"STUDIES ON GENOTYPIC AND PHENOTYPIC VARIATIONS IN *Dalbergia sissoo* Roxb."

BY

SANJAY KHAJURIA
(2012A63D)

Thesis submitted to the Chaudhary Charan Singh Haryana Agricultural University in the partial fulfillment Of the requirements for the degree of

DOCTOR OF PHILOSOPHY

IN

FORESTRY

COLLEGE OF AGRICULTURE
CCS HARYANA AGRICULTURAL UNIVERSITY
HISAR - 125 004 (HARYANA)

2016

CERTIFICATE – I

This is to certify that this thesis entitled **"Studies on genotypic and phenotypic variations in *Dalbergia sissoo* Roxb."** submitted for the degree of **Doctor of Philosphy** in the subject of **Forestry** of the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** is a bonafide research work carried out by **Mr. Sanjay Khajuria, Adm. No. 2012A63D** under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

(Dr. K. S. Bangrwa)
Major advisor
Professor & Head
Department of Forestry
College of Agriculture
CCS Haryana Agricultural University
Hisar-125 004, India

CERTIFICATE – II

This is to certify that this thesis entitled **"Studies on genotypic and phenotypic variations in *Dalbergia sissoo* Roxb."** submitted by **Mr. Sanjay Khajuria, Adm. No. 2012A63D** to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** in the subject of **Forestry**, has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

MAJOR ADVISOR **EXTERNAL EXAMINER**

HEAD OF THE DEPARTMENT

DEAN, POST-GRADUATE STUDIES

CERTIFICATE –III

FORMAT FOR P. G. THESIS

"It is certified that the thesis submitted by **Sanjay Khajuria**, Adm. No. **2012A63D**, Ph. D. student of this department has been checked and found as per specification of the format circulated by the Dean, PGS vide his Memo No. PGS/A-1/09/6926-90 dated 26. 8. 09"

MAJOR ADVISOR **PROFESSOR & HEAD**

ACKNOWLEDGEMENT

A precious debt as that of learning is the only debt that is not only difficult but also impossible to repay except perhaps through gratitude.

At the very outset, I bow my head with reverence and dedicatedly accord my recondite gratitude to the "Almighty" the merciful and compassionate whose grace, glory and blessings allowed me to complete this endeavour. Without blessing of the "Almighty God" this efforts would have remained a far-fetched dream and a sheath of notes.

I feel immense pleasure in expressing my deep sense of gratitude with reverence to my advisor Dr. K. S. Bangarwa, Professor & Head, Department of Forestry, CCS Haryana Agricultural University, Hisar. The research work undertaken would have remained unaccomplished without his valuable guidance, keen interest, continuous persuasion, and remarkable patience during the entire course of study. His unceasing encouragement, untiring efforts, inspiration, ever-willing help, precise and constructive criticism and meticulous suggestions throughout the course of this investigation enabled me in executing my research work and preparation of this manuscript. His affection and sincerity towards work has been much beyond his formal obligation as a major advisor for which I shall ever be indebted to him.

I feel profound delighted and prerogative to express my deep sense of gratefulness to my advisory committee, Dr.R.S.Dhillon, Principal scientist; Forsetry; Dr.R.C. Punia, Professor SST-cum-Director farms; Dr.R. S. Sangwan, HOD Cotton section and Dr. S. K. Goyal, Head MBA department for their valuable suggestions, everlasting help, and ever-encouraging attitude.

I do acknowledge the support of Faculty members, Professor Bhimlendra Kumari, Dr R.S.Beniwal, Dr Manoj Kumar & Dr K.K.Bhardwaj. No words can suffice my feelings of gratitude to my respected parents. With extreme humble sense of regards, I bow down my head to my beloved parents whose blessings were the constant source of inspiration, which made the task to success.

I am great of my life partner Dr Rita and my little angles Vasvi and Ashrut for their patience and sacrifice during the whole period.

I have great honour to thank our Worthy Vice Chancellor for deputing me under FIP Scheme.

I extend my sincere thanks and gratitude to my seniors Dr Verender Dalal, Dr Mahesh, Dr Kumarnag ARS, Dr Rajana ARS, Dr Dutta & Dr Kedar. I am highly thankful to my colleages and friends, Sanjay Kumar, Vijay H.M, Dr Munish Sharma, Dr Ajay, Amit singhdoha, Chavi & Gurdev Chand and my juniors Pradyuman, Hari Kesh (GPB) Sumit (Eco) and Parveen (Z) for their help and appropriate company during my stay in Hisar.

Last but not the least, I am thankful to all those who helped me directly or indirectly but whose names didn't find and mention in their endeavor, they will always remain in my heart.

SANJAY KHAJURIA

Place: Hisar
Dated: June, 2016

CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

mm	millimeter
gm	gram
kg	kilogram
cm	centimeter
m	meter
wt	weight
d.b.h.	diameter at breast height
sq. cm	square centimeter
sq. mm.	square millimeter
C.D.	critical difference
%	per cent
CV	coefficient of variance
GCV	genotypic coefficient of variance
PCV	phenotypic coefficient of variance
h^2	heritability
GA	genetic advance
GA (%)	genetic advance as per cent of the mean
FZP	Ferozpur
RSI	Reasi
HGR	Hanumangarh
MRT	Meerut
USN	Udhamsinghnagar
BST	Basti

CHAPTER-I

INTRODUCTION

Dalbergia sissoo Roxb. is one of the few important broad leaved leguminous trees of the Indo-Pakistan sub-continent, growing naturally right from Himalayan hills to the plains of Afghanistan, Pakistan, India and Malaysia. It has also been planted in several African and South East Asian countries. This species is best known internationally as a premier timber species since ages. Its mention as "Shinshapa" or "Aguru" in Sanskrit literature suggests that it is a very old species which must have been used by man since prehistoric times. *Dalbergia sissoo* Roxb. a large deciduous tree, is one of the most common, tree species valued for its timber, fodder and nitrogen fixing quality (Tewari, 1994). With its multiple uses and tolerance to a broad range of climatic and soil conditions, this species deserves much greater considerations for agroforestry plantations than those given in the past.

This tree is popularly known as "Shisham" in Indian sub-continent, though several other local names are also in use. The shisham is known as tali in Punjab and Haryana, Sissoo in parts of Uttar Pradesh and *Dalbergia sissoo* to the Botanists, who have named it in honour of Nicholas Dalberg, a Swedish Botanist. It belongs to Leguminosae (Papilionaceae) family. It is a state tree of Punjab state of India. It has a long, thick tap root and long ramifying lateral roots. Shisham is distributed in the entire sub-Himalayan region and the Himalayan valleys; throughout Indo-Gangetic plains and in Rajasthan. It grows well in tropical and sub-tropical areas with semi-arid to humid conditions and annual rainfall of 500-2000 mm with 4-6 dry months, temperature being between freezing level and 50°C on altitudes from sea level to 1500 m. It has been found suitable for sand dune afforestation with annual rainfall of even 400 mm/year but best growth is achieved with 1000-1700 mm rainfall. It prefers well drained sandy loam soils with good moisture supply. Fast rate of growth, adaptability to different sites, yield per unit area and quality of wood can be incorporated in wood species through appropriate breeding and selection.

This large deciduous tree, under favorable conditions, attains a height of 30 m and girth of 2.4 m (Bangarwa and Singh, 1998). The species is a strong light demander that grows in places with alluvial soil and sufficient water supply. Dispersed naturally by river water, the species can be found near river banks, often in association with *Acacia catechu*. Being a nitrogen fixer, the species is also consequential in ameliorating soil fertility, besides being pivotal for local communities as a fodder crop and source of fuelwood.

Provenance trials are genetically motivated field trials (Finkeldey and Hattemer, 2006) that are a constitutive segment of many breeding programs, and have been much deliberated by co-worker (Wright, 1976). Several such trials have been conducted to study; among others, morphological growth and heritability estimates of growth and wood

properties, variability in growth, physiological and biochemical characteristics (Sharma and Bakshi, 2014) and protection from diseases (Sharma *et al.,* 2010). Provenance trials have also lately gained immense importance in guiding future large-scale planting of native species over the locations outside their natural occurrence as well as planting of most adaptive and protective seed sources. With this background, a multi-locational national provenance trial of *Dalbergia sissoo* Roxb. was coordinated by the Indian Council of Forestry Research and Education, Dehradun in the year 1994-1995. Trials of such national scale have become more important in view of likely impacts of climate change on tree species and the need to plant only the best adaptive seed sources.

