higher dormancy existing in these seed lots. The inverse relationship observed between seed germination per cent and field height and collar diameter seems to be the result of poor germination due to dormancy existing in higher elevation seed sources. Such relationship may not be observed, if the seeds are properly treated before sowing. The provenance T₉ (Oachghat, solan), T₁ (Kukrai, Lucknow) and T₄ (Orai, U.P.) were found to be more vigorous on the basis of field performance and can be used for meeting the immediate seed requirement for afforestation programme.

Srivastava *et al.* (1993) conducted correlation and path coefficient studies on six attributes of *Terminalia arjuna* using data from an eight year old plantation. The study revealed that plant height and number of leaves per branch had a direct effect on leaf yield and they suggested that these two attributes should be given greater importance, while formulating selection indices.

Hooda and Raj Bahadur (1993) reported significant differences among genotypes of *Leucaena leucocephala* for some seed traits. Hundred seed weight had high genotypic correlation of variance, phenotypic correlation of variance, heritability and genetic advance, positive correlation was also noticed between seed length, breadth, thickness and weight.

Liu Zhaoxi *et al.* (1997) reported that the correlation of stem volume and dry weight was >0.95 and wood density was negatively

correlated with growth and yield but positively correlated with tree form traits in *Pinus taeda*.

Gwaze *et al.* (1997) studied the genetic and phenotypic parameters for height and stem straightness in *Pinus taeda*. They reported that age-age genetic correlation for height was high (0.76 to 0.97) and age-age genetic correlation for straightness ranged from -0.05 to 0.94. Genetic correlation between height and straightness was low.

Espinel *et al.* (1997) estimated genetic parameter for growth and form traits of seven year old progeny of *Pinus radiata* and found that stem diameter, height and branch angle were positively correlated with each other.

Reddy and Subramanian (1998) found higher genotypic correlation than phenotypic correlation in *Santalum album*. They reported strong genotypic association of plant height, basal diameter, and leaf length and leaf breadth with volume and phenotypic association of first two characters with volume.

Tyagi *et al.* (1999) reported positive correlation of germination (0.873-0.964) with all the seed characters studied *viz.*, seed length, seed width, seed thickness, seed volume and 100 seed weight among the provenances of *Grewia optiva*.

Gera *et al.* (1999) observed higher direct and indirect effects of characters *viz.*, polyphenol, number of branches, pod length and germination per cent on field height in *Dalbergia sissoo*. Further they emphasized on the use of these parameters as selection criteria for improving field height.

2.4 Genetic divergence

Assessment of genetic divergence between populations is vital to success of plant genetic improvement planned to exploit the genetic diversity within and among populations and heterosis is often obtained by wide crossing. Multivariate assessments are often made by using phenotypic population means. If these are based on sufficiently large sample sizes and the traits measured show significant differences between populations, they can provide a reasonable representation of over-all genetic performance.

Multivariate procedures have helped to evaluate germplasm collections used for evaluation, selection and breeding in a number of grass species (Humphreys *et al.*, 1980, Charmet *et al.*, 1988).

Garg and Gautam (1997) evaluated four hundred and forty one wheat germplasm collections including important varieties and exotic and indigenous accessions, for 15 metric characters using non-hierarchical Euclidean cluster analysis. All the genotypes were grouped into 12 different clusters showing the existence of high genetic diversity in the material. The intra-cluster distance was maximum (2.90) in cluster II and minimum (2.10) in cluster V. Cluster IV and X were highly diverse (6.66) from each other. Genotypes of cluster IV were highest yielder. Several collections, which may serve as good genetic donors for high spikelet fertility, dwarf-ness, long ear, bold grain, high number of ears and good source for multiple resistance against rust and powdery mildew were identified.

Mani *et al.* (1996) observed genetic divergence among 100 accessions of maize. They grouped all the accessions in to eleven clusters. The seven accessions grouped in cluster VIII showed more heterogeneous population owing to highest intra cluster distance.

Surendran and Chandrashekharan (1988) illustrated the magnitude of genetic divergence among thirty five single tree selections of *Eucalyptus tereticornis* from different agro climatic zones of Tamil Nadu. Based on the eight growth characters they applied mahalanobis D^2 statistic to identify eleven clusters among the 35 single tree selections. Three clusters were found highly divergent from each others.

Bagchi (1992) noticed very high genetic divergence among 42 provenances of *Acacia nilotica* for seed traits viz., seed length, width and thickness. Seed thickness contributed most (52.0%) to the total divergence followed by seed width (33.33%) and seed length (14.54%).

Singh (1993) studied genetic divergence among nineteen plus bamboo clumps selected from northern and southern parts of Assam and adjoining areas of Arunachal Pradesh. The plus bamboos were grouped into four clusters but the grouping of genotypes into clusters was not related to their geographical origin.

Pandey *et al.* (1995) reported high genetic divergence for sixteen quantitative traits in twelve clones of *Populus deltoids*. The clones were divided into five clusters where the inter cluster distance varied from 1.13 to 19.3.

Chauhan *et al.* (2000) assessed the magnitude of genetic divergence among the progenies of 58 plus trees of *Pinus roxburghii* at 5

year age on the basis of five growth characters *viz.*, plant height, collar diameter, current year growth, internodal length and spur dry weight to identify cluster pattern for future improvement programme in this species and the 58 progenies were grouped into 11 clusters.

Tiwari *et al.* (2002) studies the genetic divergence using Mahalanobis D2 analysis among 15 genotypes of shisham with twenty component characters at 5 years of age led to their grouping into six clusters. Three genotypes fall in cluster I, four in cluster II, three each in cluster III and IV, and only one in cluster V and VI. Maximum and minimum distances were observed between cluster IV and V and clusters III and V, respectively.

CHAPTER-III

MATERIALS AND METHODS

The present investigation entitled “**Evaluation of provenances of *Dalbergia sissoo* Roxb.**” was carried out to study the performance of CPTs of *Dalbergia sissoo* at Research farm Baronda of the department of Forestry of the Indira Gandhi Agricultural University, Raipur (Chhattisgarh) during 2004-05. The experimental details relating to experimental site, material and methodology adopted in the study are described in this chapter.

3.1 Experimental site

The experimental site, IGAU Research Farm Baronda, located at 27 km away from Raipur on the Raipur-Balodabnazar road with, 10 km aerial distance from IGAU main campus. It comes under the agro-climatic zone of central plain Chhattisgarh and located at 21° 4' N latitude and 81° 39' E longitude and situated at an altitude of 298 m above the mean sea level.

3.2 Climate and weather

The climate of study site is dry sub-humid tropical with an average yearly rainfall of 1250 mm and most of the rainfall (>80 per cent) received during monsoon season from June to first fortnight of September and a few showers are expected during winters and occasionally during summer. The average number of rainy days varies from 65 to 79. The mean maximum temperature ranges from 27.3° C in December to 42.3° C

in May. The minimum mean temperature varies from 13.2⁰ C in December to 28.3⁰ C in May. The maximum temperature goes beyond 45⁰C in May and minimum below 10⁰C in December. The relative humidity varies between 70-90 per cent from mid June to March end. Sunshine period in a day prolong more than 9 hours in summer and less than 7 hours in winter. Evaporation remain higher during April to June (10-13 mm day⁻¹) and low during July to February (2.4 to 5.0 mm day⁻¹).

The annual weather mean data for ten years recorded at meteorological observatory, IGAU, Raipur (C.G.) is presented in Fig. 3.1.

3.3 Geology

Raipur has three distinct geological formations viz. Bijapur, Cuddaph, Dharware and Archeau. Lithologically it is classified into seven areas namely, Raipur shale and limestone, Gunderdehi shale, Khairagarh sand stone, Cuddapa camas limestone, Chandrapur sand stone grit, Dharwar rocks, granite and geneisis.

3.4 Physiography

In Chhattisgarh central plains agro climatic zone, there are 10 districts viz.; Bilaspur, Dhamtari, Durg, Janjgir-champa, Korba, Kavardha, Mahasamund, Rajnandgaon, Raigarh and Raipur, which is also known as saucer-shaped upper Mahanadi basin. The longer part of this basin is undulating, flat terrain, and gentle slopes from west to east. The general geological features of the zone comprises of laterites, alluvium capping over horizontally bedded sequence of sedimentary rocks of limestone and dolomite on the top followed by limestone shade, quartzite sand stone,

granite, gneisses and meta sediments of old age. These formations have very limited primary porosity and permeability to water.

3.4.1 Soils

Soils of Chhattisgarh plains varies from lateritic/*Entisols* (20 per cent), Sandy loam/*Inceptisols* (45 per cent), clay loam/*Alfisols* (10 per cent) and clayey/*Vertisols* (25 per cent). The soil depth varies from 20 cm in *Entisols* to 100 cm in *Vertisols*, with light undulation and gentle slopes of 2 per cent. A typical-semi-arid condition of soil appears just after the rainy season due to shallow soil and high rate of percolation.

3.4.2 Physico-chemical characteristics of the soil

Soil samples up to 100 cm depth were randomly collected from 10 locations of the experimental site to determine their physico-chemical properties. A representative composite sample from the 10 random samples was drawn and used for analysis. The experimental soil is classified as *Entisols*, texturally sandy and locally known as *Bhata*. From land use classification point of view it is marginal wasteland. The detailed physico-chemical properties of soil of the experimental site are presented in Table3.1.

Table 3.1: Initial physico-chemical properties of experimental soil

Parameters	Values	Rating	Method used
A. Physical properties			
1. Mechanical composition			
Sand (%)	78		International pipette Method (Black, 1965)
Silt (%)	13		
Clay (%)	9		
Textural class	-	Sandy (<i>Entisol</i>)	
2. Bulk density (gm cc ⁻¹)	1.76	-	Soil core method (Bodman, 1942)
B. Chemical composition			
1. pH (1:2.5 soil water suspension) up to 100 cm depth	5.73	Acidic	Glass electrode pH meter (Piper, 1967)
2. Organic carbon (%) up to 100 cm depth	0.25	Low	Walkeley and black method (Jackson, 1973)
3. Available N (kg ha ⁻¹) up to 100 cm depth	147.4	Low	Alkaline per magnate method (Subbiah and Asija, 1956)
4. Available P (kg ha ⁻¹) up to 100 cm depth	4.134	Low	Olsen's method (Olsen, 1954)
5. Available K (kg ha ⁻¹) up to 100 cm depth	194.6	Medium	Flame photometric method (Jackson, 1973)
6. Available S (mg kg ⁻¹) up to 100 cm depth	3.44	Very low	Turbidometry (Tandon, 1993)

3.5 Experimental details

Tree	-	<i>Dalbergia sissoo</i>
Seed source and number (provenance)	-	45 entries of CPTs from Five geographical sources
(I) Chhattisgarh, (IGAU, collection), (GBPAT, collection), (NDUAT, collection), (HNBU, collection)		(ii) Pantnagar (U.A.) (iii) Solan (H.P.), (YSPUHF, collection) (iv) Faijabad (U.P.), (v) Garwal (U.A.) hills

Details of entries are given in Table 3.2 and 3.3.

Seed material received under exchange performance of ICFRE *Dalbergia sissoo* project

Date of plantation	-	July/August 1998
Spacing size	-	5 m x 5 m
Soil type	-	Red Lateritic
Number of replications	-	3
Plot size	-	15 m x 15 m
Experimental design	-	R.B.D.

3.6.1 Measurement of growth parameters

The following growth parameters (height, DBH, clear bole height and straight bole height) were recorded with the standard methods.

(i) Tree Height

The total height of standing trees were measured with the help of a standard graduated bamboo, meter scale and 30 m tape. The total height of the tree was recorded from the base to the tip of the tree.

(ii) Clear bole height

Clear bole height was measured from the base to the point of first green branch of the tree.

(iii) Straight bole height

The straightness or straight bole height was measured from the base point of stem to the straight point of stem of tree with the help of standard graduated bamboo, meter scale and 30 m long tape.

(iv) Diameter at breast height

Diameter at breast height was measured at 1.37 m height from the base using vernier calipers. Two measurements at right angle to each other were taken in each tree and mean of two directions represents DBH.

Table 3.2: List of entries of CPTs from different location

S. No.	Location and entries	S. No.	Location and entries
1	Pantnagar (U.P.) PSS-1	31	Faijabad (U.P.) NFSS-1
2	PSS-2	32	NFSS-2
3	PSS-3	33	NFSS-3
4	PSS-4	34	NFSS-4
5	PSS-5	35	NFSS-5
6	PSS-6	36	NFSS-6
7	PSS-7	37	NFSS-7
8	PSS-8	38	NFSS-8
9	PSS-9	39	NFSS-9
10	PSS-10	40	NFSS-10
11	Solan (H.P.) D-2	41	Garwal (U.A.) hills SSS-1
12	D-1	42	SSS-2
13	D-8	43	SSS-3
14	J-15	44	SSS-4
15	J-21	45	SSS-5
16	K-6		
17	K-8		
18	N-2		
19	N-5		
20	N-9		
21	Chhattisgarh MN-1		
22	MN-2		
23	MN-3		
24	MN-4		
25	MN-5		
26	MN-6		
27	MN-7		
28	MN-8		
29	MN-9		
30	MN-10		

Table 3.3: Location, soil characteristics and morphological features of selected

Candidate Plus Trees in Chhattisgarh

S. No.	Entries of CPTs	Place of location	Soil	Ht. (m)	DBH (cm)	CB (m)	SH (m)
1.	MN-1	Saragaon, Bilaspur	Black	12.00	37.00	4.60	4.60
2.	MN-2	Saragaon, Bilaspur	Black	11.20	32.00	6.20	4.70
3.	MN-3	Bilaspur road	Black	11.70	37.60	2.20	2.20
4.	MN-4	Rawa, Bilaspur	Sandy loamy	11.70	15.00	3.20	3.20
5.	MN-5	Koni, Bilaspur	Sandy loamy	13.40	24.60	6.20	6.20
6.	MN-6	Chaker-Bhata	Entisols	13.20	13.60	4.70	7.70
7.	MN-7	Chaker-Bhata	Entisols	14.70	16.20	4.20	6.20
8	MN-8	Chaker-Bhata	Entisols	14.20	14.10	4.40	6.40
9.	MN-9	Raigarh	Alfisols	11.70	18.60	5.90	7.20
10.	MN-10	Raigarh	Sandy loamy	26.70	65.00	9.70	7.70

3.7 Morphological characteristics of pod and seeds

To determine the morphological characteristics of pod and seeds of following parameters were recorded:

- i) **Pod size (cm):** Pod length and width were measured with help of standard meter scale, digital caliper and graph paper method.
- ii) **Number of seed:** Number of seeds per pod, number of healthy seeds per pod and no. of damage seeds per pod were measured by counting of total seed in each pod.
- iii) **Seed size (cm):** Seed length and width were also measured with help of standard scale, digital caliper and graph paper method.
- iv) **Seed thickness (cm):** Seed thickness measured with the help of screw-gauge.
- v) **Pod and seed weight:** Weight of each pod, weight of total seed per pod and weight of healthy seed per pod were weighted in an electronic Shimadzu AEU-210 top-pan balance as per ISTA (1966).

3.8.1 Phenological observations

Growth status in relation to phenological study for bark colour, branching pattern, leaves fall and formation, flowering and fruiting initiation were done by visual observations for a year.

3.9 Ranking of Entries

The ranking of trees performance was done by scoring them marks out of 10 for each character (height, DBH, clear bole ht. and straightness

ht.). So the final ranking was done by adding the marks obtained by each entries with respect to height, diameter at breast height, clear bole height and straight bole height (Table 3.4).