The tree sheds its leaves from November or December to January or February. Flowering closely follows leaf flushing. The flowers and pods are produced from March to May. Shisham prefers well drained sandy loam soil with good moisture supply and therefore thrives best in freshly deposited and well drained sandy soil with good moisture supply, and well drained sandy soil pebbles and boulders in river belts (Chaturvedi, 1956). In the natural state, it is fairly drought resistant and frost hardy (Sah *et al.*, 1988). Ripe pods may be clipped manually by climbing on the trees and picking the fruits or shaking the branches and picking the fruits from the ground. However, problems are associated with quality planting material of *Dalbergia sissoo* Roxb.in northern India as most of the stands produce forked/crooked trees, which reduce acceptability of tree species as timber. Screening and selection is emphasized to provide quality planting material to resource poor farmers of the region.

Due to multiple uses and its tolerance to the various climatic and soil conditions, this species deserves a lot of consideration for agroforestry plantation. To get maximum yield from high quality timber, tree afforestation programmmes generally require genetically superior reproductive materials. The selection of superior trees or provenances from the natural plantation of Indian tree species by seed collection and its uses on commercial scale is an applied method which can be immediately adopted to get genetic gain. Hence, it is desirable to utilize good quality seed of this species for mass propagation of vigorous seedlings. The knowledge of genetic variability and association among seed quality parameters is considered to provide considerable help in the genetic improvement of the species by way of making available reliable information on nature, extent and direction of selection. The ultimate goal of the tree breeder is to improve tree species in term of quantity and quality of wood produced. This can be achieved through the selection of superior genotypes for which often indirect selection is performed. Selection of superior phenotypes in the forestry is most effective, as even a small genetic gain can be of enormous economic benefit when distributed over a large plantation area annually (Dhillon, 1992). To achieve maximum gain per unit time, there is dire need of selection of superior phenotypes.

The available literature on shisham reveals that a very little work has been done on phenotypic variation, seed storability and genetic variation in *Dalbergia sissoo* Roxb. For the genetic improvement through selection of superior phenotypes and provenance trial in northern India, it is desirable to evaluate the naturally available genetic variation and to utilize the best material for afforestation and for future tree improvement programmes in *Dalbergia sissoo* Roxb. Therefore, it was considered necessary to survey the northern Indian states where there is ample of unexplored quality natural stands, for utilizing the existing natural variability for tree improvement.

Keeping in view the above facts, the present study entitled "Studies on genotypic and phenotypic variations in *Dalbergia sissoo* Roxb." was planned with the following objectives.

Objectives

1. To study the extent of phenotypic variation in various geographic sites
2. To find out the seed storability and loss of vigour during storage
3. To find out the extent of genotypic variation in juvenile growth of various progenies from different geographical sites
4. To find out the best seed source of *Dalbergia sissoo* Roxb. for further tree improvement programme

CHAPTER - II

REVIEW OF LITERATURE

The studies on genetic diversity of trees are essential for their proper conservation in its natural habitat. Tree breeding through the application of genetic principles is basically directed toward modifying the heredity of tree populations so that the trees are able to meet the better needs of the forester and the wood based industries. Serious attention to selective tree breeding has been paid only in the present century, mainly since 1950 and primarily for industrial wood products (Burley, 1987). Initially, work was concentrated in Europe and North America, then in Australia, Japan and Brazil, lately in Africa and Indian sub-continent. The major initial task was to convince the foresters that not only environment, but also the heredity of the trees determines their growth, form and adaptability (Zobel, 1952). Tree improvement work in India was initiated by Prof. Champion who realized the importance of geographic variation and conducted a seed origin trial of teak during 1930 (Emmanuel *et al.*, 1992). Later on in 1950, Dr. Rao published an article on Genetics and Tree Improvement. Realizing the importance of this subject, Forest Research Institute, Dehradun established a Forest Genetics Section during 1959-60 attached to Botany branch under the then Directorate of Biological Research. In the year 1961, Prof. J.D. Mathews an expert from FAO visited India to give guidelines for the proposed work. He initialy suggested the work on some priority species *viz*., *Tectona grandis, Bombax ceiba, Pinus spp*. and *Dalbergia sissoo*. In 1990-93, a well-planned systematic work on *Dalbergia sissoo* was conducted (Bangarwa, 1993) at Chaudhary Charan Singh Haryana Agricultural University, Hisar, India. After that, lot of work was done on *Dalbergia sissoo* for its genetic improvement but a little research work has been done on comparing the seed sources from different provenances belonging to different altitudinal ranges of the north western India for evaluating genetic and phenotypic variation among the different seed sources. The most relevant literature on *Dalbergia sissoo* and other species is being reviewed under the following heads;

2.1 Extent of phenotypic variation in various geographical site

2.2 Provenance evaluation for seed storability and loss of vigor during storage

2.3 Provenance cum progeny testing

2.1 Provenance variation:

Genetic diversity found in tree species is a part of nature's strategy for defense and survival against all types of risks encountered in the long life spans of forest trees (Zobel & Talbert, 1984). The use of genetic diversity of wild species for gain is the basis of tree improvement work. Geographic variation associated with distinct climatic regions in which the species grows results from genetic and environmental factor. By growing geographic variation under identical environment, the inherent variation of a species is to be identified

from environmental variation with the formula: Phenotypic variation = Genotypic variation + Environmental variation and their interaction.

2.1.1 Phenotypic Variation

2.1.1.1 Morphological characters:

Zobel *et al.* (1960) conducted studies on loblolly pine throughout its natural range on phenotypic variation and reported considerable variability in important morphological and physiological characteristics, both regionally and locally. Similarly, Khosla *et al.* (1980) made phenotypic variation studies in natural clones of *Populus ciliata* over a restricted geographical area. While reviewing variation in Indian tree species, Dogra (1981) emphasized on survey of phenotypic variation of silvicultural characteristics of tree species in their naturally distributed range.

Jatasra (1982) collected 250 strains of *Prosopis cineraria* by the random based sampling from Thar desert during May-June, 1981. The quantitative data recorded on 223 trees indicated a wide range of variability for tree height, DBH (diameter at breast height), stem height, canopy height and canopy diameter. Ranking for leaf fodder and seed yield revealed the vast exploitable variations. Continuing this study, Jatasra and Paroda (1983) reported that in natural stands of *Prosopis cineraria*, tree height varied from 4 to 22 m with mean values of 9.19 m, stem height and canopy height ranged from 1 to 8 m and 1 to 20 m, respectively. Main stem: canopy ratio (0.56) indicated that canopy grew almost double the height of stem. Branches per tree ranged from 4 to 43. Maximum variation was observed for canopy volume and least variation was observed for stem height.

Kackar *et al.* (1986a) reported variation for morphological characters of *Prosopis cineraria* in natural stands from various adaphic sites and rainfall zones of western Rajasthan. The height of trees was found variable in all the eleven provenances. The minimum and maximum mean height of 8.8 and 16.3 m were observed in Tonk provenance and Barmer provenance, respectively. The mean values of forking height varied from 2.04 to 4.28 m in Tonk and Barmer provenances. Average forking height was lower than three meter in all the provenances except Barmer and Nagaur. The value of diameter at breast height (DBH) varied from 0.26 to 2.52 m as representative of Tonk and Jalore provenances, respectively.

Jindal *et al.* (1987) in their studies of natural populations of *Tecomella undulata*, another important tree of arid zone of Rajasthan, reported wide variation for tree height, basal diameter and dbh. Maximum frequency of this species was observed in interdunal areas of Barmer district. Coefficient of variability for tree height, dbh, basal diameter and canopy diameter was also maximum in this district. In collaboration with the Forest Department, India, Emmanuel *et al.* (1992) selected approximately 1200 plus trees of different species including the prominent species *Tectona grandis, Bombax ceiba, Dalbergia sissoo* and *Pinus roxburghii.*

Bangarwa *et al.* (1992) conducted a survey in semi-arid and mesic parts of Haryana and selected suitable mother trees of *Dalbergia sissoo* having narrow crown and a clear straight bole, which could be grown in association with agriculture crops. However, Gupta *et al.* 1992 selected plus trees of *sissoo* from natural and plantation forests of Uttar Pradesh based on stem straightness, height and diameter.

Tewari (1994) suggested the requirements of plus tree selection criteria as good height, diameter, clean bole, compact crown, low branch angle and resistance to pest and diseases.

Bangarwa *et al.* (2002) while conducting studies on *Dalbergia sissoo*, reported a large variations among provenances for total height, basal diameter, unforked height and straightness. While, Kala and Kumaran (2012) conducted a genetic divergence study on selected thirty four CPTs of *Bixa orellana* L. from major growing regions and recorded substantial variability in morphological traits of selected plus trees with no relationship between the genetic divergence and geographical distribution.

Meena *et al*. (2015) while estimating genetic parameters in pods and seed traits of candidate plus trees of *Tecomella undulata* (SM.) seed, observed considerable variations in all the pod and seed characters like seeds/pod, pod length, and pod width and also concluded that the existence of substantial genetic variation, which can be utilized for further tree improvement programmes of this species.

2.1.1.2 Pod and Seed Characters:

Burley (1965) assessed variability for seed weight in thirty provenances of Sitka spruce. He did not find any apparent relationship of seed weight with latitude. However, there was a trend for northern provenances to have comparatively heavier seeds.

An exploratory survey and germplasm collection from 140 trees was undertaken by Kacker *et al.* (1986 b) from various places of Indian Thar Desert *viz*., Ajmer, Barmer, Bikaner, Churu, Jaipur, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur, Sikar and Tonk districts of Rajasthan. Analysis of three characters *i.e*. seed weight, pod length and number of seeds per pod revealed ample variation. For all the three characters studied, maximum variation was observed in the provenance of Barmer district as shown by the high values of coefficient of variation.

Shiv Kumar and Banerjee (1986) found a considerable variation in external seed characters, germination, viability, plumule and radicle ratio of *Acacia nilotica*. While Huang (1989) reported significant differences between provenances of *Acacia auriculiformis* in seed weight and seedling traits. Large variation in seed and pod characters and germination behavior were observed by Bangarwa (1993) while conducting a study on *D. sissoo* provenances.

Devagiri *et al.* (2004) carried out investigations to obtain genetic information on traits related to seed germination and vigor among different provenances of *D. sissoo* and observed significant differences among provenances for all the traits except pod width, indicating the presence of significant amount of genetic variation.

While studying the morphological characters and germination behavior of *D. sissoo,* Sheikh and Matin (2007) measured the length, breadth, thickness and weight of the fruits and seeds and found all the recorded characters highest in four seeded fruits. Chauhan and Shams (2008) recorded test weight of 397 g, number of seeds per kg 2518, germination period from third to seventh day and germination capacity more than 80% at 30±1°C in the BOD incubator while studying the various aspects of seed and pod morphology of *Delonix regia*.

Singh and Bhatt (2008a) revealed that seed germination of *D. sissoo* is temperature dependent and seeds collected from different sources showed variability in germination. Based on germination behavior on different temperature, it can be recommended that seed of *D. sissoo* should be sown in nursery beds in the months of March-April, as the optimum germination takes place at 25-30°C temperature.

Singh and Bhatt (2008b) evaluated seed morphology of Shisham from 19 different altitudinal sources and selected, trees indicating large variations in pod (greater pod size and more seeds per pod) and seed morphology (larger and heavier seeds with higher percent germination) for the collection of seeds, which were sown to select taller seedlings to raise quality planting material of this promising species of central Himalaya, India.

Kaushik *et al.* (2011a) assessed the magnitude of variability in forty plus trees of *Pongamia pinnata* collected from different parts of Haryana, and based on morphometric studies, considerable diversity was found among the selected germplasm. Sahoo *et al.* (2011) found significant variations among seed and pod characters with high phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and high heritability coupled with high genetic advance for 100 pod weight and 100 seed weight. Genotypic correlation was found higher than phenotypic correlation and all the characters were found positively correlated with each other.

While studying morphometric characters of seventeen seed sources of *Pongamia pinnata,* Kumar (2012) found significant genetic variability among pod, seed and seedling traits with highest number of branches, seed thickness, internodal distance and pod breadth on 100 seed weight, whereas Meena *et al*. (2015) while estimating genetic parameters in pods and seed traits of candidate plus trees of *Tecomella undulata* (SM.) seed observed considerable variations in all the pod and seed characters like seeds/pod, pod length, and pod width and also concluded that the existence of substantial genetic variation, which can be utilized for further tree improvement programmes of this species.

2.1.2 Provenance Evaluation:

During the course of evolution, different species have become adapted to different specific climate conditions, soil type and other environmental factors so that they suit them best. With the increasing pressure on land, it has become essential to choose particular provenance which suits best to a particular environmental conditions so as to obtain highest yield per unit area (Rawat *et al*., 1987).

It has been found that in *Pinus roxburghii, P. wallichiana, Tectona grandis, Dalbergia sissoo* and *Acacia arabica* seed origin makes big differences in growth and quality of plantations (Suri and Seth, 1959; Champion and Seth, 1968). Khurana and Khosla (1980) made a range wide trial on *Populus ciliata* with 84 clones and subsequently, the number of clones were increased to 134. Nine promising provenances were singled out for genotypic site interaction trial.

Rao (1984) conducted provenance trial of *Eucalyptus* spp. at three sites and identified provenances for different rainfall regions. While Mathur *et al.* (1984) conducted extensive study on the germination behaviour of provenances of *A. nilotica* based on 18 treatments comprising 12 provenances of variety "Jcquemontii", three provenances of variety "Vedian", and three provenances of sub species *cupressiformis* was conducted in the seed testing laboratory at Forest Research Institute, Dehradun. The morphological variation and physiological differences, and their effect on germination behaviour of seeds of different varieties and provenances were recorded. They found that out of the various provenances of *A nilotica* var jaquemontil *viz;* Fazilka, Paratwara, Rohtak and Kurukshetra provenances have been proved to be better. Sagwal (1985) also studied the clonal performance of *Acacia nilotica* clones from Himachal Pradesh. Results of a study on growth among 6 years old tree geographic sources of shisham in Pakistan have been reported by Rehman and Hussain (1986). The trial indicated that the average diameter of the trees originating from Chichawatni, Changa Manga and Mardan were 7.1, 7.0 and 6.4 cm, respectively. These preliminary results have shown that generally the trees originating from Chichawatni are significantly better than Mardan.

Chauhan (1987), while studying twenty eight clones of *Populus ciliata* collected from their geographical distribution in the western Himalaya, found high range of diversity with regard to survival percentage, height, trunk diameter, fresh and dry weight, leaf area and overall growth among different provenances.

Shiv Kumar and Banerjee (1986) conducted provenance trials of *Acacia nilotica* and identified variation for height, diameter, number of nodes and branch length. Rehman *et al.* (1988) discussed survival and height growth data of a number of indigenous and exotic tree species and seed sources of *Acacia nilotica* and *Prosopis cineraria* at the nursery stage.

Significant differences were noted between the sources pointing to the possibility of selection of the best seed sources for afforestation in Pakistan.

Madoffe and Maghembe (1988) reported that provenance variation existed for growth characters after seventeen years in teak. They recommended that selection of superior trees be made from all the provenances in order to maintain a broad genetic base for teak in Tanzania. While Puri *et al*. (1989) in a provenance trial identified best, provenances of *Leucaena* for Doon Valley. Ngulube (1989) while conducting provenance trial of *Gliricidia sepium* to evaluate variation within the species, the nursery stage of this trial showed significant differences in seed germination and seedling survival between provenances. He further emphasized the importance of a nursery evaluation phase in provenance-elimination trials, and suggested that useful gains might be obtained in this species by breeding.