Table 3.4: Table-points/scores awarded for different entries of *Dalbergia sissoo*

Characteristics	Performing traits	Point/score
A) Height (m)	2-3	0
	3-4	1
	4-5	2
	5-6	3
	6-7	4
	>7	5
B) Diameter at breast height (cm)	2-4	0
	4-6	1
	6-8	2
	8-10	3
	10-12	4
	>12	5
C) Clear bole height (m)	0-1	0
	1-2	1
	2-3	2
	3-4	3
	>4	4
D) Straight bole height(m)	0-1	0
	1-2	1
	2-3	2
	3-4	3
	4-5	4

3.10 Statistical analysis

The data thus obtained were subjected to statistical analysis in RBD design for field study as described by Panse and Sukhatme (1967) and Chandel (1984). The analysis of variance (ANOVA) Table was setup as under:

Source of variation	Degree of freedom	Sum of squares	Mean squares	F calculated
Replication	$(r-1)$	RSS	$Mr = \frac{RSS}{(r-1)}$	$\frac{Mr}{Me}$
Treatment	$(t-1)$	TSS	$Mt = \frac{TSS}{(t-1)}$	$\frac{Mt}{Me}$
Error	$(t-1)(r-1)$	ESS	$Me = \frac{ESS}{(r-1)(t-1)}$	
Total	$(tr-1)$			

F calculated were compared with F tabulated. Any of items was considered significant if F calculated was higher than F tabulated.

Error variance (V_e) = Error mean square due to provenance (EMS) = M_e

Genotypic variance (V_g) =

$$\frac{\text{Treatment mean square due to provenances} - \text{Error mean square due to provenances}}{\text{No. of replications}}$$

$$(V_g) = \frac{M_t - M_e}{\text{No. of replications}}$$

Phenotypic variance (V_p) = (V_g) + (V_e)

Where,

N = total number of observations

R = number of replications

Mr = mean sum of squares due to provenances

Mt = mean sum of squares due to provenances

Me = mean sum of squares due to errors

The critical differences (CD) were calculated as under:

$$CD = SEd \times t_{0.05}$$

Where is the standard error of difference calculated as:

$$SEd = \sqrt{\frac{2Me}{r}}$$

And $t_{0.05}$ is the t value at 5 per cent level of significance.

Computation of variability parameters

The following variation parameters were analyzed.

Coefficients of variability were worked out as suggested by Burton and De Vane (1953):

$$PCV(\%) = \frac{\sqrt{V_p}}{\bar{X}} \times 100; \quad V_p = \text{Phenotypic variance}$$

$$GCV(\%) = \frac{\sqrt{V_g}}{\bar{X}} \times 100; \quad V_g = \text{Genotypic variance}$$

$$ECV(\%) = \frac{\sqrt{V_e}}{\bar{X}} \times 100; \quad V_e = \text{Environmental variance}$$

Where,

PCV = Phenotypic coefficient of variability

GCV = Genotypic coefficient of variability

ECV = Environmental coefficient of variability

$\bar{X}$ = Population mean of the character

Seed sources coefficient of variability was calculated as given by Pillai and Sinha (1968):

$$CV(\%) = \frac{SD}{\bar{X}} \times 100$$

Where,

CV = Coefficient of variability

SD = Standard deviation

$\bar{X}$ = Population mean

Heritability was calculated as suggested by Burton and De Vane (1953) and Johnson *et al.* (1955)

$$h^2 = \frac{V_g}{V_p} \times 100$$

Where,

h^2 = Broad sense heritability

V_g = Genotypic variance

V_p = Phenotypic variance

The expected genetic advance at five per cent selection intensity was calculated by the formula suggested by the Lush (1940) and further used by Burton and De Vane (1953) and Johnson *et al.* (1955):

$$\text{Genetic advance} = h^2 \times \sqrt{V_p \times K}$$

Where,

h^2 = Heritability (Broad sense)

V_p = Phenotypic variance

K = Selection differential at five per cent selection intensity $K = 2.06$

(Allard, 1960)

Genetic gain was worked out following the method suggested by Johnson *et al.* (1955):

$$\text{Genetic gain}(\%) = \frac{\text{Genetic advance}}{\bar{X}} \times 100$$

3.11 Photography

Colour photography descriptions were also recorded for evidence of research work by using SLR Cannon AE-1 programme with 30-70 mm zoom camera.

CHAPTER-IV

RESULTS AND DISCUSSION

The present study was conducted with the object of collecting some basic information on selected 45 entries from different geographical area (provenances) which could enlighten the strategy to be adopted in genetic improvement of shisham (*Dalbergia sissoo* Roxb.) under Raipur agro-climatic situation.

A characteristics feature of all living organism is the immense natural variability present for various characteristics in most populations. In naturally wide spread species, variations are to be expected between population growing under different geographical conditions. So selection of the phenotypical superior provenance is one of the major factors affecting establishment and productivity for plantation. Thus, evaluation of provenances research helps the forester in the choice of the right promising phenotypes, best suited to locality /region. The glaring example mentioned here is of *Dalbergia sissoo* Roxb. The growth characteristics and seed source studies showed the potential gains in productivity, simply by selection of the best promising provenance for prevailing environmental conditions.

Additionally, it also provides information on the basic material for tree breeding and involving improved plant stock within a provenance and for inter provenance hybridization where necessary for combining productivity

and adoption. The result and discussion pertaining to different aspects of the present study has been furnished under the following heads.

4.1 Genetic variability

4.1.1 Co-efficient of variation for tree growth and pod-seed characters

4.1.2 Mean performance for tree growth and pod-seed characters

4.1.3 Phenotypic, genotypic and environmental coefficient of variation for tree growth and pod-seed characters

4.2 Heritability for tree growth and pod-seed characters

4.3 Genetic advance for tree growth and pod-seed characters

4.4 Genetic gain for tree growth and pod-seed characters

4.5 Phenological observations

4.6 Growth performance and ranking of entries from different geographical proven

4.7 Estimation of heritability (broad sense) for different provenances

4.1 Genetic variability

4.1.1 Co-efficient of variation for tree growth and pod-seed characters

The co-efficient of variation (CV), which helps comparing the genetic variability for different growth characters was computed highest 0.59 per cent in (D-8, Solan) and least in 0.05 per cent (NFSS-1, Faijabad) for total height. In dia-meter at breast height, highest CV was recorded in 1.15 per cent (PSS-3, Pantnagar) and lowest in 0.05 per cent (MN-6, Chhattisgarh) population. Highest CV for clean bole height was

recorded in 1.26 per cent (J-15, Solan) and lowest for 0.14 per cent (NFSS-1, Fajjabad). The highest CV for straight bole height in 5.1 per cent (N-5, Solan) and lowest in 0.09 per cent (MN-9, Chhattisgarh) (Table 4.1).

The co-efficient of variation (CV) for different pod-seed characters was computed highest in 12.81 per cent (J-15, Solan) and least in 0.73 per cent (NFSS-1, Fajjabad) for pod length. In pod width, highest CV was recorded in 16.98 per cent (PSS-6, Pantnagar) and lowest in 0.53 per cent (N-9, Solan) provenance. Highest CV for number of seeds per pod was recorded in 14.72 per cent (PSS-9, Pantnagar) and lowest in 2.08 per cent (MN-1, Chhattisgarh) provenance. In wt. of per pod highest CV was recorded in 11.6 per cent (PSS-2, Pantnagar) and lowest in 0.48 per cent (PSS-10, Pantnagar).

Among the seed traits greatest CV for seed length was recorded in 8.09 per cent (PSS-9, Pantnagar) and lowest for 0.53 per cent (PSS-5, Pantnagar) provenance. For seed width, CV ranged from 1.14 per cent (NFSS-3, Fajjabad) to 6.97 (PSS-10, Pantnagar), for seed thickness it varied between 0.43 per cent (MN-9, Raipur) to 4.74 per cent (PSS-5, Pantnagar) provenance.

Among the wt. of total seed per pod, greatest CV recorded in 11.39 per cent (PSS-9, Pantnagar) and lowest in 1.23 per cent (SSS-5, Garwal) provenances. Between all the pod and seed traits studied, pod width followed by number of seed per pod was found most variable characters among the population (Table 4.2).

Dhanai, *et al.* (2003) observed that minimum co-efficient of variation (CV) for seed length, seed width and seed thickness respectively

provenance of Laagasu, Kund and Mandi. However, it was superior compare to other provenance.

4.1.2 Mean performance for tree growth and pod-seed characters

Mean and range of different growth characteristics are given in Table 4.3. Total height was ranged between 2.86 to 7.48 m with a mean 5.13 m. The character of diameter at breast height was varied from 3.5 to 12.43 cm with a mean of 7.81 cm. The clean bole height varied from 1.25 to 3.91 m with a mean of 2.17 m. Straight bole height varied from 1.14 to 4.41 m with a mean of 2.3 m.

Mean and range of different pod-seed characteristics are given in Table 4.4. The mean performance of pod length was 5.51 cm with a minimum of 4.2 cm and maximum 6.06 cm. The mean of pod width was 0.92 cm with a minimum 0.863 cm and maximum 1.05 cm. Number of seeds per pod had a mean of 2.03 with a minimum 1.56 and maximum 2.43. The minimum and maximum for weight of per pod was 0.08 g and 0.205 g, respectively with a mean of 0.163 g. The mean performance of seed length was 0.896 cm, with a minimum 0.59 cm and maximum 1.2 cm. The mean of seed width was 0.39 cm with a minimum 0.376 cm and maximum 0.41 cm. The mean of seed thickness was 0.179 cm with a minimum and maximum of 0.168 to 2.2 cm, respectively. Weight of seeds per pod had a mean performance of 0.039 g with a minimum of 0.031 g and maximum of 0.047.

Nautiyal *et al.* (2003) found significant inter-clonal variation in height and collar diameter of *Dalbergia sissoo* clones under Dehradun conditions. However studies pertaining to the higher mean of growth

performance of *Dalbergia sissoo* provenances also support the present investigation showing better of U.P. and Uttaranchal (Rehman and Hussain, 1986; Devagiri, 1997).

Mikhailov (1987) observed that the effect of higher mean performance of seed length, seed width, seed thickness and weight of 100 seeds as most viable character of Shisham, which helps for selection of superior seed source/provenance.

4.1.3 Phenotypic, genotypic and environmental co-efficients of variation for tree growth and pod-seed characters

Phenotypic, genotypic and environmental co-efficients of variation were calculated for different growth characters and different pod-seed characters are presented in Table 4.3 and 4.4. The phenotypic co-efficients of variation (PCV) was higher in magnitude than that of genotypic co-efficients of variation (GCV). And environmental co-efficients of variation (ECV) was higher in magnitude than that of genotypic co-efficient of variation (GCV).

Among the different growth characters, clean bole height had highest magnitude of phenotypic co-efficient of variation (42.98%). The high magnitude of phenotypic co-efficient of variation was recorded for straight bole height (38.89 %). The moderate magnitude of phenotypic coefficient of variation was recorded for dia-meter at breast height (31.91%). Low magnitude of phenotypic co-efficient of variation was recorded for total height (28.18 %).

The highest genotypic co-efficient of variation was recorded for clear bole height (28.12%). The high magnitude of genotypic co-efficient

of variation was recorded for straight bole height (26.97%). The moderate magnitude of genotypic co-efficient of variation was recorded for diameter at breast height (24.36 %). Low magnitude of genotypic co-efficient of variation was recorded for total height (21.81).

The highest environmental co-efficient of variation was recorded for clean bole height (36.71%). The high magnitude of environmental co-efficient of variation was recorded for straight bole height (35.71%). The moderate magnitude of environmental coefficient of variation was recorded for diameter at breast ht. (20.72%). Low magnitude of environment co-efficient of variation was recorded for total height (17.84 %).

Among the different pod-seed characters, number of seeds per pod had highest magnitude of phenotypic co-efficient of variation (14.42%). The high magnitude of phenotypic co-efficient (> 10 %) were recorded for seed length (13.16 %) and weight of seeds per pod (11.20 %). Moderate magnitude of phenotypic co-efficient of variation (5-10 %) were recorded for pod width (8.33 %) and pod length (8.01 %). Low magnitude of phenotypic co-efficient of variation (<5.0 %) were recorded for seed width (3.86 %), weight of per pod (2.54 %) and seed thickness (2.36 %).

The highest genotypic co-efficient of variation was recorded for weight of seeds per pod (6.57 %). The high magnitude of genotypic co-efficient of variation (>5.0%) were recorded for number of seeds per pod (6.04 %) and seed length (5.36 %). Moderate magnitude of genotypic co-efficient of variation (2-5 %) were recorded for pod length (4.58 %) and pod width (2.59 %). Low magnitude of genotypic coefficient of variation

(<2.59 %) were recorded for seed width (1.72 %), seed thickness (1.023 %) and weight of per pod (0.989%).

The highest environmental co-efficient of variation was recorded for number of seeds per pod (12.93 %). The high magnitude of environmental co-efficient of variation (>7.0 %) were recorded for seed length (12.02 %), weight of seeds per pod (9.07 %) and pod width (7.91 %). Moderate magnitude of environment co-efficient of variation (3-7 %) was recorded for pod length (6.60 %), seed width (3.46 %) and seed thickness (3.38 %). Low magnitude of environmental co-efficient of variation (<3.38 %) was recorded for weight of per pod (1.27 %).

Bangarwa (1993) reported that the higher phenotypic co-efficient of variation (PCV), genotypic co-efficient of variation (GCV) and Environmental Co-efficient of variation (ECV) for straight bole height. The moderate and low magnitude of PCV, GCV and ECV respectively for main stem height, basal diameter and total height of *Dalbergia sissoo*.

Chouhan and Singh (1984) found that high genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV) for plant height and number of pods per plant in soybean.

Dhanai *et al.* (2003) observed that the higher phenotypic co-efficient of variation (PCV), genotypic co-efficient of variation (GCV) and environmental co-efficient of variation (ECV) for number of seeds per pod. The moderate magnitude of phenotypic co-efficient of variation (PCV), genotypic co-efficient of variation (GCV) and environmental co-efficient of variation (ECV) for pod length. Low magnitude of PCV, GCV and ECV

respectively for pod width, seed width, seed thickness, 100 seed weight and seed length of *Albizia chinensis* in H.P. condition

4.2 Heritability for tree growth and pod-seed characters

Heritability in the broad sense was calculated for each growth characters. Highest heritability estimates were observed for total height (84.24 %). The high magnitude of heritability estimates were observed for straight bole height (81.34%), dia-meter at breast height (78.10%) and clear bole height (74.86%) showed in Table 4.3.

Heritability in broad sense was also calculated for each pod-seed character. Highest heritability estimates were observed for pod length (52.30 %). The high magnitude of heritability estimates (>40 %) was observed for weight of per pod (43.49 %). Moderate magnitude of heritability estimates (30-40 %) was observed for weight of seeds per pod (34.45 %). Low magnitude of heritability estimates (<30 %) were observed for seed thickness (29.2 %), seed width (19.74 %), number of seeds per pod (19.69 %), pod width (18.66 %) and seed length (16.55%).

Several researchers have also given same opinion as noted in this experiment. The high heritability for total height, straight bole height, basal diameter and clear bole height respectively have been also witnessed by Singh and Bangarwa (1995), Bangarawa (1993) and Bangarawa (1995).

High heritability accompanied by high genetic advance for several growth characteristics have earlier been reported in *Prosopis cineraria* (Sonlanki *et al.*, 1993), *Terminalia arjuna* (Srivastave *et al.*, 1993) and *Azadirchta indica* (Dhillon *et al.*, 2003). Hosalli (1997) concluded moderate to high genetic heritability for seedling height, collar diameter,

inter nodal length, shoot and root fresh and dry weight among 49 species of *Leucaena leucocephala*.

Dhanai *et al.* (2003) found that higher magnitude of heritability, respectively for pod length and weight of per pod of *Albizia chinensis* in H.P. condition. Johnson *et al.* (1955) moderate magnitude of heritability was observed for weight of seeds per pod of soybean.

Hooda and Raj Bahadur (1993) reported that the high heritability for 100 seed weight of *Leucaena leucocephala*. Dhanai *et al.* (2003) recorded low heritability for number of seeds per pod, seed length and seed thickness of *Albizia chinensis*. Chamola (1990), Jain (1990), Tomar (1990) and Singh (1992) observed low heritability for number of seeds per pod of soybean.

The traits possessing low heritability are difficult to improve through phenotypic selection of the superior provenance.