Neil (1990) conducted provenance trial of *Dalbergia sissoo* in Nepal after collecting seed material from Nepal and Pakistan, observed small differences among seven provenances of Nepal and large differences between provenances of Nepal vis-a-vis that of Pakistan. Whereas in another study on provenance variation in *Dalbergia sissoo*, significant variation was observed among provenances for seed and pod characters. Variation was higher for seed and pod weight in comparison to seeds per pod, seed length, seed breadth, pod length and pod breadth. Pod length and breadth had no association with seeds per pod, seed length and 100 seed weight (Bangarwa and Singh, 2001).

2.2 Provenance evaluation for Seed Storability and loss of vigor during storage.

Dalbergia sissoo is one of the most important leguminous tree species in India, yielding timber, fuel and fodder. Due to the increasing demand of this species for afforestation purposes, it is highly desirable to utilize good quality seed of this species for mass propagation of vigorous seedlings. The knowledge of genetic variability and association among seed quality traits is considered to provide considerable help in the genetic improvement of the species by way of making available reliable information on nature, extent and direction of selection.

Bangarwa *et al*. (1995) in their study on seed quality parameters in *Dalbergia sissoo* observed that there was a significant differences between progenies for germination after accelerated ageing. Standard germination and tetrazolium tests showed viability above 80 per cent for all the progenies except one. They also found that Vigor index measured when seeds were selected was significantly higher than when seeds were randomly taken.

Kumar and Bangarwa (1996) reported that germination percent of all the progenies in all the four conditions of storage was reduced significantly at an interval of 15 days in stored seeds of *Azadirachta indica.*

Yadav *et al.* (1998) studied that seeds from five trees of shisham (*Dalbergia sissoo)* in each of eight girth classes *viz*., 0-30, 31-60, 61-90, 91-120, 121-150, 151-180, 181-210 and

211-240 cm inside the existing shisham plantation of CCS Haryana Agricultural University, Hisar were subjected to the measurement of seed quality parameters namely, electrical conductivity (µ mhos/cm/seed), germination (%), viability (%), accelerated ageing (%) and vigor index. Highly significant variation was recorded for seed and electrical conductivity among girth classes studied. Seed size gave highly positive correlation with seed germination, viability, accelerated ageing and vigor index. Whereas electrical conductivity was negatively correlated with all the seed quality parameters studied.

Kumar and Bangarwa (2005) in their study on influence of storage period and storage conditions on vigor of Neem, reported that the rate of decrease in seed vigor was higher with the advancement of storage period. The average vigor index-I and vigor index -II were recorded negligible after 60 days of storage. The rate of reduction in vigor indices was highest in cold storage, whereas it was lowest in cloth bag storage at room temperature.

Panwar and Srivastava (2015) conducted a study on seed germination and storage behavior of *Eremostachys superba* and reported that maximum germination percentage was observed in seeds stored at 0-4^{0}C for 6 months (35.15%) as compared to the freshly collected seeds (5.7%).

2.3 PROGENY TESTING

It is necessary to test the progeny for confirming that they possess a good genotvpe and are capable of transmitting their good traits to the progeny (Kedharnath, 1982b).

Considerable variability with regard to crooked or straight bole and growth rate exists in *Dalbergia sissoo* (Vidakovic and Siddiqui, 1968; Vidakovic and Ahsan, 1970). Such variation occurs even in one year old trees so far as the crookedness in stem is concerned, as was evident from a high coefficient of variation for 23 one year old open pollinated progenies. Selection of shisham trees based upon stem form would be profitable as environment has relatively little effect on this trait as compared to growth. Teak seedlings showed no branching up to 3 years (Champion and Seth, 1968). Variability studies and selection for superior tree form can be made on species showing inherent tendencies to form straight bole such as *Tectona, Shorea etc.* (Dogra, 1981).

A study was made by Vidakovic and Siddiqui (1968) about heritability of height and diameter growth in shisham using parent progeny test. A number of plus trees of shisham with an apparent higher growth rate of diameter and height, were selected in 1963. The seeds from these trees were collected in 1966. The plants were grown in rows so that progeny of every mother tree was represented by one or two rows of plants. About 30 to 35 plants were selected at random from progeny of each mother tree. Measurement of progenies were undertaken at the end of the first vegetation period. Calculations of heritability for diameter, height and crookedness were carried out by using regression for parent progeny test.

Heritability for height and diameter was very low whereas for crookedness, the heritability was high.

Therefore, it was suggested to raise progenies from a large number of parent trees under the same environmental conditions and subsequently to carry out intensive selection within and between progenies (Sheikh, 1989).

The results of a study on growth and heritability among 6 years old trees of shisham originating from Pakistan have been reported by Rehman and Hussain in 1986. The results indicated that generally the trees originating from Chichawatani were significantly different from those originating from Mardan. Similar observations have been endorsed by Hussain and Abbas (1974).

In case of teak, half sib analysis was done by Kedharnath *et al*. (1960). They have calculated broad sense heritability for height, girth and number of internodes as 1.00, 0.88 and 0.91, respectively.

Both half sib and full sib progeny trials were laid out for *Bombax* (Venkatesh, 1969). Half sib progeny trials were also conducted for *E. tereticornis, E. camaldulensis*, *E. grandis* (Venkatesh and Vakshasya, 1977; Kedharnath, 1982) and *Santalum album* (Bagchi and Kulkarni, 1987; Bagchi *et al.*, 1987). There were evidences for sufficient genetic variation in mean plant height between families.

Solanki *et al.* (1984) studied variability and heritability for growth parameters in *Prosopis cineraria*. Progenies of different trees showed significant variation and high heritability accompanied by high genetic advance for plant height.

Surendran and Chandrasekharan (1984) studied heritable variation and genetic gain estimates in half sib progenies of *Eucalyptus tereticornis*. Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability estimates and genetic advance as percentage of mean were worked out for eight characters studied in 35 plus trees. The heritability estimates for girth at base, number of branches, leaf breadth and leaf length: breadth ratio were consistent at different stages of growth.

Gupta and Patil (1988) made an investigation of the variation in fodder and fuelwood yield with different plant characteristics in 40 accessions of *L. leucocephala*. The analysis of variance indicated significant differences among the accession for all the characters. Moderate to high estimates of broad sense heritability were observed for most characters.

Dean *et al*. (1988) estimated genetic parameters for height, stem diameter, straightness, internode length and wood density, 5-16 years after planting, in 4 open pollinated progeny tests of hoop pine in Australia. All the traits appeared to be moderately heritable and favorably genetically correlated.

Volker *et al.* (1990) estimated genetic parameters for growth stem form and branch size from measurements made at around six years in seedling seed orchard of *Eucalyptus globulus*. Individual heritability for volume and stem form was moderate.

Jindal *et al.* (1991) studied variability and changes in genetic parameter of height in juvenile progenies of *Tecomella undulata*. Significant differences, among progenies were observed. Heritability and genetic advance showed decreasing trend with increasing age. They also reported the non significant correlation of juvenile height at different stages with mean height of one year old progenies in the field and suggested that selection for height at juvenile stages in nursery may not be effective. Sindhu *et al.* (1990) revealed considerable variability for collar diameter, shoot length and number of leave/seedling between different provenances of Sandal.

Bangarwa (1993) studied the economically important morphological characters (diameter at breast height, total height, main stem height, clear bole height, straightness, crown spread and pod and seed) of *sissoo* trees from 20 diverse sites of Uttar Pradesh, Punjab, Haryana and Rajasthan and put the progenies for progeny testing, results suggested that the best adapted genotypes could be isolated through selection and progeny testing and he also found the characters straightness and main stem height strongly under genetic control. Ample genetic variations were observed for total height, unforked height, clear bole height, basal diameter, and straightness in 43 progenies at the age of 14 months after transplanting (Bangarwa, 2002). The progeny of PT-116, from Dabwali was found extraordinary good with higher values for total height, unforked height, basal diameter and straightness.

Dhillon *et al.* (2003) worked on the genetic variability, heritability, genetic advance and correlation coefficients for growth characters in thirty-six plus trees progenies of Neem and found heritability and genetic advance as percent of mean moderate to high for field emergence, clear stem height, basal diameter and straightness, indicating the effectiveness in selection for these characters for developing productive trees for agroforestry. They also observed positive and highly significant correlation for basal diameter with seedling height, clear stem height and number of branches

An investigation by Devagiri *et al.* (2004) was carried out to obtain genetic information on traits related to seed germination and vigor among different provenances of *Dalbergia sissoo* and estimated the broad sense heritability over 80% for all the traits except for pod width, which was only 3.76%. High heritability coupled with same intensity of genetic gain signified the presence of additive gene effect, which could be reliable for affecting selection.

Gera *et al.,* (2004) studied the genetic variation in seed germination and growth characteristics of eleven different populations of *Albizia procera* for forty months and found

no correlation between seed germination and nursery growth. The relative performance of provenances was consistent throughout the year in field stage.

Costa *et al.,* (2005) studied total height and diameter of thirty progenies of *Leucaena leucocephala* up to 13 months and found low genetic variability with low heritability coefficients (3.38-5.13%) unutilized the traits. Individuals having moderate magnitude of heritability for progenies provide considerable genetic progress from selection and identified the best inbred lines.

While assessing growth performance of 34 progenies of *D. sissoo***,** Dogra *et al.* (2005) found significant differences in height, GBH and clear bole height between the progenies.

Ginwal *et al.* (2005) determined the source variation in *Jatopha curcas* seeds collected from ten locations in central India and observed significant source variation in seed morphology (colour, size and weight), seed germination (viability, germination percentage, germination energy and germination value) and seedling growth parameters (survival percentage, seedling height, collar diameter, leaves/plant and seedling biomass). The phenotypic and genotypic variance, their coefficient of variability and broad sense heritability also showed a sizeable variability.

The pattern of variation in seed characteristics, germination behavior and seedling traits of *Jatropha curcas* was elucidated by Dhillon *et al.* (2008) who found significant variations among all the seed sources. The seed weight was significantly correlated with all the germination indices, plant height and collar diameter. The coefficients of variation, heritability and genetic advance were relatively high for germination and medium for growth traits.

While studying the progenies of thirty-nine plus trees of *Pongamia pinnata,* Hooda *et al.* (2009) observed significant variations among the progenies for germination percentage, shoot and root length, collar diameter and seedling biomass and heritability and genetic advance as percent of mean moderate to high for 100 seed weight, oil and protein contents, collar diameter, root and shoot length, indicating the effectiveness in selection for these characters for developing productive trees. Based on Mahalanobis D^2 analysis, they showed geographical diversity not to have, any direct relationship with genetic diversity.

Kaushik *et al.* (2011) estimated genetic variation in growth traits of progenies of *Pongamia pinnata* L. under rain fed conditions, and differences among progenies were significant for all the growth traits at the age of 4.5 years.

Sofi and Singh (2011) observed large variations for seed germination and nursery growth among families derived from seedling seed orchard of *D. sissoo* at Yamunanagar and they observed significant positive correlation among seed weight, plant height, germination in laboratory and nursery and collar diameter of the species.

Gurunathan *et al.* (2014) conducted a trail on *Pongamia pinnata* and found that shoot length, collar diameter, fresh weight and dry weight had shown significant difference between the sources. Broad sense heritability was highest for rooting (99.58%) followed by fresh and dry weight. Fresh weight showed high genetic advance. The sources Mundara (Tikamgarh) and Khadauli (Agra) performed better in terms of dry matter production as well as rooting.

Thakur and Thakur (2015) conducted a study on variability, heritability, genetic gain, genetic advance and correlation in growth characteristics of progenies of *Melia azedarach* and found the highly significant and positive genotypic and phenotypic correlations for majority of the characters. Plant height had significantly positive genotypic and phenotypic correlation with number of branches (0.85 and 0.82) and collar diameter (0.84 and 0.81) whereas collar diameter showed positive and significant genotypic and phenotypic correlation with number of branches (0.83 and 0.74) and number of leaves (0.70 and 0.65).

Gera *et al.* (2016) conducted a provenance trial of *Dalbergia sissoo* Roxb. and observed that the parameters of diameter, height and volume over bark varied significantly with regard to seed sources, but not with regard to replications.

CHAPTER-III

MATERIALS AND METHODS

The present study on "Genotypic and phenotypic variations in *Dalbergia sissoo* Roxb." comprised of collection of seeds and recording morphological data from different sites (hereafter referred as provenances), seed storability and loss of vigor during storage and provenance cum progeny testing to find extent of genetic variation in juvenile growth and to find out best seed source of *Dalbergia sissoo* Roxb. was conducted in the Department of Forestry, Chaudhry Charan Singh Haryana Agricultural University, Hisar, India. The details of materials and methods adopted are given below:

3.1 Location of Sites (Provenances)

Six sites (Table 3.1) *viz;* Ferozpur from Punjab, Reasi from Jammu and Kashmir, Hanumangarh from Rajasthan, Meerut and Basti from Uttar Pradesh and Udham Singh Nagar from Uttrakhand were selected. Latitude, Longitude and Altitude of six sites (provenances) are given in table: 3.1.

Table 3.1: Details of Sites (Provenances)

Provenance/Site	Accession No.	State	Latitude (^{0}N)	Longitude (^{0}E)
Ferozpur	1-10	Punjab	31°0	75°0"
Reasi	11-20	Jammu & Kashmir	33°0	75°0"
Hanumangarh	21-30	Rajasthan	29°0	75°0"
Meerut	31-40	Uttar Pradesh	29°0	77°5"
Udamsingh Nagar	41-50	Uttrakhand	29°0	80°.0"
Basti	51-60	Uttar Pradesh	27°0	82°.5"

3.2 Experimental material

3.2.1 Pod/Seed collection

Ten trees of *Dalbergia Sissoo* Roxb. were selected at random so as to provide an ample of prevailing variation from natural population of all the six sites during December 2013- February 2014 for studying the phenotypic variation and pod/ seed collection by keeping an isolation distance of about 200 meters from tree to tree. Total tree height (m), diameter at breast height (cm), clean bole height (m), straightness, crown diameter (m), unforked height (m) and approximate age were recorded from all the sixty trees (10×6). Sufficient number of pods were collected from all selected trees for recording pod length, pod breadth, pod weight, seeds per pod, seed weight, seed length, seed breadth, seed thickness, weight of 100 pods, and weight of 1000 seeds and were kept separately. In this way we had pods from 60 trees (10×6) progenies.

3.2.2 Morphological Observations

3.2.2.1 Total height (m)

The total height of standing tree is the perpendicular distance from the top of the shoot to the ground. The total height of the tree was recorded with the help of Ravi's multimeter.

3.2.1.2 Diameter at breast height (cm)

The diameter of the individual tree was recorded with the help of diameter tape, measurements were taken in centimeters at breast height (1.37 m) from the ground level.

3.2.1.3 Clean bole height (m)

Clean bole height is the distance between ground level and crown point. The crown point is the position of the first crown forming branch, living or dead. Clean bole height of all the sampled trees were recorded with the help of a steel tape directly wherever it was feasible while at other places Ravi's altimeter was used for this purpose which gave the height of the clean bole on the stem.

3.2.1.4 Straightness

The individual selected trees were judged for straightness. They were scored subjectively allowing 0 to 5 points, the number of points allowed depend upon the relative straightness of the individual. Thus a tree which contains a slight amount of spiral and slight crook in one place receives zero points while, a perfectly straight individual with no spiral receives 5 points.

3.2.1.5 Crown diameter (m)

It was calculated by measuring the linear distance between two leading side shoots, passing along the stem in horizontal line. Similarly, the length was measured between two similar leading shoots in different directions and at right angle to the previous measurement along the stem in a line. The mean was computed to get the crown spread in meters.

3.2.1.6 Unforked height (m)

The stem height up to the unforked point where main stem remains leading, was recorded by Ravi multimeter.

3.2.1.7 Approximate tree age (Years)

It was determined by consulting the owner, experienced farmers and a team of scientists by visual observation of tree and mean of all the observation was considered the age of tree.