4.3 Genetic advance for tree growth and pod-seed characters

Genetic advance was recorded for different growth and different pod-seed characteristics. The highest genetic advance (GA) was recorded for dia-meter at breast height (2.082). The high magnitude of genetic advance (GA) was recorded for total height (1.45). Moderate magnitude of genetic advance was recorded for straight bole height (0.671). Low magnitude of genetic advance was recorded for clean bole height (0.515) showed in Table 4.3.

Similarly the highest estimates genetic advance was recorded for seed thickness (0.78). The high magnitude of genetic advance (>0.2) was recorded for pod length (0.205). Moderate estimates genetic advance

(0.10-0.20) was observed for weight of per pod (0.169). Low magnitude of genetic advance (<0.10) were observed for number of seeds per pod (0.083), seed length (0.028), pod width (0.011), seed width (0.0043) and weight of seeds per pod (0.00213).

Bangarawa (1993) and (1995) supported as high genetic advance (GA) for diameter at breast height. The moderate magnitude of genetic advance for total height. Low magnitude of genetic advance respectively for straight bole height and clear bole height at *Dalbergia sissoo* in the present investigation.

Hooda and Raj Bahadur (1993) reported that high magnitude of genetic advance (GA), respectively for seed length, breadth, thickness and weight in *Leucaena leucocephala*.

The present investigation also supported by Dhanai *et al.* (2003). They observed at *Albizia chinensis* in high magnitude of genetic advance (GA) for pod length. The moderate magnitude of GA was observed for weight of per pod, seed thickness and seed length. Low magnitude of GA was observed for number of seeds per pod, weight of seed per pod and seed length.

High magnitude of GA respectively for pod bearing length, plant height and number of primary branches of primary branches of soyabean. These results are in agreement with the findings of Chamola (1990) and Tomar (1990) for pod bearing length. Other researchers reported as high estimate of GA for plant height (Singh, 1986; Sharma, 1988; Tomar, 1990; Mahajan *et al.*, 1994 and Mehetre *et al.*, 1998).

Moderate estimate of genetic advance was observed for the characters numbers of pods per plant, which is supported by Sharma (1988) and Chamola (1990).

Low estimate of genetic advance was observed for number of seeds per plant, 100 seed weight, pod length and number of seeds per pod. These results are in agreement with Chamola (1990), Sharma (1988) and Narolia (1990).

4.4 Genetic gain for tree growth and pod-seed characters

The highest genetic gain as percentage of mean was recorded for straight bole height (29.18%). The high estimate of genetic gain as percentage of mean was recorded for total height (28.26%). Moderate estimates genetic gain as percentage of mean was recorded for diameter at breast height (26.63%). Low estimates of genetic gain as percentage of mean was recorded for clean bole height (23.76 %) showed in Table 4.3.

The highest genetic gain as percentage of mean was recorded for pod length (3.72 %). The high estimates of genetic gain as per percentage of mean (>3.0 %) were recorded for weight of per pod (3.21 %). Moderate estimates of genetic gain as percentage of mean (2-3 %) were recorded for seed thickness (2.06 %), number of seed per pod (2.03 %). Low estimates of genetic gain as percentage of mean (< 2 %) was recorded, respectively for weight of seeds per pod (1.53 %), pod width (1.16 %), seed width (1.09 %) and seed length (1.01%).

Similarly results finding by Bangarwa (1993 & 1995) the high magnitude of genetic gain as percentage of mean, respectively for straight bole height, total height, diameter at breast height and clear bole height in

Dalbergia sissoo. Hosalli (1997) reported that high genetic gain as percentage of mean for seedling height, collar diameter, inter nodal length, among 49 species of *Leucaena leucocephala*.

Dhanai *et al.* (2003) reported as high genetic gain as percentage of mean for pod length of *Prosopis cineraria*. Moderate genetic gain as percentage of mean respectively for seed thickness, number of seeds per pod and pod width of *Prosopis cineraria*.

4.5 Phenological observations

Phenological records were made by visual observation during 2004-2005 from July to June presented in Table 4.5.

4.5.1 Colour of bark

Colour of bark was generally dark brown in all the entries of CPTs. There was not observed any remarkable changes in the bark colour, because age of all the entries were quite obtain and belongs to equal age of group, similar environment and management. It may be differentiate at maturity stage.

4.5.2 Branching pattern

Branching pattern of *Dalbergia sissoo* was reported epicormic. In the present study of branching pattern were also recorded epicormic in all the entries. This plantation of all the entries was at 5x5 m having uniform rectangularity and it had uniform age, therefore no remarkable change of branching pattern was seen.

4.5.3 Leaf fall

Leaves fall take place generally in November-January. The leaf fall was started from November in all the entries and it continue unto January.

High leaf fall was recorded in end of December which gradually decreased till the initiation of new leaves.

4.5.4 Leaf initiation

New Leaf initiation appears between February and April. The leaves initiations were started in first week of February and it was gradually continued till the end of April, with peak of new leaf formation in March. Thus in the mid of summer all the entries had new flush of full grown green leaves.

4.5.5 Flowering

The flowers bud formation started from March to April. The beginning of flowering was recorded poorly in First week of March. It was gradually increased with increasing the temperature. The start of April was recorded highest flowers which remain till the first week of May.

4.5.6 Fruiting

Pale green young pods appear by end of April, in masses all the entries of CPTs and it was related to flowering pattern. Poorly fruiting was recorded in mid of May. Moderately fruiting was also observed in first week of October. Highly fruiting period was also recorded in end of October; they become full sized and gradually turn from yellowish green to brown start in November and ripen pods were available during December.

Since the edaphic and climatic conditions primarily controlled the foliage fall, foliage initiation, flowering and fruiting behaviour. In the plantation 45 entries the edaphic, climatic and management facilities were more or less similar, therefore during the study period no significant variation was observed in the 45 entries.

Krishnaswamy and Mathauda (1954) recorded hasten foliage initiation and flowering in February-March, because during period at high mean temperatures and low relative humidity was recorded.

Kumar and Paliwal (1996) observed that similarly new leafing and flowering of 10 provenances of *Dalbergia sissoo*, in January-March, influence by chief- meteorological forces. It appears that high mean temperatures and low relative humidity is required for activation of leaf and flower formation. In the present study more or less similar environmental condition as well as management practice made available to all the entries gave uniform results of leaf fall, leaf formation, flowering and fruiting pattern.

4.6 Prediction of tree growth performance and scoring of different entries

Prediction of overall maximum score was recorded for different entries, MN-9 (Raigarh, Chhattisgarh), NFSS-1, NFSS-2, NFSS-7, NFSS-8 (Faijabad, U.P.) and PSS-5 (Pantnagar, Uttaranchal) as evident in Table 4.6. However, NFSS-7 from Faijabad, U.P. recorded maximum height (7.48 m), followed by N-9 from Raigarh, Chhattisgarh (7.28 m) and NFSS-2 from Faijabad, U.P. While D-2, (Solan, H.P.) showed minimum height (3.73 m) followed by PSS-9 from Pantnagar, Uttaranchal (3.77 m) and J-15 Solan, H.P. (3.79m). Similarly the maximum DBH was recorded for, NFSS-2 (12.43cm) followed by MN-9 (11.30 cm) and NFSS-7 (11.28 cm). However, minimum DBH was observed for MN-3 (4.50 cm) followed by PSS-10 (4.60 cm) and N-5 (5.50 cm). The maximum clear bole height was recorded for K-8 (4.40 m) followed by NFSS-4 (3.92 m) and MN-9 (3.91

m). However minimum clear bole height was observed for J-15 (1.25 m) followed by D-2 (1.33 m) and PSS-2 (1.39 m). The maximum straight bole height (4.37 m) was observed in MN-9 (Raigarh, Chhattisgarh) and minimum (1.15 m) in D-1 (Solan, H.P.).

Dogra *et al.* (2006) reported that maximum score for clone 192 (Gonda, Tulsipur, U.P.) followed by clone-204, clone-232, clone-68 (Gonda, U.P.) and clone-12 (Pathari, Haridwar, Uttaranchal) of *Dalbergia sissoo* under Dehradun condition.

4.7 Estimation of heritability (broad sense) for different entries proven

Heritability estimates were in general high for all the traits studied (Table 4.7). Entries, MN-9 (Raigarh, Chhattisgarh) showed maximum heritability (93.42 %) followed by NFSS-1 (90.10%) and NFSS-2 (89.90%) from Faijabad, U.P. Lowest heritability (48.91%) for PSS-10 from Pantnagar, Uttaranchal. Heritability estimates in broad sense were more than 50% for all characteristics except PSS-10 (48.91%) and PSS-2 (49.85%) from Pantnagar, Uttaranchal.

Dogra *et al.* (2006) reported that highest heritability for clone-12 (Gonda, Tulsipur, U.P.) followed by clone-2 (Chiryapur, Sabalgarh range, Uttaranchal), clone-66 (Chhichrauli, Yamunanagar, Haryana), clone-10 (Pathri, Haridwar, Uttaranchal), clone 192, 204 and 232 (Gonda, Tulsipur, U.P.) of *D. sissoo* under Dehradun condition.

Nautiyal *et al.* (2003) found significant inter-clonal variation in height and collar diameter of *Dalbergia sissoo*, clones under Dehradun condition. The growth performance of *Dalbergia sissoo* provenances also

supports the performance of U.P. and Uttaranchal, (Rehman and Hussain, 1986; Devagiri, 1997; Singh, 1998; Sagata and Nautiyal, 2001).

High heritability accompanied by high genetic advances for by several growth characteristics have earlier been reported in *Prosopis cineraria* (Srivastava *et al.*, 1993) and *Azadirachta indica* (Dillion *et al.*, 2003). Johnson *et al.* (1955) suggested that heritability estimates are usually more helpful in predicting its results and effect for selecting better genotypes.

CHAPTER-VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

Evaluation of forty five entries of *Dalbergia sissoo* Roxb. collected from five different provenances were grown in three Replication in a randomized block design and studied to determine the variability, heritability, genetic advance and genetic gain and inter-relationship among the total height, diameter at breast height, clear bole height, straight bole height, pod length, pod width, number of seeds per pod, weight of per pod, seed length, seed width, seed thickness, weight of seeds per pod and to establish the relative importance of each as they affected of tree improvement.

The total height and pod length exhibited highest estimates of heritability. Highest magnitude of expected genetic advance for diameter at breast height and seed thickness. The straight bole height and pod length exhibited highest estimates as genetic gain. Thus, these traits should respond to selection as sufficient additive variance is indicated.

Phenological characteristics of different entries of CPTs showed no any remarkable significant variation in the early growth period.

The entries from Chhattisgarh, (MN-9, Raigarh) which showed overall better performance on the basis of higher estimates of heritability for total height, diameter at breast height, clear bole height and straight bole height.

Suggestion for future work

- I. It is opined at the initial stage we should have a broad genetic base which can be achieved through intensive selection of phenotypes from different evaluated entries collected from different location.
- II. Selection of the superior individual from the promising families in the progeny test for the establishment of second generation seed orchard.
- III. On the basis of high heritability, high expected genetic advance and genetic gain as percentage of mean, it is suggested that the simple phenotypic selection procedure can be adopted to improve the characters viz., straight bole height, clear bole height, total height and diameter at breast height.
- IV. Germplasm should be maintained separately after evaluation of best one for further future tree improvement programme as well as the dissemination of plus trees seed material for commercial farm forestry.

“Evaluation of Provenances of *Dalbergia sissoo* Roxb.”

By

Fatte Lal Patel

ABSTRACT

The present investigation was conducted at research farm of Baronda. Indira Gandhi Krishi VishwaVidyalaya, Raipur (Chhattisgarh). Experimental materials consist of fourty five entries which were grown in randomized block design with three replication in 1998. After the growth of 6.6 years, tree growth characteristics viz., total height, diameter at breast height, clear bole height, straight bole height and pod-seed characteristics viz., pod length, pod width, number of seeds per pod, weight of per pod, seed length, seed width, seed thickness and weight of seeds per pod were recorded and analysed for variability, heritability, genetic advance and genetic gain.

Among all the growth characters, straight bole height was found most variable characters, while clear bole height had higher phenotypic, genotypic and environmental co-efficient of variability. High heritability was observed for the all character studied. Higher heritability was estimated for total height. The expected genetic advance was high for diameter at breast height. The highest magnitude of genetic gain as percentage of mean for straight bole height.

Among all the pod-seed characters pod length was most variable characters. Highest magnitude of phenotypic, genotypic and environment coefficients of variation was observed for the number of seeds per pod. Highest broad sense heritability was estimated for pod length while the weight of per pod showed moderate heritability. The expected genetic advance was high for seed thickness. The highest magnitude of genetic gain as percentage of mean for pod length. While the weight of per pod showed moderate genetic gain.

The entries from Chhattisgarh, MN-9 showed overall better performance on the basis of higher estimates of heritability of total height, diameter at breast height, clear bole height and straight bole height. The rest of the considerable entries were in order of NFSS-1 > NFSS-2 > NFSS-8 > NFSS-7 from Faijabad (U.P.).The poorest scoring entries were PSS-10 and PSS-2 from Panthnagar (U.A).

Dept. of Forestry
College of Agriculture
IGAU, Raipur (C.G.)

Dr. M.N. Naugraiya
Major Advisor

REFERENCES

- Alvarez, A. and montalvo, J.M. (1990). Genetic improvement of *Pinus cubensis*. Estimates of heritability and genetic gain of wood production. *Revista Forestal Bora Coa*. 20(2) : 31-42.
- Arunachalam, V. (1981). Genetic distance in plant breeding. *Indian J. Genet.* 41(2) : 226-236.
- Arya, S., Toky, O.P., Bisht, R.P., Tomar, R. and Harris, P.J.C. (1995). Provenance variation in seed germination and seedling growth of *Prosopis cineraria* (L.) Druce in arid India. *Silvae Genetica*. 44 (1) : 55.
- Arya, S., Toky, O.P., Tomar, R., Bisht, R.P. and Harris, P.J.C. (1992). Provenance variation in seed and pod characteristics of *Prosopis cineraria* (L.) Druce in Arid India. *J. Tree Sci.* 11(2) : 86-94.
- Bab, V. K. (1976). Genetic studies of national population of *Pinus densiflora*. *Kor. J. Breed.* 8 : 41-47.
- Bagchi, S.K. (1992). A preliminary study on genetic divergence of *Acacia nilotica* through seed parameters. *Indian Forester*. 118(6) : 416-424.
- Bagchi, S.K. and Dobriyal, N.D. (1990). Provenance variation in seed parameters of *Acacia nilotica*., *Indian Forester*. 116 (12) : 958-961.

- Boyle, J. B. and Morgestern, E. R. (1987). Some aspects of the population structure of black spruce in Central New Bunschwick. *Silv. Genet.* 36 (2) : 53-60.
- Brewbaker, J.L., Plunckett, D.L. and Gonglez, V. (1972). Forestry Research Bulletin. Hawaii-Agricultural Station. 30(18) : 45-51.
- Burton, G.W. and E.W. Devane (1953). Estimating heritability in tall *Festuca arundinacea* form replicated clonal material. *Agron. J.* 4 : 78-81.
- Chadha, K.M., Patnaik, S.S. & Gurumurthi, K. (1992). Country Report: India. In Reginal Review and Country Reports on Tree Breeding and Propagation. FAO/UNDP Field Report No. 2.pp. 49-68.
- Chamola, R. (1990). Genetic analysis of yield and yield components of soybean varieties under water logging situation. *M. Sc. (Ag.) Thesis*, JNKVV, Jabalpur.
- Chauhan, S.K., Sehgal, R.M. and Gautam, P.L. (2000). Genetic divergence among progenies of *Pinus roxburghii*. *Indian Journal of Forestry.* 23(1) : 70-74.
- Chauhan, V.K. and Verma, S. (1993). Progeny performance of different provenances of Khair (*Acacia catechu*) *J.Tree. Sci.* 12(1) : 51-54.
- Chauhan, V.S. and Singh, B.B. (1984). Genetic variability and heritability in soybean. *Indian of Agric Sci.* 54(3) : 273-276.
- Devagiri, G.M., Dhiman, R.C. and Nautiyal, S. (1998). Seed source variation in pod and seed traits of *D. sissoo* Roxb. *Ann. For.* 6 (2) : 148-155.

- Dhanai, C.S., Uniyal, A.K. and Todaria, N.P. (2003). Provenance variation in pod and seed characteristics of *Albizia chinensis* (Osbeck) in Western Himalaya. *Indian Journal of Forestry*. 26(3) : 201-207.
- Dhillon, R.S., Bisla, S.S. and Tomer, R.P.S. (1995). Variability studies of seed characters of in *D. sissoo* Roxb. *Ind. J. of Forestry* 18(1) : 53-55.
- Dhillon, R.S., S.S. Bisla, S. arya and M.S. Hooda (2003). Genetic variation, heritability and correlation for growth parameters in *Azadirachta indica*. *Ann. For.* 11 (2) : 215-221.
- Dillion, R.S., Bisla, S.S., Dhanda, S.K. and Singh, V.P. (1995). Genetic variation and heritability of some growth trails in Shisham (*Dalbergia sissoo* Roxb.) *Annals of Biology*. 11(1-2) : 107-111.
- Dogra, A.S., Nautiyal, S., Nautiyal, D.P. and Singh, G. (2006). Field performance of twenty three clones of *Dalbergia sissoo* in clonal seed orchard. *Indian Forester*. 132 (3) : 273-280.
- Espinel, S. and Aragoness, A. (1997). Genetic parameter estimates for *Pinus radiata* in Basque country, Northern Spain. *New Zealand Journal of Forestry Science*. 27(3) : 272-279.
- F.A.O. (1985). A guide to Forest seed handling: with special reference to tropics. FAO Forestry No. 20/2, FAO.pp. 1090-1100.
- FAO (1993). Forestry Statistics Today for Tomorrow: Wood and Wood Based Products. FAO, Rome. pp. 22-34.

- Garg, D.K. and Gautam, P.L. (1997). Genetic divergence studies in wheat germplasm using non-hierarchical Euclidean cluster analysis *Indi. J. Pl. Genet. Resources*. 10(1) : 11-15.
- Gera, M., Gera, N. and Aggarwal, R. (1999). Path analysis in *Dalbergia sissoo*. *Indian Forester*. 12(7) : 660-664.
- Gera, M., Gera, N. and Ginwal, H.S. (1999). Seed source variation in germination and early growth among ten indigenous populations of *D. sissoo* Roxb. *Indian Forester*. 8 (7) : 165- 170.
- Gera, N., Gera, M. and Purohit, M. (1999). Source variation in *Albizia procera* Roxb. (Benth.) for seed and seedling characteristics. *Seed Research*. 27(2) : 165-169.
- Ginwal, H.S., Gera, M. and. Sharma, S. (1998). Seed source variation in *Dalbergia sissoo* Roxb. Pod, seed and germination characteristics of seventeen diverse population in India. *Malyasian For*. 61(1) :1-14.
- Greham, A., Assi, B.J. and Chalupa, V. (1985). Growth studies in *Pinus ponderosa* under Easter Washington conditions. *Bot. Gaz*. 146(3) : 111-115.
- Gupta, T. and Sehgal, R.N. (2000). Genetic variability in Phenotypic characters of *Toona Ciliata*. *Indian Journal of Forestry*. 23(4) : 422-427.
- Gupta, V.K. and Patil, B.D. (1988). Genetic variability and path analysis in white popinal (*Leucaena latisiliqua*). *Ind. J. Agr. Sci*. 58(6) : 483-484.

- Gwaze, D.P., Woolliams, J.A. and Kanowski, P.J. (1997). Genetic parameters for height and stem straightness in *Pinus taeda* Linnaeus in Zimbabwe. *Forest Genetics*. 4(3) : 156-169.
- Hanover, J.W. and Barnes, B.V. (1969). Heritability of height growth in Western white pine seedlings. *Silv. Genet.* 18(3) : 80-82.
- Hooda, M.S. and Bahadur, R. (1993). Variability, correlation and path coefficient analysis for some seed traits in subabul (*Leucaena leucocephala*) *Seed Res.* 21(1) : 49-51.
- Hosalli, R. B. (1997). Variation and character association studies in some *Leucaena* species/varieties. *M.Sc. (For.) Thesis* of Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.). pp. 29.
- Humphreys, M.O., Thoma, I.D., Chareton, K.H. and Tyler, B.F. (1980). Grass and clover ecotype collected in old permanent meadows. *In: Welsh plan/Breeding Station Report*, U.K. pp.1-26.
- Jain, J.K. (1990). Biometrical studies of economic and physiological traits in soybean (*Glycin max.* (L.) Merrill). *M.Sc. (Ag.) Thesis*, JNKVV, Jabalpur.
- Jhonsen, K.H., P.P. and Selier, J.R. (1988). Root growth potention and root activity of Northern and Southern provenances of eastern white pine seedlings grown in a Virginia nursery. *Can. J. For. Res.* 18(5) : 610-614.

- Johnson, H.V., Robinson, H.F. and Comstock, R.E. (1955b). Genotypic and phenotypic correlation in soybean and their implication. *Agron. J.* 47 : 477-480.
- Johnson, H.W., Robinson H.F. and Comstock R.F. (1955). Estimation of genetic and environmental variability in Soybean. *Agron. J.* 47 : 314-318.
- Kedarnath, S. and Vakashasya, R.K. (1977). Estimates of component of variance, heritability and correlation among some growth parameters in *Eucalyptus teriticornis*. In: Third world consultation of forest tree breeding, Canberra. CSIRO division forest research. pp. 667-676.
- Khosla, P.K. (1984). Genetic Improvement of Agroforestry Trees. In: Khosla *et al.* (ed.) Agroforestry Systems-A New Challenge. Pub. Indian Society of Tree Scientists, Solan, H.P., India. pp. 151-160.
- Khosla, P.K., Sehgal, R.N., Dhall, S.P. and Chauhan, K.C. (1985). Path coefficient analysis of correlation between shoot dry weight and other character in *Pinus roxburghii* progeny. *J. Tree. Sci.* 4(1) : 15-19.
- Kiss, G. and Yeh, F. C. (1988). Heritability estimates for height for young spruce in British columbia. *Can. J. For. Res.* 18(2) : 158-162.
- Krishnaswamy, S.S. and Mathauda, G.S. (1954). Phenological behaviour of a few forest species at New Forest, Dehradun. *Indian For.* 80(3&4) : 124-153, 187-204.

- Kumar, A. and Paliwal, G.S. (1996). The annual rhythm of biological calendar in *Dalbergia sissoo* Roxb. *Indian J. Forestry* (communicated).
- Kumar, A., Chawhann, P.H. and Matharoo, A.K. (2003). Improvement through selection of plus trees in *Gmelina arborea*. *J. of Tropical Forest Sci.* 15(3) : 441-449.
- Kumar, R., Sharma, K.R. and Gupta, L.M. (2005). Variability status in Candidate Plus trees of shisham (*Dalbergia sissoo* Roxb.). *Environment & Ecology*. 23(1) : 170-172.
- Kumar, R., Sharma, K.R. and Gupta, L.M. (2005). Variation physico-chemical characteristics of wood of Candidate Plus Trees of shisham (*Dalbergia sissoo* Roxb.). *Indian Forester*. 131(4) : 1012-1023.
- Liu Zhaoxi, H.E. Yu You: SUN Haiqing, Jing Min and Lu Benshu. (1997). Genetic study and pulpwood selection of loblolly pine provenances. I. Geographical variation and correlation analysis of economic traits. *Forest Research*. 10(3) : 253-258.
- Manga, V.K. and Sen, D.N. (1996). Genetic parameters for seed traits in *Dalbergia sissoo*. *Indian J. Forestry*. 19 : 148-151.
- Mani. V.P., Singh, N.K. and Bist, G.S. (1996). Genetic divergence in indigenous maize (*Zea mays*. L.) germplasm of U.P. Hills. *Indian Journals of Plant Genetic Resources*. 9 (2) : 309-312.

- Mehetre, S.S., Mahajan, C.R., Ghatge, R.D. and Dhumal, P.M. (1994). Induced genetic variability and character association in soybean. *Crop Res.* 8 : 348-353.
- Mikhailov, V. (1987). Variation in the dimensions, weight and form of seeds of *Pinus nigra* in the Slavyanka mountains. *Gorskostopanska, Nauka.* 24: 26-37.
- Namkoong, G. (1984). Genetic structure of forest tree population. In proc. of the XV. International congress of Genetic, Genetics New Frontiers. Chopra, G.L., B.C. Joshi, R.P. Sharma, H.C. Bansal (eds.) Vol. IV. Oxford and IBH Publishing Co. pp. 351.
- Natiyal, S., Pal, M., Sagta, H.C., Rawat, R.S. and Negi, D.S. (2003). Clonal variation in growth, flowering and seed production of *Dalbergia sissoo* in a clonal seed orchard. *J. Trop. For. Sci.* 15(1) : 97-108.
- Nautiyal, S. (2005). Vegetative propagation technology for mass propagation- *Dalbergia sissoo*. *ICFRE Newsletter.* 3 (3) : 1&2.
- Neil, P.E. (1989). *Dalbergia sissoo* provenances testing in Nepal *Nitrogen Fixing Tree Res. Rep.* pp. 8-130.
- Pandey, Deepak, Tewari, S.K. and Tripathy, S. (1995). Genetic divergence in *Populus deltoids* Bart. *Ind. J. Gen. Pl. Breed.* 55 (2) : 129-131.
- Panes, V.G. and Sukhatme, P.V. (1967). Provenance trial of *Acacia nilotica*. *J. of Tree Sci.* 5(1) : 53-56.

- Ramchandra, N.G. (1996). Provenance variation in seed and seedling parameters in *Acacia catechu* L.F. Willd. *Ph.D. Thesis*. F.R.I., Deemed University, Dehradun. pp. 224.
- Rathiam, M., Surendran, C. and Kondas, S. (1982). Inter-relationship of seed yield components in *Eucalyptus tereticornis*. *Ind. For.* 108(7) : 465-470.
- Reddy, M.M. and Subramniam, S. (1998). Correlation and path coefficient studies in Sandal (*Santalum album* L). *Ann. For.* 6 (1) : 39-43.
- Rehfeldt, G.E. (1985). Ecological genetics of *Pinus contorta* in the Wasatch and Uinta mountains of Utah. *Can. J. Forest Research*. 15 (3) : 424-430.
- Rehman, S.A. and A. Hussain (1986). Growth and heritability estimates among six years old three geographical sources of Shisham (*Dalbergia sissoo* Roxb.) in Pakistan. *Pak. J. For.* 36 (2) : 67-72.
- Sagta, H.C. and S. Nautiyal (2001). Growth performance and genetic divergence of various provenances of *Dalbergia sissoo* Roxb. at nursery stage. *Silvae Genetica*. 50(3-4) : 93-99.
- Salazar, R. (1989). Genetic variation of 16 provenances of *Acacia mangium* at nursery level in Turrialba, Costa Rica. *Commonwealth Forestry Rev.* 66 (4) : 263-272.
- Samarawira, F. (1988). Genetic analysis of traits related to seed germination among provenances of date palm (*Phoenix dactylifera* L.) *Silv. Genet.* 37(5-6) : 171-175.

- Shekhar, S., Shrigirishi, N., Shukla, N.K., Dubey, P. and Burfal, B.S. (2002). Effect of seed sources on germination and morphological traits in *Acacia nilotica*. *Ind. J. For.* 25(1) : 1-6.
- Shivkumar, P. and Banerjee, A.C. (1986). Provenance trial of *Acacia nilotica*. *J. Tree Sci.* 5(1) : 53-56.
- Sidhu, D.S. (1997). Selection of plus trees for genetic improvement of stem form in shisham (*Dalbergia sissoo*). *Indian Journal of Forestry*. 20(1): 20-25.
- Singh, J. and Bangarwa, K.S. (1995). Progeny testing for growth parameters in *Dalbergia sissoo* Roxb. *Annals of Biology*. 11 : 111-114.
- Singh, Jitender, Bangarwa, K.S. and Singh, J. (1995). Heritable variation and genetic gain estimates in half-sib progenies of *Dalbergia sissoo* Roxb. *Crop Research*. 10(1) : 96-98.
- Singh, N. (1998). Physiological and biochemical parameters genetic improvements in *Dalbergia sissoo* Roxb. *Ph. D. Thesis*, F.R.I. (Deemed University), Dehradun. pp. 200.
- Singh, N. and Pokhriyal, T.C. (2001). Variations in pod and seed traits in six different *Dalbergia sissoo* seed sources. *J. of Tropical For. Sci.* 13(1) : 162-170.
- Singh, N.B (1992). Propagation, selection and establishment of clonal seed orchard of chilgoza pine (*Pinus garardiana* Wall.). *Indian Forester*. 98 (2) : 901-908.

- Singh, N.B. (1993). Analysis of genetic divergence in *Bambusa tulda* Roxb. from North East India. *Advances in Horticulture and Forestry*. 3 :187-191.
- Singh, N.B. and Beniwal, B.S. (1993). Variability, heritability and genetic gain in some growth characters in *bombusa balcooa*. *Indian Forester*. 199(3) : 205-210.
- Singh, N.B. and Chaudhary, V.K. (1993). Variability, heritability and genetic gain in cone and nut characters of Chilgoa pine (*Pinus gerardiana* Wall.). *Silvae Genetica*. 42 : 2.-3.
- Sniezko, R.A. and Stewart, H.T.L. (1989). Range wide provenance variation in growth and nutrition of *Acacia albida* seedling propagated in Zimbabwe. *For. Ecol. Manage*. 27 : 179-197.
- Solanki, K.R., Muthana, K.D., Jindal S.K. and Arora, G.D. (1984). Variability, heritability and correlations for growth parameters in *Prosopis cineraria*. *Ind. J. Tree Sci*. 3 : 86-88.
- Srivastava, A. (1995). Seed source variation studies in *Bauhinia variegata* Linn. *M.Sc. thesis* submitted to Dr. Y.S. Parmar Univ. of Horticulture and Forestry, Nauni, Solan. (H.P). pp.97.
- Srivastava, M., Mandal, S. K. and Abraham, Z. (1986). Correlations and path coefficient analysis of morphological characters and coleol yield of *Coleus forskohlii* Briq. *Ind. J. Agri. Sci*. 56(2) : 86-89.
- Srivastava, P.K., Siddiqui, A.A. and Goel, A.K. (1993). Genetic variability in half-sib seedlings of *Terminalia arjuna*. *Indian Forester*. 119(1) : 53-58.

- Srivastava, S.K., Verma, N. and Mishra, C.M. (2001). Evaluation of seed sources variation on different seed parameters of *Dalbergia sissoo* Roxb. *Ind. J. Forestry*. 4 (2) : 135-140.
- Stebbins, G.L. (1950). Variation and Evaluation in Plants. Pub. Columbia Univ. Press New York. pp. 643.
- Surendran, C., and Chandrashekharan, P. (1984). Heritability, variation and genetic gain estimates in half-sib progenies of *Eucalyptus teretiornis*. *J. Tree Sci*. 3(1-2) :1-4.
- Tewari, D.N. (1994). A monograph on *Dalbergia sissoo* Roxb. Pub. International book distributors, Dehradun.
- Tewari, S.K., Subhanjana, Shukla, A.K. and Pandey, S.B.S. (2002). Genetic divergence in shisham (*Dalbergia sissoo* Roxb.). *Indian Journal of Forestry*. 25(1) : 21-24.
- Tomar, N.S. (1990). Evaluation in soybean germplasm (*Glycine max* (L.) Merrill). *Ph.D. Thesis* JNKVV, Jabalpur.
- Troup, R.S. (1921). The Silviculture of Indian Trees. Vol. II, Oxford, Clarendon press.
- Verma, P.S., Dhaka, R.P.S. and Singh. H.N. (1988). Genetic variability and correlation studies in sugarcane. *Ind. J. Genet*. 48(2) : 213-218.
- Wright, J.W. (1976). Introduction to Forest Genetic, Academic Press, New York.