3.2 .2 Observations of pod and seed characters

Seeds were collected during December 2013 to February 2014 from ten individual plus trees of each provenance, keeping the isolation distance of about more than 200 meters. Thus, the trees were selected at random so as to provide a sample of prevailing genetic variation in the population. Sufficient pods of each individual tree were collected and kept separately. Pods were allowed to dry in the in the sun shine and the following observations were recorded.

3.2.2.1 Pod length (cm) and breadth (mm)

Twenty pods per tree in three replications were taken randomly measured with the help of scale and average length and breadth were worked out.

3.2.2.2 Pod Weight (g)

One hundred pods in three replications were taken randomly and weighed on Owalabor Top Pan Electric Balance in grams, up to two decimal points.

3.2.2.3 Seeds per pod

Seeds of one hundred pods in three replications were extracted counted and average seed number per pod was worked out.

3.2.2.4 Seed Weight (g)

One hundred seeds in three replications were weighed per replication on Owalabor top pan electric balance in grams from each provenance and mean was calculated.

3.2.2.5 Seed length and breadth (mm)

Length and breadth of individual seed was recorded of the ten randomly selected seeds in three replications with the help of Vernier Caliper and the size was calculated by multiplying length and breadth separately and expressed in square millimeter.

3.2.2.6 Seed thickness (mm)

Ten randomly selected seeds in three replications were taken and measured with the help of Vernier Caliper.

3.2.2.7 Weight of 100 pods (g)

One hundred pods in three replications were taken randomly and weighed on Owalabor Top Pan Electric Balance in grams, up to two decimal points.

3.2.2.8 Weight of 1000 seeds (g)

One thousand seeds in three replications were taken randomly and weighed on Owalabor Top Pan Electric Balance in grams, up to two decimal points.

3.3 Provenance evaluation for seed storability and loss of vigor during storage

Seeds collected from all the ten trees from each provenance sites were composited. In this way, six composite lots arising from six sites were stored for 18 months at room temperature. The seed quality tests were conducted in laboratories of Department of Seed science & Technology and Department of Forestry, Ch.Charan Singh Haryana Agricultural University, Hisar. The various tests were applied to all the six provenances and the following observations were recorded.

3.3.1 Moisture content (%)

This was calculated by low constant temperature oven method by keeping the sample for 17 hours at temperature of 103^0C, and then the following formula was used;

$$\text{SMC (\%)} = \frac{\text{Loss in weight}}{\text{Weight of working sample}} \times 100$$

3.3.2 Seed viability (Tetrazolium test)

The tetrazolium viability test (Moore, 1985) based on three replications of 50 seeds each was followed. The seeds were moistened for 16 h at room temperature. After peeling off seed coat, seeds were stained in 0.5 per cent tetrazolium chloride, pH 7.0 for 4-5 h at 38°C. The seeds stained completely red were considered as viable seeds and expressed in percentage.

3.3.3 Electrical conductivity (dSm^{-1})

After soaking 50 seeds in 75 ml of distilled water for 24 hours, the electrical conductivity of soaked solution was determined.

3.3.4 Standard germination test (Vigour Index)

Three replications with 50 seeds per replication for each lot were placed on moistened rolled towel papers (B.P) at $28C^0$ with 90-95 per cent RH in the seed germinator. First count of normal seedlings was recorded on fourth day and final count on tenth day (ISTA, 1985) and normal seedlings were expressed as percent germination.

3.3.4.1 Seed vigor index-I

It was calculated by the given formula;

Vigor Index = Standard germination (%) × Seedling length (cm)

3.3.4.2 Seed vigor index-II

It was calculated by the following formula;

Vigor Index = Standard germination (%) × Seedling dry wt (mg)

3.4 Provenance cum Progeny Testing

3.4.1 Experimental Site/Layout

The site of the experiment was Nursery Area of Department of Forestry, Chaudhry Charan Singh Haryana Agricultural University Hisar (29^0 N latitude and 75^0.46'E longitude

and with an altitude 215 m). The climate of Hisar consists of three distinct seasons *i.e* hot and dry summer from April to June with maximum and minimum temperature of 47°C and 30°C, respectively, which is followed by rainy season from July to October with maximum and minimum temperature of 40°C and 25°C, respectively and winter season which extends from November to March with maximum and minimum temperatures of 28°C and 5°C respectively. The average annual rainfall usually occurs 400 mm. The 70-80 per cent of total rainfall occurs during monsoon season from July to September.

3.4.2 Layout of Experiment

The seeds of all the 60 progenies arising from six geographical sites (provenances) were grown in nursery area of Department of Forestry, Chaudhary Charan Singh Haryana agricultural University, Hisar during second, week March 2014. Raised beds were prepared of 0.50 meter in width, 4.0 meter in length and 0.25 meter in height. Hundred seeds of each progeny were sown in three replication in lines spaced 10 centimeters apart, seed to seed distance was 5.0 centimeter and placed at a depth of 1.5 centimeter and then covered with thin layer of fine soil. The beds were irrigated soon after the sowing and were kept moist by sprinkling with the help of garden sprinkler. No chemical fertilizer was applied to the seedlings. Weeding of the nursery beds were under taken as and when considered necessary to keep the growing seedling free from weeds. Germination percentage was observed by counting the number of seeds successfully germinated under each replication. At the end of first and second growing season, following observations were recorded:

3.4.1.4 Shoot length (cm)

Shoot length was recorded in centimeter from the ground level to the apical bud of the leading shoot. It was measured by meter rod or marked pole. The shoot length is written as total height.

3.4.1.5 Unforked height (cm)

Height up to main shoot to first branch of the seedling first branch was recorded in centimeters from the base of the.

3.4.1.6 Clear bole height (cm)

Clear bole was measured in centimeters from ground level up to the unbranched stem. It is written as Basal diameter.

3.4.1.7 Root length (cm)

Root length was measured in centimeters with the help of measuring tape after digging out the seedling from the ground.

3.4.1.8 Fresh weight (g)

Fresh weight of each individual sapling was recorded in grams at the time of final observation. It was measured by digital balance.

3.4.1.9 Dry weight (g)

Dry weight in grams was taken after sun drying of seedling with the help of digital weighing balance up to two decimal points.

3.4.1.10 Total biomass (g)

Total fresh weight and oven dried weight of the shoot; root, seed and pod were measured in weighing balance for each sample at the time final observation. The average mass of each sample was calculated per unit area.

3.4.1.11 Plant straightness

The individual selected trees were judged for straightness. They were scored subjectively allowing 0 to 5 points, the number of points allowed depend upon the relative straightness of the individual. Thus, a tree which contains a slight amount of spiral and slight crook in one place, receives zero points while a perfectly straight individual with no spiral receives 5 points.

3.4.1.12 Root weight (g)

Root was separated from the shoot part and each sample was measured in gram.

3.4.1.13 Shoot weight (g)

Shoot were separated from the root part and each sample were measured in gram at the time of final observation

3.4.1.14 Index score analysis

Index score analysis was carried out in sixty progenies of *Dalbergia sissoo* from six provenances by using data for different characters *viz* plant height, basal diameter, unforked height, clear bole height, root length, fresh weight, total biomass, plant straightness, root weight, shoot weight and dry weight. One, two, and three index scores were given to various classes of plant height, basal diameter, unforked height, clear bole height, root length, fresh weight, total biomass, plant straightness, root weight, shoot weight and dry weight.

3.5 Statistical Analysis

To study the phenotypic and genotypic variations in the *Dalbergia sissoo* Roxb., the statistical analyses of the data obtained during the course of investigation was done by following statistical models given as under:

3.5.1 Analysis of variance (ANOVA)

Analysis of variance was carried out as per the procedure given by Panse and Sukhatme (1967) using the mean values of random plants in each replication from all treatment to find out the significance of treatment effect.