- Yadav, S., Hooda, M.S. and Bangarwa, K.S. (1998). Effect of seed size on physiological seed quality in shisham (*Dalbergia sissoo*). *Indian Journal of Forestry*. 21(1) : 13-15.
- Yadav, S.S. and Bangarwa, K.S. (1997). Performance of *Dalbergia sissoo* Roxb. in a 12 year provenance trial in Haryana. *Ind. J. Forestry*. 21 (1) : 13-15.
- Zobel, B.J. and Talbert, J. (1984). Applied Forest Tree Improvement. John Wiley and Sons, New York. pp. 505.

Year	Maximum Temp. (°C)	Minimum Temp. (°C)	Total Rainfall Annual (mm)	Relative Humidity (per cent)
1996	32.2	19.6	1122.8	69.66
1997	32.2	19.6	1208.4	79.90
1998	32.3	20.6	1088.1	83.41

**Appendix I: Mean annual meteorological data in study
area**

S No.	Location and entries		Pod length	Pod width	No. of seed /pod	No. of healthy seed /pod	No. of damag seed /pod	% of seed setting	Wt. of per pod (g)
	1999	32.5	(cm)	(cm)	19.0	858.8		79.40	
	Pantnagar (U.P.)								
1	PSS-0	32.9	5.87	0.89	2.23	1.87	0.36	87.94	0.079
2	PSS-2		6.03	1.05	2.03	1.9	0.3	87.06	0.087
3	PSS-3		5.82	0.85	1.93	1.7	0.23	95.67	0.113
4	PSS-4	32.9	5.86	0.92	2.17	1.87	0.03	92.73	0.109
5	PSS-5		6.06	0.93	2.27	1.9	0.37	94.77	0.101
6	PSS-6	33.5	5.48	0.86	2.1	1.93	0.17	97.90	0.140
7	PSS-7		5.57	0.91	2.1	1.83	0.27	91.43	0.136
8	PSS-8	34.2	5.59	0.88	1.9	1.83	0.07	95.41	0.141
9	PSS-9		5.43	0.90	2	1.67	0.33	96.67	0.086
10	PSS-10		5.29	0.85	1.93	1.77	0.16	96.67	0.078
	Solani (H.P.)		34.4		20.3	985.5		78.4	
11	D-2		6.20	0.88	2.1	1.93	0.17	97.33	0.099
12	D-1	34.6	5.71	0.82	1.87	1.11	0.14	98.34	0.090
13	D-8		4.72	0.86	1.63	1.6	0.03	95.67	0.087
14	J-15		5.27	0.86	1.8	1.73	0.07	96.67	0.089

Appendix II: Morphological characters of pod from different entries
of
Dalbergia sissoo in Seedling Seed Orchard

15	J-21	6.06	0.89	2.0	1.8	0.2	91.33	0.149
16	K-6	4.63	0.87	1.56	1.5	0.06	100	0.142
17	K-8	5.7	0.88	1.87	1.73	0.14	90.00	0.090
18	N-2	4.47	0.85	1.67	1.53	0.14	96.00	0.086
19	N-5	5.57	0.88	1.77	1.67	0.1	96.00	0.139
20	N-9	5.43	0.88	1.87	1.83	0.04	94.33	0.125
Chhattisgarh								
21	MN-1	5.79	0.89	2.27	1.97	0.3	96.67	0.153
22	MN-2	5.62	0.92	2.4	2.3	0.1	98.33	0.104
23	MN-3	5.68	0.96	2.23	2	0.23	99.33	0.098
24	MN-4	5.57	0.94	2.1	1.73	0.37	100	0.095
25	MN-5	5.20	0.89	1.93	1.87	0.06	100	0.09
26	MN-6	5.7	0.96	2.13	2	0.13	100	0.095
27	MN-7	5.65	0.93	2	1.9	0.1	100	0.093
28	MN-8	5.22	0.87	1.97	1.87	0.1	100	0.092
29	MN-9	5.60	1.02	2.13	1.97	0.16	100	0.105
30	MN-10	5.77	0.96	2.3	2.27	0.04	100	0.098
Faijabad (U.P.)								
31	NFSS-1	5.65	0.94	2.43	2.23	0.2	99.33	0.150
32	NFSS-2	5.22	0.92	2.3	2.03	0.27	100	0.152
33	NFSS-3	5.44	0.89	2.2	2.06	0.14	99.33	0.089
34	NFSS-4	5.55	0.92	2.23	2.21	0.02	92.33	0.086
35	NFSS-5	5.36	0.95	2.1	2.03	0.07	100	0.094
36	NFSS-6	5.47	0.93	2.03	1.9	0.13	92.00	0.09
37	NFSS-7	5.19	0.99	1.97	1.77	0.2	95.67	0.093
38	NFSS-8	5.69	0.90	1.9	1.77	0.13	94.67	0.086
39	NFSS-9	5.35	0.93	1.73	1.63	0.1	98.33	0.091
40	NFSS-10	5.28	0.92	1.77	1.63	0.14	96.67	0.087
Garwal (U.A.) hills								
41	SSS-1	5.62	0.97	2.13	2.06	0.07	83.87	0.155
42	SSS-2	5.67	1.03	2.22	2	0.22	98.67	0.102
43	SSS-3	5.37	0.95	2.03	1.87	0.16	97.33	0.160
44	SSS-4	5.37	0.95	2.06	1.93	0.13	98.00	0.159
45	SSS-5	5.27	0.97	2	1.83	0.17	98.67	0.163
Mean		5.512	0.917	2.03±	1.87	0.158	96.2	0.105
SEm		±0.21	±0.04	0.152	±0.133	±0.01	±2.78	±0.15
CD at 5%		0.588	0.117	0.42	0.369	0.015	7.72	0.419

**Appendix III : Morphological characters of seed from different entries of
Dalbergia sissoo in seedling seed orchard**

S. No.	Location and entries	Seed length (cm)	Seed width (cm)	Seed thickness (cm)	Wt of seed/ pod (g)	Wt of healthy seed/pod (g)
1	Pantnagar (U.P.)	0.83	0.42	0.188	0.031	0.028
2	PSS-2	0.89	0.40	0.187	0.038	0.034
3	PSS-3	0.84	0.39	0.198	0.039	0.036
4	PSS-4	0.85	0.39	0.172	0.039	0.037
5	PSS-5	0.90	0.38	0.174	0.034	0.031
6	PSS-6	0.95	0.38	0.172	0.034	0.032
7	PSS-7	0.91	0.38	0.167	0.034	0.032
8	PSS-8	0.87	0.39	0.168	0.033	0.032
9	PSS-9	0.85	0.39	0.171	0.032	0.031
10	PSS-10	0.85	0.38	0.172	0.033	0.031
11	Solan (H.P.)	0.87	0.39	0.170	0.04	0.039
12	D-1	0.83	0.39	0.169	0.039	0.036
13	D-8	0.84	0.39	0.170	0.036	0.035
14	J-15	0.85	0.39	0.170	0.037	0.037
15	J-21	0.86	0.39	0.170	0.040	0.038
16	K-6	0.87	0.39	0.170	0.037	0.037
17	K-8	0.85	0.39	0.170	0.038	0.036
18	N-2	0.85	0.39	0.170	0.035	0.033
19	N-5	0.87	0.39	0.170	0.038	0.037
20	N-9	0.87	0.38	0.170	0.039	0.038
21	Chhattisgarh	0.93	0.40	0.172	0.038	0.034
22	MN-2	0.94	0.41	0.187	0.043	0.040
23	MN-3	0.95	0.39	0.185	0.040	0.037
24	MN-4	0.95	0.39	0.184	0.040	0.038
25	MN-5	0.92	0.40	0.182	0.038	0.036
26	MN-6	0.99	0.40	0.188	0.039	0.037
27	MN-7	0.97	0.39	0.185	0.038	0.037
28	MN-8	0.97	0.40	0.189	0.038	0.037
29	MN-9	0.67	0.40	0.187	0.040	0.039
30	MN-10	0.96	0.39	0.186	0.042	0.041
31	Faijabad (U.P.)	0.96	0.37	0.172	0.038	0.037
32	NFSS-2	0.96	0.38	0.176	0.040	0.038
33	NFSS-3	0.91	0.39	0.179	0.040	0.038
34	NFSS-4	1.02	0.40	0.184	0.043	0.040
35	NFSS-5	0.91	0.39	0.178	0.041	0.040
36	NFSS-6	0.87	0.40	0.178	0.041	0.039
37	NFSS-7	0.89	0.39	0.18	0.042	0.040
38	NFSS-8	0.88	0.40	0.178	0.042	0.039
39	NFSS-9	0.90	0.39	0.180	0.040	0.039
40	NFSS-10	0.92	0.38	0.175	0.038	0.036
41	Garwal (U.A.) hills	0.98	0.40	0.20	0.048	0.047
42	SSS-2	0.99	0.39	0.188	0.044	0.042
43	SSS-3	0.95	0.38	0.191	0.038	0.036
44	SSS-4	0.98	0.39	0.192	0.037	0.036

45	SSS-5	0.99	0.40	0.196	0.039	0.037
Mean		0.904	0.391	0.179	0.0385	0.0367
SEm		±0.062	±0.010	±0.029	±0.002	±0.0131
CD at 5%		0.172	0.029	0.0081	0.006	0.036

Table 4.1: Co-efficient of variance for tree growth characteristics of different entries of *Dalbergia sissoo*

S. No.	Location and entries	Total height (%)	Dia-at breast height (%)	Clear bole height (%)	Straight bole height (%)
1	Pantnagar (U.P.) PSS-1	0.45	0.21	0.23	0.54
2	PSS-2	0.52	0.19	0.57	0.49
3	PSS-3	0.36	1.15	0.76	0.40
4	PSS-4	0.18	0.24	0.56	0.63
5	PSS-5	0.08	0.15	0.29	0.57
6	PSS-6	0.28	0.08	0.23	0.38
7	PSS-7	0.12	0.09	0.52	0.33
8	PSS-8	0.17	0.19	0.46	0.56
9	PSS-9	0.22	0.29	0.47	0.84
10	PSS-10	0.24	0.18	0.75	0.59
11	Solan (H.P.) D-2	0.21	0.21	1.04	0.35
12	D-1	0.36	0.18	0.66	0.59
13	D-8	0.59	0.09	0.50	0.57
14	J-15	0.09	0.23	1.26	1.25
15	J-21	0.13	0.38	0.62	2.8
16	K-6	0.16	0.15	0.82	3.9
17	K-8	0.19	0.19	0.19	0.26
18	N-2	0.29	0.18	0.52	0.49
19	N-5	0.21	0.22	1.10	5.1
20	N-9	0.39	0.15	0.39	0.56

Conti.....

S. No.	Location and entries	Total height (%)	Dia-at breast height (%)	Clear bole height (%)	Straight bole height (%)
21	Chhattisgarh MN-1	0.15	0.39	0.38	0.39
22	MN-2	0.07	0.26	0.52	0.36
23	MN-3	0.38	0.50	0.49	0.97
24	MN-4	0.11	0.16	0.83	0.45
25	MN-5	0.13	0.07	0.52	0.50
26	MN-6	0.18	0.05	0.34	0.24
27	MN-7	0.14	0.36	0.21	0.37
28	MN-8	0.25	0.23	0.31	0.41
29	MN-9	0.06	0.19	0.27	0.09
30	MN-10	0.46	0.14	0.19	0.51
31	Faijabad (U.P.) NFSS-1	0.05	0.16	0.14	0.44
32	NFSS-2	0.09	0.06	0.43	0.53
33	NFSS-3	0.19	0.10	0.29	0.14
34	NFSS-4	0.14	0.11	0.37	0.29
35	NFSS-5	0.12	0.65	0.29	2.56
36	NFSS-6	0.29	0.16	0.56	0.84
37	NFSS-7	0.15	0.21	0.16	0.54
38	NFSS-8	0.21	0.13	0.17	0.37
39	NFSS-9	0.26	0.11	0.66	0.65
40	NFSS10	0.12	0.18	0.57	0.76

Conti.....

S. No.	Location and entries	Total height (%)	Dia-at breast height (%)	Clear bole height (%)	Straight bole height (%)
41	Garwal (U.A.) hills SSS-1	0.19	0.19	0.55	0.48
42	SSS-2	0.27	0.14	0.53	0.22
43	SSS-3	0.25	0.06	0.83	0.50
44	SSS-4	0.10	0.14	0.59	0.48
45	SSS-5	0.51	0.21	0.63	0.67

Table 4.2: Co-efficient of variance for pod-seed characteristics of different entries of *Dalbergia sissoo*

S. No.	Location and entries	Pod length (%)	Pod width (%)	No. of seed Pod ⁻¹	Wt. of pod ⁻¹ (%)	Seed length (%)	Seed Width (%)	Seed thickness (%)	Wt. of total seed pod ⁻¹ (%)
	Pantnagar (U.P.)								
1	PSS-1	0.804	4.97	11.17	10.8	4.56	5.66	1.25	8.36
2	PSS-2	2.82	8.29	12.9	11.6	1.59	1.19	1.33	3.25
3	PSS-3	4.57	4.99	8.79	10.6	4.61	2.39	4.3	3.63
4	PSS-4	2.81	6.57	10.23	9.3	3.1	4.88	4.74	3.17
5	PSS-5	2.06	15.38	9.07	6.9	0.53	6.5	3.39	9.39
6	PSS-6	7.08	16.98	10.29	8.5	6.89	2.44	1.64	10.30
7	PSS-7	7.18	8.65	12.03	9.8	5.24	4.43	2.69	5.36
8	PSS-8	1.46	2.67	12.89	9.56	2.86	2.45	1.29	8.66
9	PSS-9	7.53	8.59	14.72	8.4	8.09	2.09	1.94	11.39
10	PSS-10	0.536	5.57	6.45	0.48	4.76	6.97	1.52	5.66
	Solan (H.P.)								
11	D-2	1.32	1.07	3.89	0.49	1.43	7.55	1.17	4.08
12	D-1	1.43	0.54	12.56	0.52	0.57	1.22	1.20	3.2
13	D-8	3.9	0.95	2.89	2.16	2.57	2.39	1.11	3.43
14	J-15	12.81	4.37	7.86	6.12	0.96	3.63	0.96	5.87
15	J-21	0.777	1.06	7.07	0.83	0.95	1.22	1.44	2.31
16	K-6	1.02	0.54	6.02	3.53	0.54	2.46	0.74	4.64
17	K-8	3.79	1.86	11.01	.376	4.52	2.09	0.75	3.72
18	N-2	9.59	3.62	5.66	2.85	1.46	3.25	0.86	3.59
19	N-5	11.11	1.61	10.67	3.5	1.44	3.63	0.79	5.68
20	N-9	9.06	0.53	11.56	6.72	1.09	1.29	0.53	7.55

Conti....

S. No.	Location and entries	Pod length (%)	Pod width (%)	No. of seed Pod ⁻¹	Wt. of pod ⁻¹ (%)	Seed length (%)	Seed Width (%)	Seed thickness (%)	Wt. of total seed pod ⁻¹ (%)
21	Chhattisgarh MN-1	1.63	1.06	2.08	3.81	3.86	1.89	0.92	3.312
22		9.64	4.46	10.27	9.89	4.59	3.45	3.84	4.43
23		7.73	10.04	9.11	7.14	4.79	2.39	1.35	4.28
24		8.08	4.44	6.73	3.57	4.31	2.52	1.94	4.21
25		5.59	1.99	6.45	0.97	3.87	1.19	1.19	2.15
26		7.16	10.04	11.67	4.31	0.96	3.62	0.78	2.21
27		5.28	5.66	4.08	4.33	0.98	2.39	1.67	2.46
28		4.72	5.44	6.34	6.41	0.92	1.16	0.43	2.04
29		6.36	4.5	12.3	8.20	2.53	1.19	0.48	2.17
30		5.89	4.6	7.09	0.98	0.85	3.17	2.78	4.09
31	Faijabad (U.P.) NFSS-1	0.73	4.09	3.86	1.3	3.57	2.53	0.73	5.84
32		1.57	3.86	10.65	6.19	2.52	6.20	3.51	6.51
33		3.45	1.59	7.42	5.12	4.75	1.14	0.86	2.07
34		9.11	4.36	12.34	4.41	5.34	2.39	3.57	1.99
35		0.89	4.86	3.89	9.37	5.46	2.09	1.38	3.54
36		4.38	5.76	13.27	6.85	1.06	1.18	0.75	3.98
37		5.48	8.77	4.79	5.33	1.83	3.63	2.53	4.11
38		5.22	8.59	9.37	6.61	0.97	2.04	2.41	5.16
39		1.41	5.34	5.44	2.24	1.95	4.79	3.19	2.08
40		1.61	6.02	5.34	1.42	4.91	4.29	2.84	2.88

Conti.....