Sources of variation	Degrees of freedom	MSS	F-ratio
Replication	r-1	MSSr	MSSt/MSSe
Treatment	k-1	MSSt	
Error	(k-1) (r-1)	MSSe	
Total	Kr-1		

Where,

r = number of replications

k = number of genotypes

MSSr, MSSt and MSSe = Mean sum of squares for replication, treatment and error, respectively

3.5.2 Estimation of Genetic variability parameters

3.5.2.1 Mean

On the basis of individual plant observations, the mean for each character in all the populations was computed as follows.

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i$$

Where

$\bar{X}$ = Sample mean Sample mean

X_i – Individual value

n = Number of observations

3.5.2.2 Range

The minimum and maximum value on the basis of individual plant observations was used to indicate the range for a given character.

3.5.2.3 Variance

In all the populations, variance was computed for all the characters as follows.

$$\text{Variance} = \frac{1}{n-1} \sum (Y_i - \bar{Y})^2$$

Where,

Y_i = Individual value

$\bar{Y}$ = Population mean

n = Number of observations

3.5.2.4 Standard deviation (SD) = $\sqrt{\text{Variance}}$

Where,

d = Deviation of individual value from population mean

n= Number of observation

$$\text{Standard error (SE)} = \frac{SD}{\sqrt{n}}$$

3.5.2.5 Critical difference

Critical difference for all the characters was calculated to compare the treatment means. Critical difference was calculated with the help of standard error for the difference of two means and tabulated value‘t’ at 5 per cent level of significance for error degree of freedom.

CD. = S. Ed × 't' at 5% error degree of freedom.

3.5.2.6 Estimation of variance

Genotypic, phenotypic and environmental variance

The variance due to genotype, phenotype and environmental were computed as follows.

$$\text{Genotypic variance } (\sigma^2 g) = \frac{\text{Treatment MSS} - \text{Error MSS}}{r}$$

$$\text{Phenotypic variance } (\sigma^2 p) = \sigma^2 g + \sigma^2 e$$

Where,

'r' is number of replications

3.5.2.7 Coefficient of variability

The coefficient of variation being a standardized form of variance is useful for comparing the extent of variance between different characters with different scales. Genotypic and phenotypic coefficients of variation were estimated according to Burton (1952) based on the estimate of genotypic and phenotypic variance.

$$\text{Genotypic coefficient of variability (GCV \%)} = \frac{\sigma^2 g \text{ X } 100}{\bar{X}}$$

$$\text{Phenotypic coefficient of variability (PCV \%)} = \frac{\sigma^2 p \text{ X } 100}{\bar{X}}$$

Where,

$\bar{X}$ = General mean

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

The genotypic and phenotypic coefficient of variation was categorized by Sivasubramanian and Menon (1973) as,

0-10% = Low

10-20% = Moderate

>20% = High

3.5.2.8 Heritability

Heritability in broad sense was calculated as the ratio of genotypic variance to the phenotypic variance and expressed in percentages (Falconer, 1981).

$$\text{Heritability } (h^2) = \frac{\sigma^2 g}{\sigma^2 p} \text{ X } 100$$

The calculated heritability was classified into three groups as suggested by Johnson *et al.*, (1955);

0-30% = Low, 30-60% = Moderate and > 60% = High

3.5.2.9 Expected genetic advance (GA)

Genetic advance as per cent mean of each character was worked out by adopting the following formula given by Johnson *et al.* (1955).

$$GA = k \text{ X } h^2 \text{ X } \sqrt{\sigma^2 p}$$

Where,

h^2 = Heritability in broad sense

k = Selection differential which is equal to 2.06 at 5 per cent intensity of selection (Lush, 1949)

$\sqrt{\sigma^2 p}$ = Phenotypic standard deviation

3.5.2.10 Genetic advance as per cent of mean (GAM)

Genetic advance as percentage over mean worked as suggested by Johnson *et al.* (1955).

$$GAM = \frac{GA}{\bar{X}} \text{ X } 100$$

Where,

GA = Genetic advance

$\bar{X}$ = General mean

Genetic advance as per cent of mean was categorized as follows (Johanson *et al.*, 1955).

0-10 % = Low

10-20 % = Moderate

>20 % = High

Table 3.2: Weather data of Hisar during the year 2014 and 2015

Monthly data 2014											
MONTH	**MAX**	**MIN**	**GMIN**	**AVP**	**AVP**	**RH**	**RH**	**AVG**	**BRI**	**PAN**	**RAIN**
	TEMP	**TEMP**	**TEMP**	**(mm)**	**(mm)**	**(%)**	**(%)**	**WS**	**SUN**	**EVAP**	**FALL**
	°C	**°C**	**°C**	**M**	**E**	**M**	**E**	**KM/H**	**HRS**	**(mm)**	**(mm)**
JAN	18.0	5.6	2.0	7.7	10.0	97	69	3.3	4.0	1.0	2.0
FEB	20.8	7.6	3.6	8.8	11.8	95	67	4.2	6.0	1.7	12.5
MAR	25.2	11.5	8.1	11.4	13.5	92	58	4.4	6.8	2.8	47.0
APR	33.7	17.0	1.4	14.1	13.3	73	35	5.2	9.3	5.6	16.4
MAY	38.4	22.2	0.0	16.8	14.1	66	30	6.1	9.3	7.2	56.5
JUN	41.0	26.3	0.0	19.1	18.1	61	34	7.4	8.4	8.8	71.6
JUL	37.4	27.5	0.0	23.5	22.2	77	51	7.5	6.7	7.0	74.6
AUG	36.4	26.3	0.0	23.4	22.2	80	52	6.2	7.6	5.8	34.2
SEP	34.7	23.8	0.0	21.6	20.1	84	52	6.5	7.9	4.9	81.5
OCT	33.2	18.5	0.0	16.0	14.1	84	39	3.8	8.2	3.8	21.3
NOV	28.2	10.2	0.0	9.6	9.1	84	32	2.3	7.2	2.8	0.0
DEC	19.5	6.0	2.0	7.8	8.8	96	61	2.7	4.8	1.2	9.0
Monthly data 2015											
MONTH	**MAX**	**MIN**	**GMIN**	**AVP**	**AVP**	**RH**	**RH**	**AVG**	**BRI**	**PAN**	**RAIN**
	TEMP	**TEMP**	**TEMP**	**(mm)**	**(mm)**	**(%)**	**(%)**	**WS**	**SUN**	**EVAP**	**FALL**
	°C	**°C**	**°C**	**M**	**E**	**M**	**E**	**KM/H**	**HRS**	**(mm)**	**(mm)**
JAN	16.2	6.0	3.1	7.7	9.7	97	73	3.5	3.3	1.0	15.4
FEB	23.5	9.6	7.1	9.9	11.6	91	54	5.0	6.2	2.1	12.2
MAR	26.5	12.4	10.1	12.7	13.1	92	54	4.6	7.2	3.2	121.1
APR	34.0	19.2	0.0	15.1	13.0	72	35	6.0	8.9	5.3	91.1
MAY	40.4	23.0	0.0	16.0	13.1	58	26	6.3	9.1	8.2	0.0
JUN	38.2	24.6	0.0	20.8	19.6	71	47	7.2	7.6	7.4	151.3
JUL	35.1	26.2	0.0	24.3	24.2	85	61	7.7	6.4	5.5	164.5
AUG	34.2	25.9	0.0	24.7	24.5	89	65	7.2	5.6	4.9	48.6
SEP	36.0	23.2	0.0	19.8	18.8	77	43	5.8	8.5	5.5	19.1
OCT	35.1	19.1	0.0	15.8	13.1	79.6	32.7	4.1	8.8	4.8	15.2
NOV	28.2	12.8	0.0	11.6	10.9	90.2	38.1	2.3	6.0	2.2	0.0
DEC	23.3	7.3	1.3	8.6	9.8	96.2	46.7	2.4	5.3	1.4	0.0

CHAPTER – IV

RESULTS

Present study was resolved into three broad experiments as per the objectives of the study. Accordingly, the results obtained have been presented under three different heads (4.1, 4.2, & 4.3).

4.1 Extent of phenotypic variation in various geographic sites

4.1.1 Phenotypic Variation

4.1.1.1 Morphological characters of trees in various provenances

The data on various morphological characters of all the selected trees were recorded at the time of seed collection in order to study the naturally occurring phenotypic variation. Data recorded were compiled and analysed statistically. The mean, range and coefficient of variation for various morphological characters are presented in Table 4.1 and illustrated in the Figure 4.1.