S. No.	Location and entries	Pod length (%)	Pod width (%)	No. of seed Pod ⁻¹	Wt. of pod ⁻¹ (%)	Seed length (%)	Seed Width (%)	Seed thick-ness (%)	Wt. of total seed pod ⁻¹ (%)
	Garwal (U.A.) hills								
41	SSS-1	1.51	4.88	5.85	0.89	0.88	3.45	3.71	4.91
42	SSS-2	1.66	4.56	4.42	1.3	0.83	2.44	1.76	3.17
43	SSS-3	0.88	4.05	4.64	1.72	1.5	2.46	0.89	2.04
44	SSS-4	0.93	3.75	6.03	0.90	2.6	4.21	2.79	4.29
45	SSS-5	4.48	1.94	2.32	0.95	0.82	3.52	2.14	1.23

**Table 4.3: Estimation of genetic parameters for tree growth characteristics
of *Dalbergia sissoo***

Parameters	Total height. (m)	Dia-meter at breast height (cm)	Clear bole height (m)	Straight bole height (m)
Mean	5.13	7.81	2.17	2.3
Range				
Maximum	7.48	12.43	3.91	4.41
Minimum	2.86	3.5	1.25	1.14
Phenotypic co-efficient variance (PCV)	28.18	31.91	42.98	38.89
Genotypic co-efficient variance (GCV)	21.81	24.36	28.12	26.67
Environmental co-efficient variance (ECV)	17.84	20.72	36.71	35.71
Heritability (%)	84.24	78.10	74.86	81.34
Genetic advance	1.45	2.082	0.515	0.671
Genetic gain (%)	28.26	26.63	23.76	29.18

Table 4.4: Estimation of genetic parameters for pod and seed characteristics of different entries of *Dalbergia sissoo*

Parameters	Pod length (cm)	Pod width (cm)	No. of seeds Pod ⁻¹	Wt. of pod ⁻¹ (g)	Seed length (cm)	Seed width (cm)	Seed thickness (cm)	Wt. of seeds Pod ⁻¹ (g)
Mean	5.51	0.92	2.03	0.163	0.896	0.39	0.179	0.039
Range								
Maximum	6.06	1.05	2.43	0.205	1.2	0.41	0.22	0.047
Minimum	4.2	0.863	1.56	0.078	0.59	0.376	0.168	0.031
Phenotypic Co-efficient of variance (PCV)	8.01	8.33	14.42	2.54	13.16	3.86	2.36	11.2
Genotypic Co-efficient of variance (GCV)	4.58	2.59	6.04	0.989	5.36	1.72	1.023	6.57
Environmental Co-efficient of variance (ECV)	6.60	7.91	12.93	1.27	12.02	3.46	3.38	9.07
Heritability (%)	52.3	18.66	19.69	43.485	16.55	19.74	29.2	34.41
Genetic advance	0.205	0.011	0.083	0.169	0.028	0.0043	0.78	0.00213
Genetic gain (%)	3.72	1.16	2.03	3.01	1.01	1.09	2.06	1.53

Table 4.6: Growth performance and ranking of different entries in Seedling Seed Orchard of *Dalbergia sissoo*

S. No.	Location and entries	Height (m)	Marks (A)	DBH (cm)	Marks (B)	CBH (m)	Marks (C)	SBH (m)	Marks (D)	Total (A+B+C+D)
	Pantnagar (U.P.)									
1	PSS-1	3.99	1	6.67	2	1.77	1	1.48	1	5
2	PSS-2	3.87	1	5.52	1	1.39	1	1.47	1	4
3	PSS-3	4.14	2	6.60	2	1.98	1	1.77	1	6
4	PSS-4	4.62	2	6.22	2	1.89	1	1.66	1	6
5	PSS-5	6.05	4	8.08	3	3.72	3	2.92	2	12
6	PSS-6	4.31	2	8.48	3	2.78	2	2.12	2	9
7	PSS-7	6.97	4	7.84	2	2.79	2	3.27	3	11
8	PSS-8	6.74	4	8.20	3	2.64	2	2.61	2	11
9	PSS-9	3.77	1	7.75	2	1.47	1	1.24	1	5
10	PSS-10	3.89	1	4.60	1	1.42	1	1.18	1	4
	Solan (H.P.)									
11	D-2	3.73	1	6.87	2	1.33	1	1.15	1	5
12	D-1	4.97	2	8.03	3	1.67	1	1.78	1	7
13	D-8	5.13	3	8.75	3	1.59	1	1.91	1	8
14	J-15	3.79	1	6.01	2	1.25	1	1.79	1	5
15	J-21	4.44	2	5.61	1	1.72	1	1.74	1	5
16	K-6	6.11	4	7.24	2	1.84	1	2.15	2	9
17	K-8	5.78	3	5.03	1	4.40	4	2.71	2	10
18	N-2	4.41	2	6.88	2	1.58	1	2.17	2	7
19	N-5	3.75	1	5.50	1	1.58	1	2.18	2	5
20	N-9	5.02	3	8.33	3	1.75	1	1.97	1	8

Conti.....

S. No.	Location and entries	Height (m)	Marks (A)	DBH (cm)	Marks (B)	CBH (m)	Marks (C)	SBH (m)	Marks (D)	Total (A+B+C+D)
21	Chhattisgarh MN-1	5.34	3	8.81	3	2.06	2	2.71	2	10
22	MN-2	4.40	2	6.85	2	1.70	1	1.97	1	6
23	MN-3	3.12	1	4.50	2	1.42	1	1.24	1	5
24	MN-4	4.24	2	8.43	3	2.18	2	2.43	2	9
25	MN-5	5.07	3	9.05	3	2.12	2	2.10	2	10
26	MN-6	5.97	3	9.05	3	2.08	2	3.00	2	10
27	MN-7	5.17	3	7.46	2	1.97	1	1.89	1	7
28	MN-8	5.89	3	8.98	3	2.24	2	2.57	2	10
29	MN-9	7.28	5	11.30	4	3.91	3	4.37	4	16
30	MN-10	4.29	2	7.54	2	3.81	3	2.13	2	9
31	Faijabad (U.P.) NFSS-1	7.10	5	11.19	4	2.92	2	4.11	4	15
32	NFSS-2	7.27	5	12.43	5	2.52	2	3.15	3	15
33	NFSS-3	5.82	3	10.73	4	2.42	2	2.97	2	11
34	NFSS-4	5.48	3	5.75	1	3.92	3	3.66	3	10
35	NFSS-5	6.06	4	9.21	3	2.38	2	2.43	2	11
36	NFSS-6	5.51	3	9.27	3	2.13	2	2.05	2	10
37	NFSS-7	7.48	5	11.28	4	2.59	2	3.14	3	14
38	NFSS-8	7.03	5	11.20	4	2.33	2	3.20	3	14
39	NFSS-9	5.78	3	9.77	3	2.20	2	2.69	2	10
40	NFSS-10	6.29	4	10.17	4	1.93	1	2.30	2	11

Conti.....

S. No.	Location and entries	Height (m)	Marks (A)	DBH (cm)	Marks (B)	CBH (m)	Marks (C)	SBH (m)	Marks (D)	Total (A+B+C+D)
	Garwal (U.A.) hills									
41	SSS-1	5.52	3	8.20	3	2.67	2	2.90	2	10
42	SSS-2	3.99	1	5.14	1	1.98	1	1.78	1	4
43	SSS-3	4.37	2	6.05	2	2.30	2	2.10	2	8
44	SSS-4	4.31	2	5.75	1	1.87	1	2.14	2	6
45	SSS-5	4.92	2	5.69	1	1.68	1	1.56	1	5
SEm ±		0.54		0.93		0.42		0.36		
CD (p=0.05)		1.487		2.529		1.17		0.99		

Where:

DBH = Diameter at breast height,

CBH = Clear bole height,

SBH = Straight bole height,

Table 4.7: Heritability (broad sense) estimates for different entries of *Dalbergia sissoo*

S. No.	Location and entries	Heritability (%)
--------	----------------------	------------------

		Height	Diameter at breast height	Clear bole height	Straight bole height	Average of Total
1	Pantnagar (U.P.)	75.4	78.76	50.24	59.87	66.07
2	PSS-2	60.03	37.23	46.23	55.89	49.85
3	PSS-3	87.98	79.16	54.87	57.85	69.97
4	PSS-4	86.67	77.87	50.24	54.89	67.42
5	PSS-5	95.68	88.86	79.67	78.20	85.60
6	PSS-6	82.36	82.31	68.98	79.86	78.38
7	PSS-7	88.58	79.68	78.58	89.87	84.18
8	PSS-8	90.98	79.86	79.58	84.27	83.67
9	PSS-9	71.32	77.16	49.76	48.89	61.78
10	PSS-10	52.16	52.17	41.15	50.14	48.91
11	Solan (H.P.)	68.18	75.13	65.87	56.87	66.51
12	D-1	78.58	75.85	79.87	68.89	75.80
13	D-8	83.06	75.01	70.98	78.96	77.00
14	J-15	72.57	70.01	61.08	56.18	64.96
15	J-21	75.48	53.28	60.01	56.86	61.41
16	K-6	89.98	71.01	78.68	79.85	79.88
17	K-8	80.86	81.28	71.35	87.54	80.26
18	N-2	70.58	75.68	68.76	86.58	75.40
19	N-5	58.79	68.17	67.89	76.89	67.94
20	N-9	76.85	86.98	75.67	75.87	78.84

Conti...

S. No.	Location and entries	Heritability (%)				
		Height	Diameter at breast height	Clear bole height	Straight bole height	Average of Total

	Chhattisgarh					
21	MN-1	76.89	79.58	78.86	85.67	80.25
22	MN-2	70.10	70.28	56.98	78.69	69.01
23	MN-3	76.58	72.85	57.67	68.47	68.89
24	MN-4	79.01	85.85	71.32	71.85	77.01
25	MN-5	77.56	87.87	76.54	84.98	81.74
26	MN-6	80.56	85.67	78.97	82.56	81.94
27	MN-7	81.68	78.98	71.25	71.58	75.87
28	MN-8	86.38	78.98	75.48	83.54	81.10
29	MN-9	98.84	89.89	88.98	95.98	93.42
30	MN-10	78.28	81.28	75.85	82.04	79.36
	Faijabad (U.P.)					
31	NFSS-1	96.84	88.58	76.89	90.58	90.10
32	NFSS-2	95.84	89.68	83.98	90.10	89.90
33	NFSS-3	88.69	82.34	77.85	82.10	82.75
34	NFSS-4	88.65	78.49	70.25	85.58	80.74
35	NFSS-5	86.65	84.12	77.98	86.98	83.93
36	NFSS-6	88.21	74.25	78.69	82.98	81.03
37	NFSS-7	95.68	77.89	80.98	89.87	86.11
38	NFSS-8	93.24	79.35	85.98	89.98	87.14
39	NFSS-9	86.28	77.98	73.98	83.87	80.53
40	NFSS-10	87.98	81.65	74.95	82.86	81.86

Conti.....

S. No.	Location and entries	Heritability (%)				
		Height	Diameter at breast height	Clear bole height	Straight bole height	Average of Total
	Garwal (U.A.) hills					
41	SSS-1	84.87	78.95	74.93	79.95	79.68
42	SSS-2	68.73	55.84	49.85	61.24	58.92
43	SSS-3	83.45	74.25	70.54	77.89	76.53
44	SSS-4	78.45	69.87	61.24	73.01	70.64
45	SSS-5	72.58	61.35	59.98	70.98	66.22

Table 4.5: Phenological observations of different entries of Candidate Plus Trees of *Delbergia sissoo*

[illegible]

[illegible]

Conti....

S. No.	Location and Entries	Color of bark	Branching pattern	Leaf fall					Leaf initiation					flowering					Fruiting				
				1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Garwal (U.A.) hills		Dark brown	Epicormic	FN	EN	FD	ED	MJ	FF	EF	FM	EM	EA	FM	EM	MA	EA	MM	EA	MM	FO	MN	D
41	SSS-1	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
42	SSS-2	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
43	SSS-3	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
44	SSS-4	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	
45	SSS-5	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	”	

FN = First week of November

FF = First week of February

FM = First week of March

EA = End of April

1 = Beginning

EN = End of November

EF = End of February I

EM = End of March

MM = Mid of May

2 = Poorly

FD = First week of December

FM = First week of March

MA = Mid of April

FO = First week of October

3 = Moderately

ED = End of December

EM = End of March

EA = End of April

MN = Mid of November

4 = Highly

MJ = Mid of January

EA = End of April

MM = Mid of May

D = December

5 = Ending

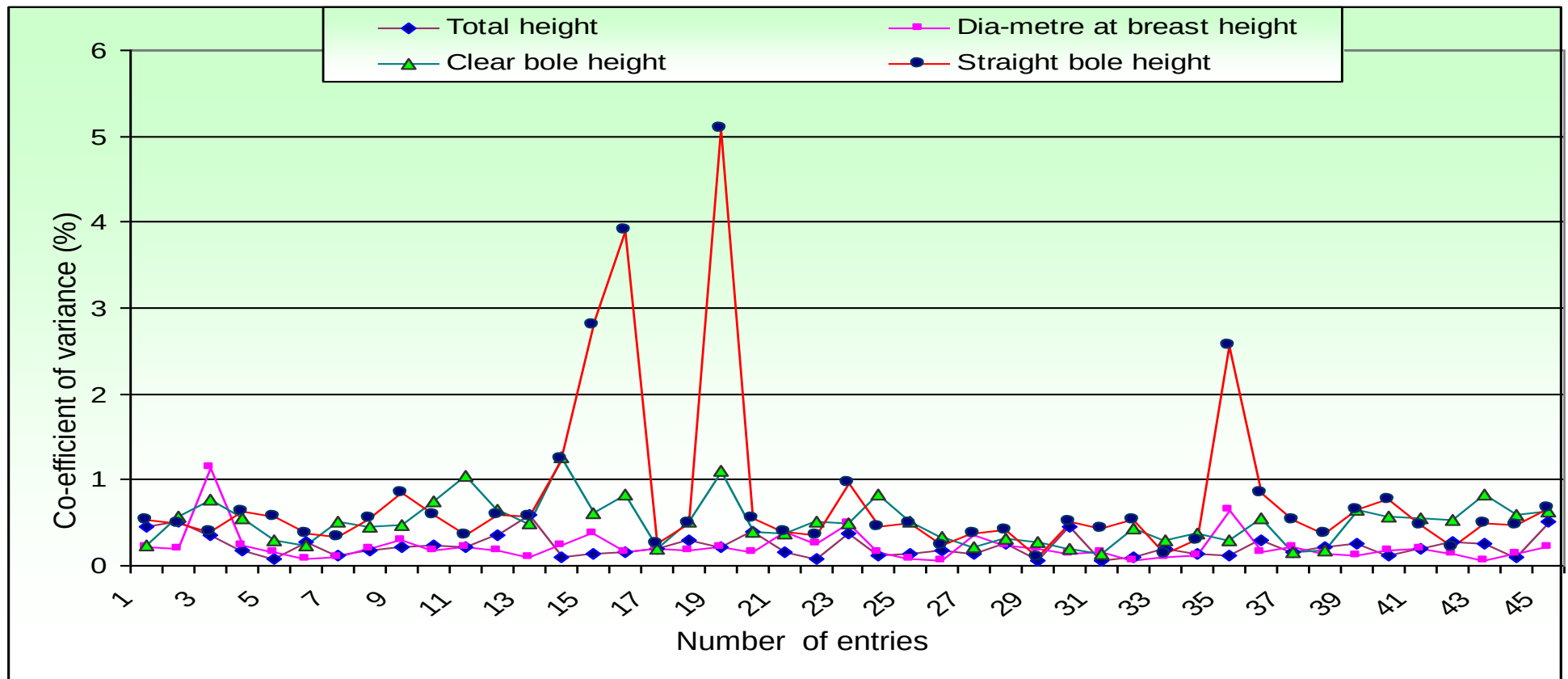


Fig. 4.1 : Co-efficient of variance for tree growth characteristics of different entries of *Dalbergia sissoo*

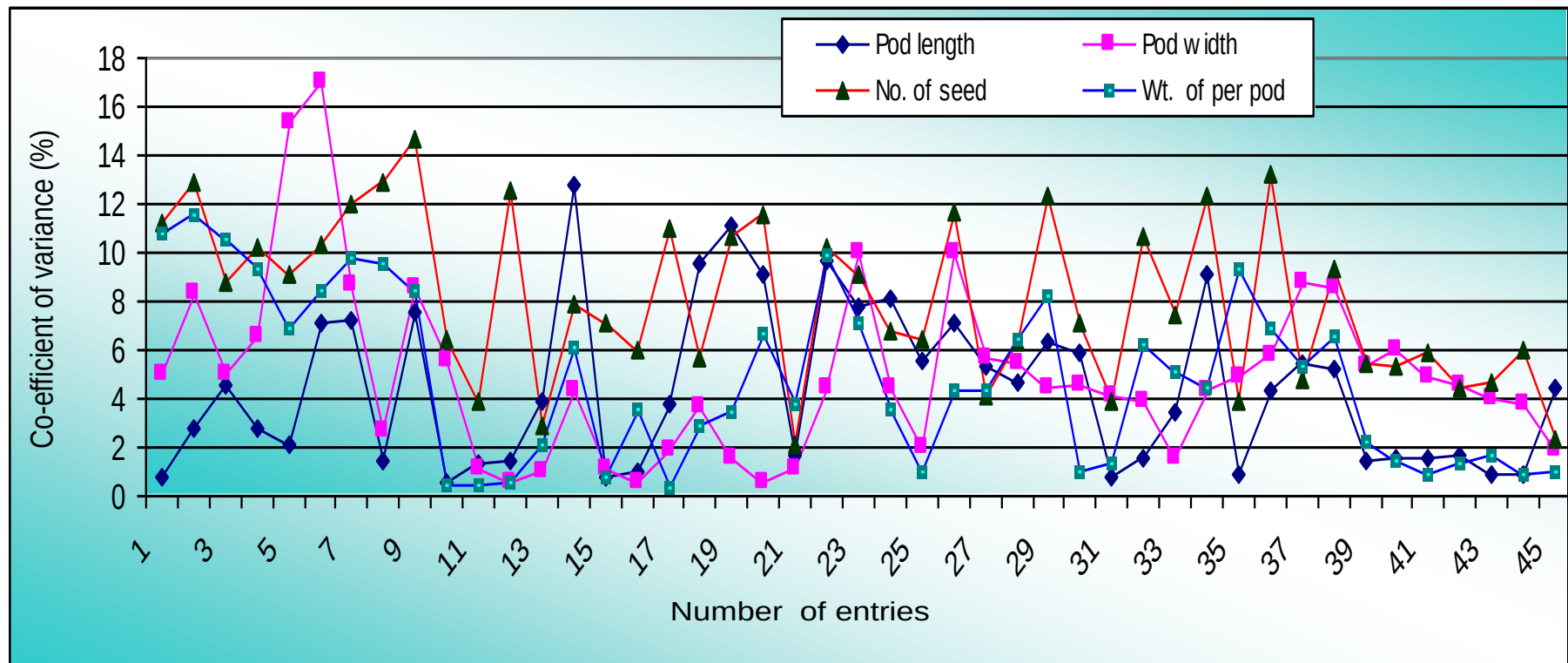
1-10 = Pantnagar (U.A.),

21-30 = Chhattisgarh,

41-45 = Garwal (U.A.) hills

11-20 = Solan (H.P.),

31-40 = Fajjabad (U.P.),



A

Fig. 4.2 : Co-efficient of variance for pod characteristics of different entries of *Dalbergia sissoo*

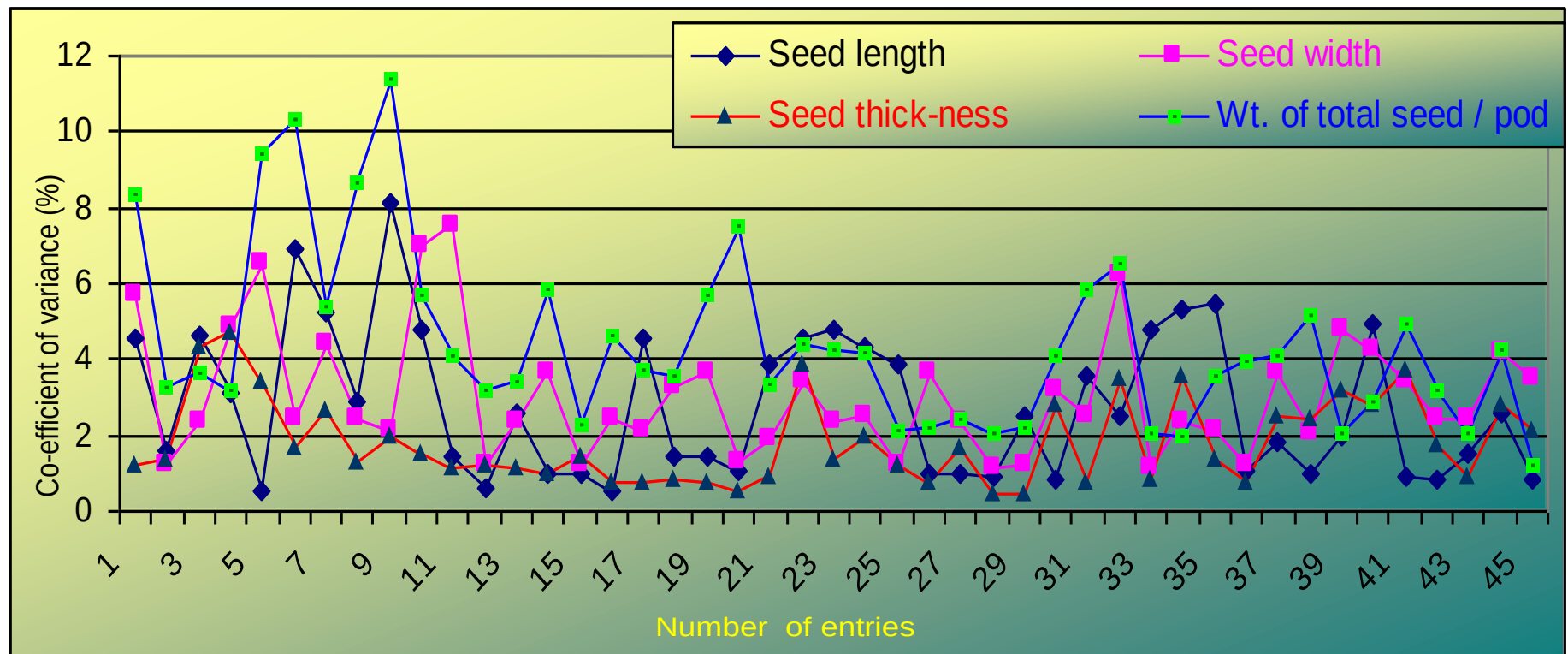
1-10 = Pantnagar (U.A.),

11-20 = Solan (H.P.),

21-30 = Chhattisgarh,

31-40 = Faijabad (U.P.),

41-45 = Garwal (U.A.) hills



B

Fig. 4.2 : Co-efficient of variance for seed characteristics different entries of *Dalbergia sissoo*

1-10 = Pantnagar (U.A.),

11-20 = Solan (H.P.),

21-30 = Chhattisgarh,

31-40 = Faijabad (U.P.),

41-45 = Garwal (U.A.) hills

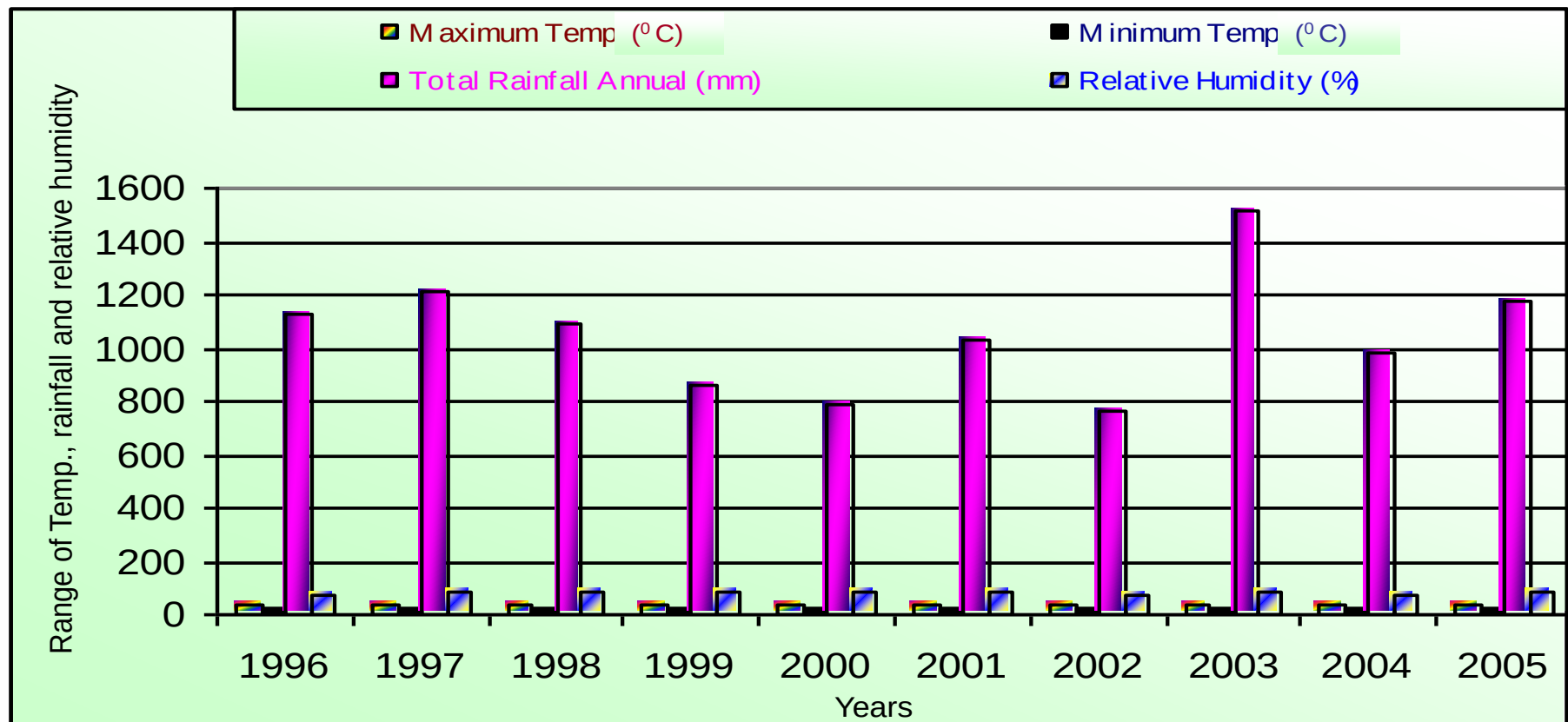


Fig. 3.1 : Annual mean meteorological data in study area

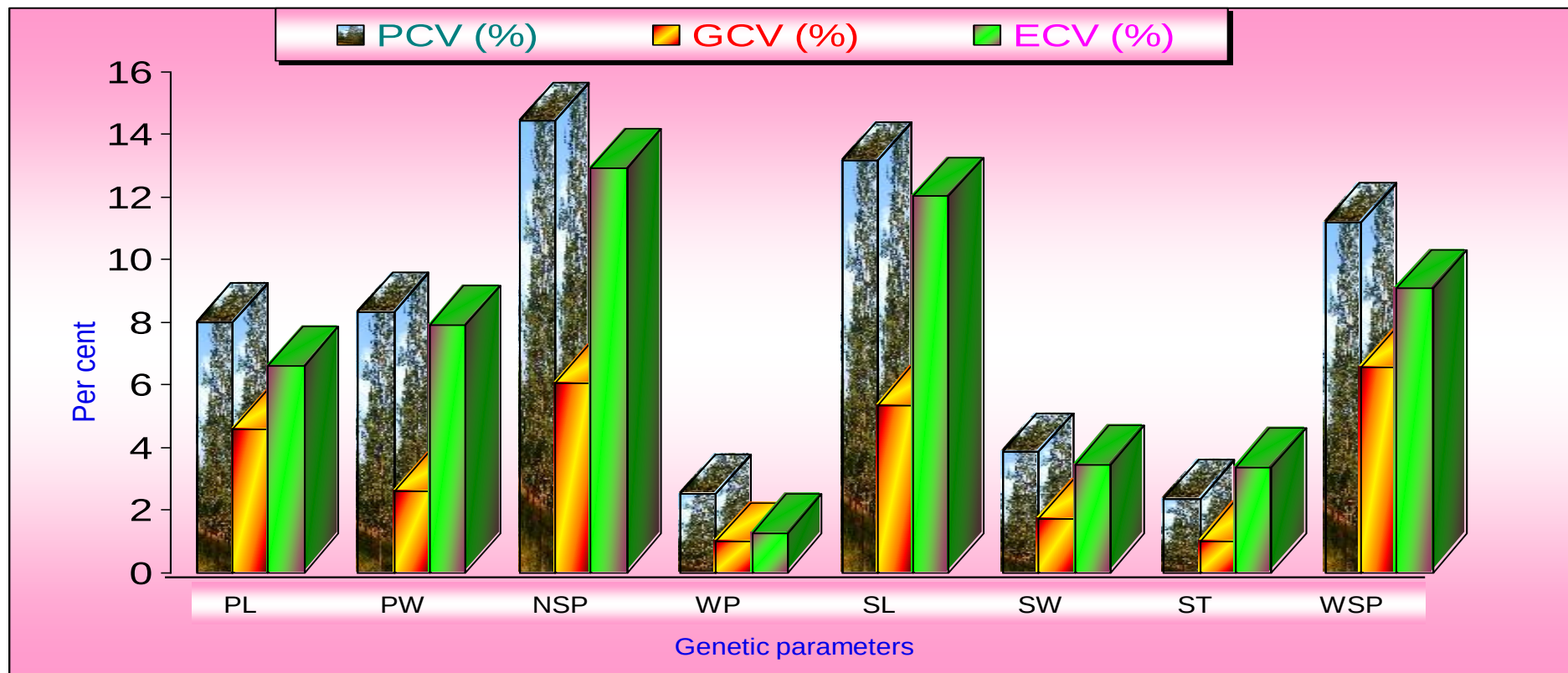


Fig . 4.4: Estimation of genetic parameters for pod-seed characteristics

PCV = Phenotypic co-efficient of variance, GCV = Genotypic co-efficient of variance,
ECV = Environmental co-efficient of variance

PL = Pod length (cm),

NSP = No. of seeds pod⁻¹,

SL = Seed length (cm),

ST = Seed thickness (cm).

PW = Pod width (cm),

WP = Weight of pod⁻¹ (g),

SW = Seed width (cm),

WSP= Weight of seeds pod⁻¹ (g)

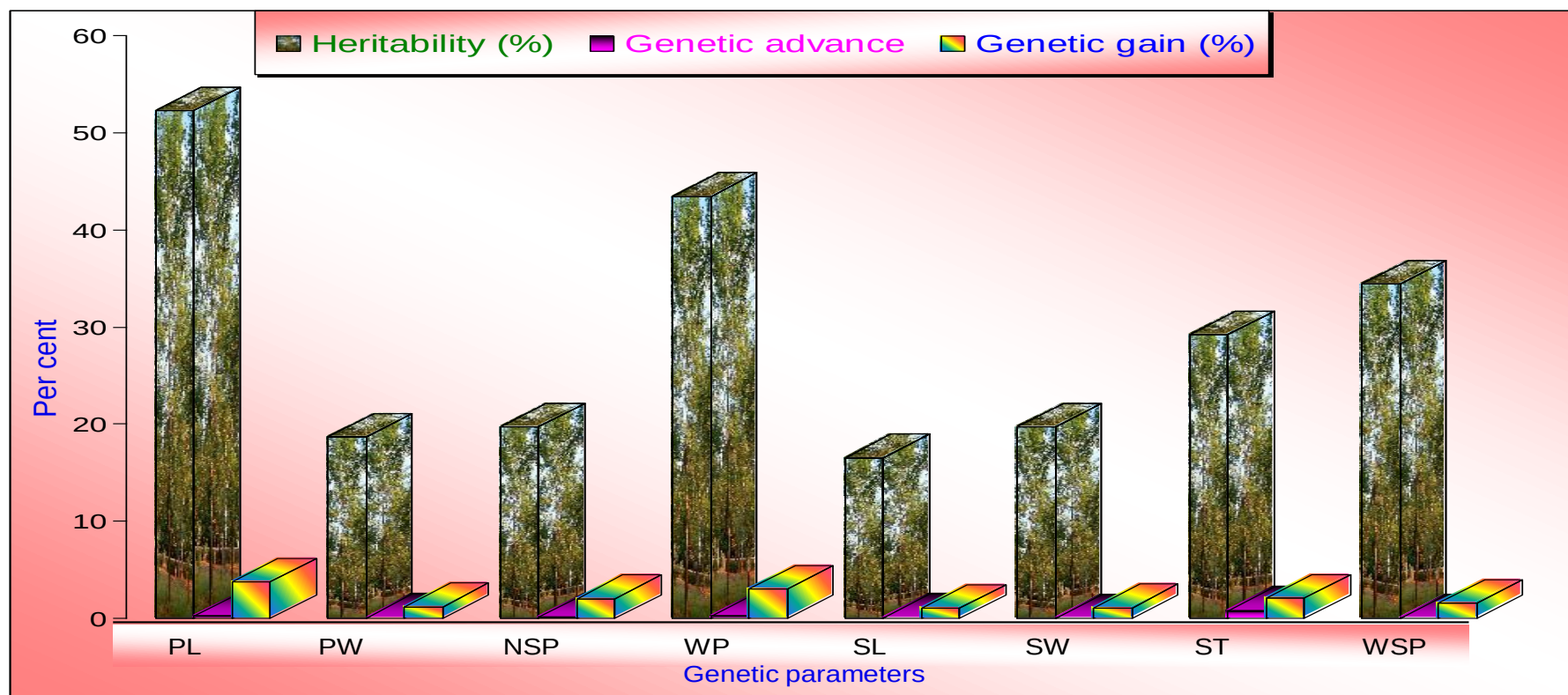


Fig .4.5 : Estimation of genetic parameters for pod-seed characteristics

PL = Pod length (cm),

NSP = No. of seeds pod⁻¹,

SL = Seed length (cm),

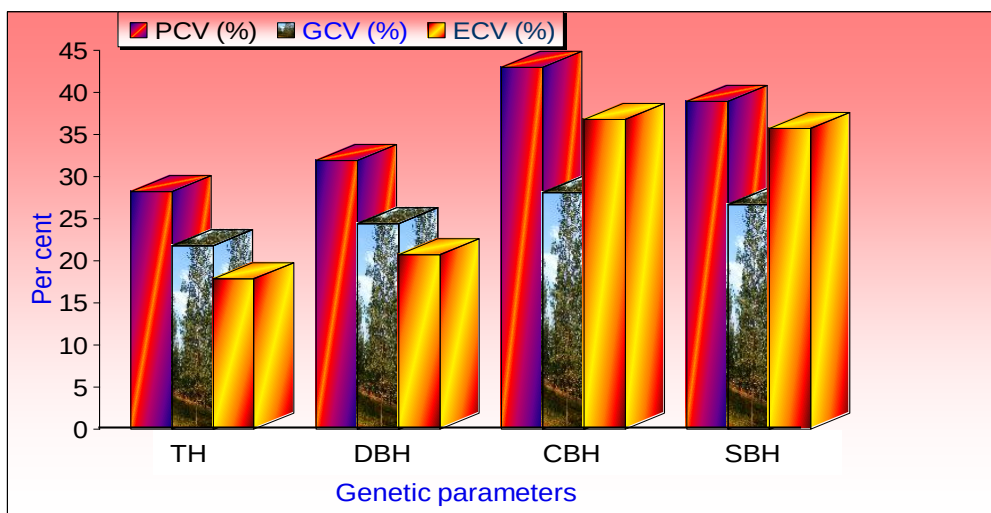
ST = Seed thickness (cm).

PW = Pod width (cm),

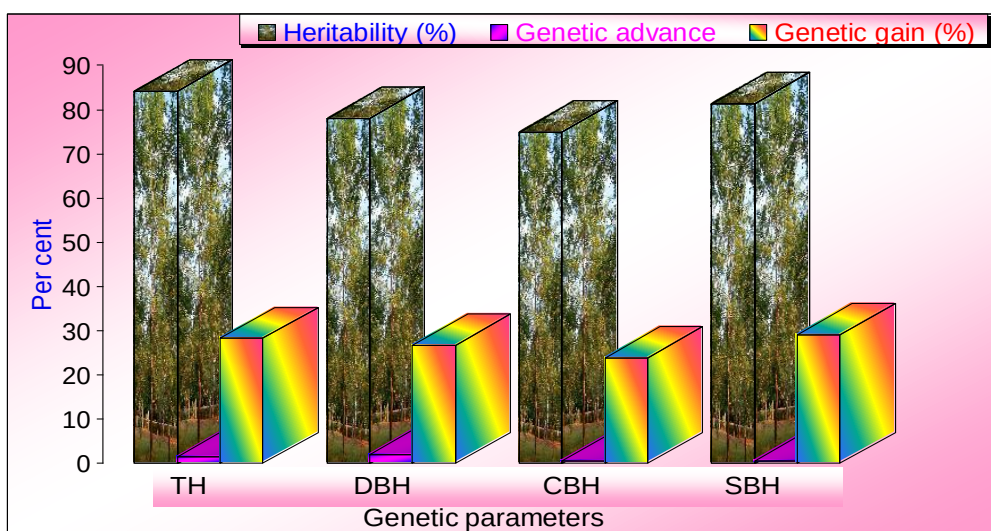
WP = Weight of pod⁻¹ (g),

SW = Seed width (cm),

WSP= Weight of seeds pod⁻¹ (g)



A



B

Fig. 4.3: Estimation of genetic parameters for tree growth characteristics

PCV = Phenotypic co-efficient of variance

GCV = Genotypic co-efficient of variance

ECV = Environmental co-efficient of variance

TH = Total height (m),

DBH = Diameter at breast height (cm),

CBH = Clear bole height (m)

SBH = Straight bole height (m)

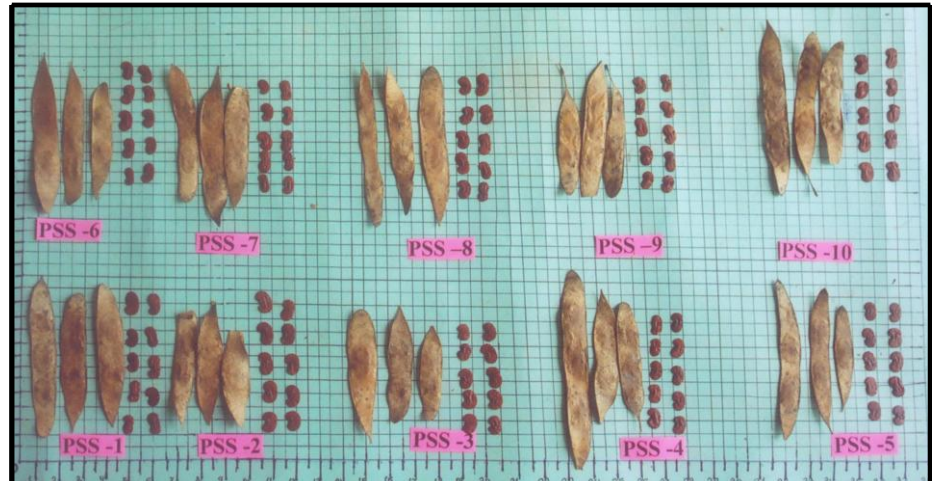


Plate 1: Morphological variations of pod and seed of different entries of *Dalbergia sissoo* collected from different geographical sources of Pantnagar (U.P.)

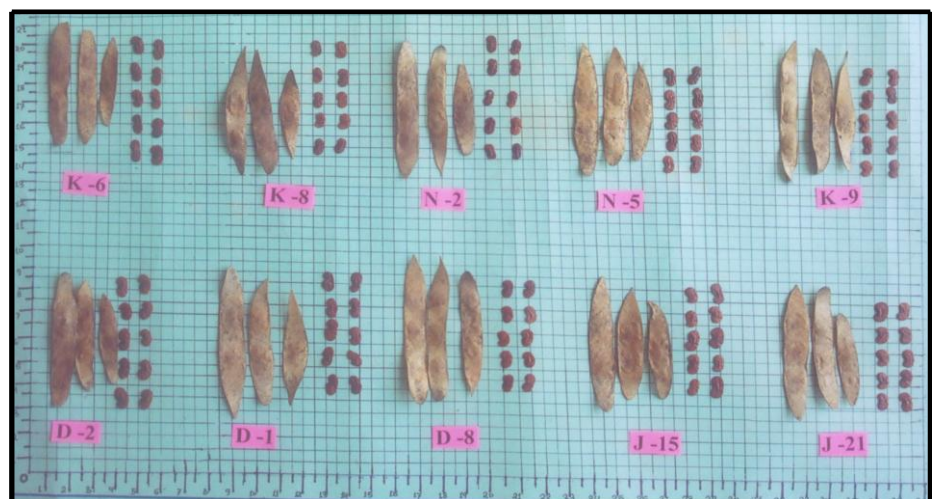


Plate 2: Morphological variations of pod and seed of different entries of *Dalbergia sissoo* collected from different geographical sources of Solan (H.P.)

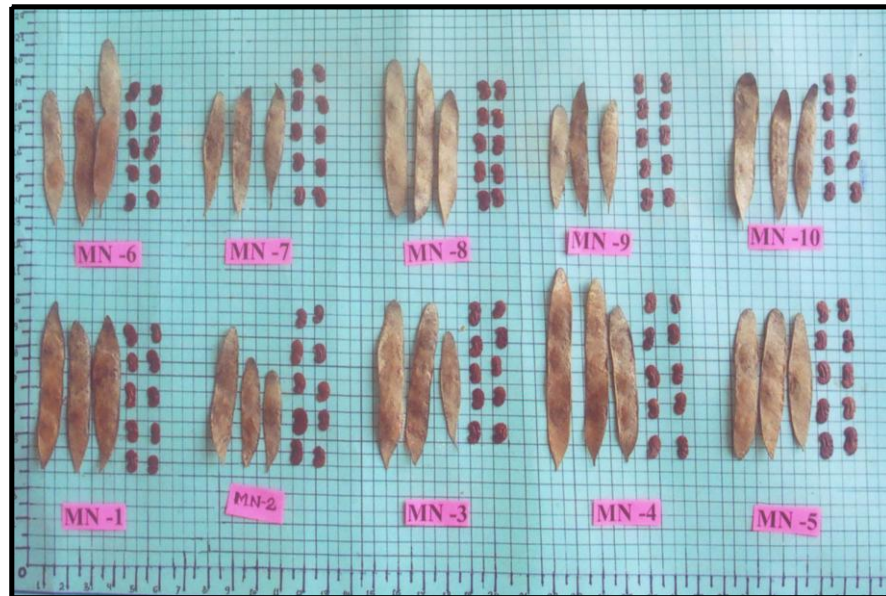


Plate 3: Morphological variations of pod and seed of different entries of *Dalbergia sissoo* collected from different geographical sources of Chhattisgarh

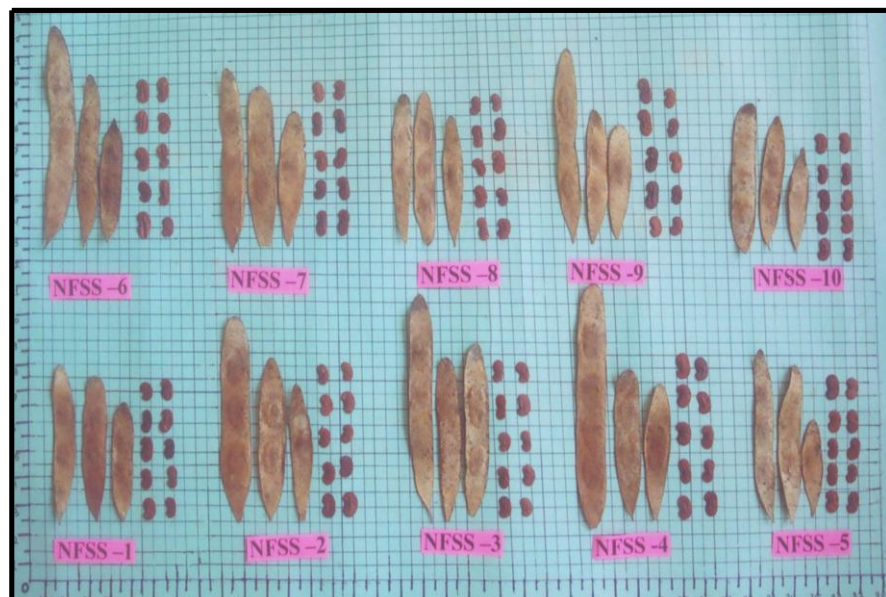


Plate 4: Morphological variations of pod and seed of different entries of *Dalbergia sissoo* collected from different geographical sources of Faijabad (U.P.)

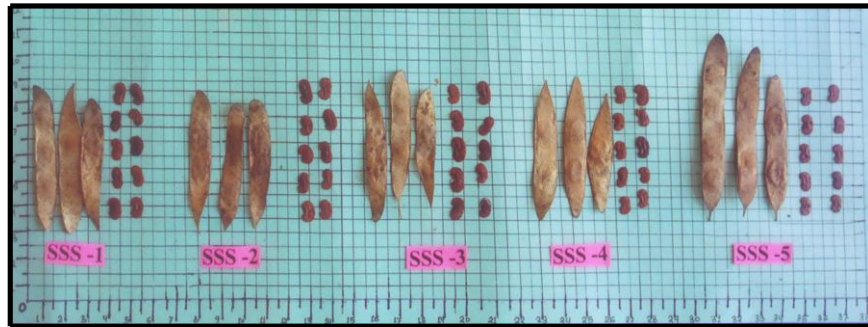
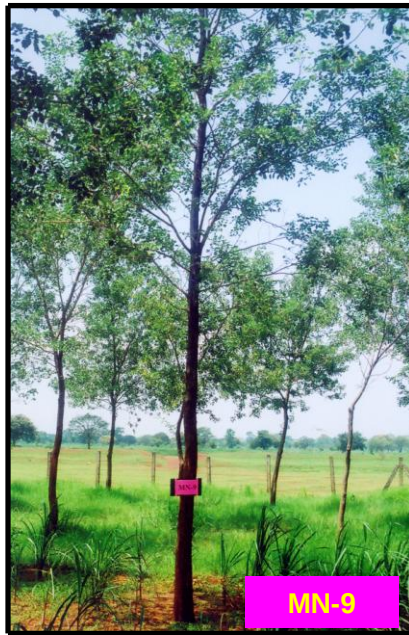


Plate 5: Morphological variations of pod and seed of different entries of *Dalbergia sissoo* collected from different geographical sources of Garwal (U.A.) hills



Plate 6: View of growth performance of different entries of *Dalbergia sissoo*



A



B



C



D

Plate 7: View of most promising entries of *Dalbergia sissoo*