Total height (m)

The height of trees ranged from 8.0 to 19.2 m with mean value of 14.40 m and coefficient of variation of 20.7 per cent. Highest coefficient of variation for height was observed at Udhamsingh Nagar (31.4 percent) followed by Meerut (20.6 per cent). The minimum average height was observed in Hanumangarh (12.45 m) provenance. The maximum average height was observed at Reasi followed by Ferozpur and Basti provenances.

Diameter at breast height (DBH)

Diameter at breast height (DBH) varied from 20.0 to 58.0 cm with mean value of 38.4 cm and coefficient of variation of 25.67 per cent. The highest coefficient of variability was observed at Basti (46.5%) provenance with mean value of 40.5 cm followed by Udhamsingh Nagar and Meerut provenances. The lowest coefficient of variation (11.7%) was seen in Ferozpur provenance.

Clear bole height (m)

Clear bole height ranged from 2.2 to 5.6 m with mean value of 4.25 m and coefficient of variation 24.78 per cent. Maximum mean value of clear bole height was observed at Udhamsingh Nagar (4.35 m) provenance followed by Ferozpur and Meerut provenances. The maximum coefficient of variability for clear bole height was observed at Ferozpur (32.4 percent) provenance.

Table 4.1: Phenotypic variation for morphological characters in various provenances in *Dalbergia sissoo*

Provenance	Parameter	Total height (m)	Diameter at breast height (cm)	Clear bole height (m)	Straightness	Crown diameter (m)	Unforked height (m)	Approximate age (yr.)
Ferozpur	**Mean**	15.45	34.0	4.3	2.33	7.55	6.9	27.00
	Range	13.5-17.4	30.0-38.0	3.2-5.4	2.0-5.0	6.8-8.3	5.2-8.7	22-32
	CV	11.2	11.7	32.4	40.23	15.6	21.7	13.31
Reasi	**Mean**	16.2	32.0	3.9	3.5	9.55	5.8	32
	Range	13.2-19.2	28.0-36.0	2.2-5.6	2.0-5.0	7.6-11.5	3.8-7.8	27-37
	CV	18.9	12.78	27.5	40.3	22.7	30.34	7.75
Hanumangarh	**Mean**	12.45	53.0	4.0	3.0	12.75	8.5	29.5
	Range	11.7-13.2	48.0-58.0	3.2-4.8	1.5-4.5	9.2-16.3	5.5-11.5	27-32
	CV	8.9	11.9	19.7	20.7	22.6	27.8	8.98
Meerut	**Mean**	15.8	35.5	4.3	3.25	5.00	8.7	29.5
	Range	12.4-19.2	26.0-45.0	3.7-4.9	1.9-4.6	4.2-5.8	5.0-12.4	22-37
	CV	20.6	20.3	9.5	28.2	11.9	28.6	13.98
Udhamsingh Nagar	**Mean**	12.5	33.0	4.35	3.95	5.05	10.9	37
	Range	8.0-17.0	20.0-46.0	3.1-5.6	3.2-4.7	2.5-7.6	5.5-16.3	32-42
	CV	31.4	32.6	24.8	16.9	34.8	39.79	11.37
Basti	**Mean**	13.75	40.5	3.3	2.8	6.0 0	8.05	27
	Range	10.8-16.7	23.0-58.0	2.4-4.2	1.0-4.6	3.8-8.2	5.2-10.9	22-32
	CV	17.6	46.5	27.67	42.09	29.6	27.6	9.80
Overall	**Mean**	14.40	38.4	4.25	3.22	7.70	8.15	30.33
	Range	8.0-19.2	20.0-58.0	2.2-5.6	1.0-5.0	2.5-16.3	3.8-16.3	22-42
	CV	20.7	25.67	24.78	30.89	28.90	35.76	9.34

Straightness

A wide range of variability was observed for stem straightness. Tree straightness varied from 1.0 (crooked or least straight) to 5.0 (completely straight). Maximum coefficient of variability for straightness was observed at Basti (42.09 per cent) provenance followed by Reasi and Ferozpur provenances. The mean values for straightness were highest at Udhamsingh Nagar (3.95) followed by those at Reasi and Meerut (3.6) provenances. The trees having straightness value of 5.0 were observed at Ferozpur and Reasi provenances.

Crown diameter (m)

Crown diameter varied from 2.5 m to 16.3 m with mean value of 7.70 m and coefficient of variation of 28.90 per cent. The largest crown diameter was found in Hanumangarh provenance followed Reasi and Ferozpur, whereas minimum crown diameter was observed in Udhamsingh Nagar.

Unforked height (m)

The highest values for unforked height was observed at Udhamsingh Nagar (16.3 m) provenance followed by Meerut (12.4 m) and Hanumangarh (11.5 m) provenances. The highest mean value of unforked height was observed at Udhamsingh Nagar (10.9 m) provenance followed by Meerut (8.7 m) and Hanumangarh (8.5 m) provenance. The highest coefficient of variation (39.79 per cent) was observed in Udhamsingh Nagar followed by Reasi (30.34 per cent) provenance.

Approximate age (years)

The range of age was 22 to 42 years. The maximum age (42 yrs.) was found in Udhamsingh Nagar provenance followed by Reasi and Meerut provenances. The highest coefficient of variation (13.98 per cent) was found in Meerut provenance followed by Ferozpur and Udhamsingh Nagar provenances.

Correlation coefficient among various tree characters in different provenances in *Dalbergia* sissoo Roxb.

The correlation coefficient among various morphological characters were estimated and presented in Table 4.2. Total height was found significantly correlated with all the characters viz., diameter at breast height, clear bole height, straightness, crown diameter and unforked height.

Table 4.2: Simple correlation coefficient among various tree characters in *Dalbergia sissoo*

	Total height (m)	D.B.H (cm)	C.B.H. (cm)	Straightness	Crown diameter (m)	Unforked height (m)	Approximate age (yr.)
Total height (m)							
D.B.H (cm)	0.600**						
C.B.H. (cm)	0.812**	0.846**					
Straightness	0.444**	0.324^{**}	0.387^{**}				
Crown diameter (m)	0.761**	0.736**	0.678**	0.376^{**}			
Unforked height (m)	0.423**	0.579**	0.678**	0.473**	0.398**		
Approximate age (yr.)	0.587**	0.490**	0.464**	0.234^{NS}	0.567**	0.587**	

At ** 1 % significant level

4.1.1.2 Provenance evaluation for seed and pod characters in *Dalbergia sissoo*

The data on seed characters with respect to coefficient of variability, heritability and genetic advance, provenance variation for pod and seed characters has been presented in Tables 4.3-4.4.

Provenance variation for pod and seed characters

The mean values for seed and pod characters of all the six provenances are presented along with CD in Table 4.3 The phenotypic coefficient of variation (PCV) for seed and pod characters varied from 13.27% for pod breadth to 31.80% for seeds per pod. Regarding genotypic coefficient of variation (GCV), almost similar trend was observed. The differences between PCV and GCV were observed low for all the seed and pod characters. Heritability estimates in broad sense were higher than 57.80% for all the seed and pod characters. The genetic advance as percentage of mean ranged from 12.90% for weight of 100 pods to 42.10% for the weight of 1000 seeds. Simultaneous consideration of all the parameters of variability (Table 4.4) indicated that the seed and pod characters had higher proportion of variation as heritable in natural populations of *Dalbergia sissoo*.

Pod length (cm)

Maximum pod length (5.21 cm) was observed in Basti provenance followed by 5.09 cm and 4.99 cm in Meerut and Ferozpur provenances, respectively. The lowest pod length (4.90 cm) was observed in Udhamsingh nagar provenance (Table 4.4).

Pod breadth (mm)

Maximum pod breadth (8.14 mm) was observed in Udhamsingh Nagar provenance followed by 8.04 mm and 7.91 mm in Basti and Ferozpur provenances, respectively. The lowest pod breadth of 7.34 mm was observed in Hanumangarh provenance.

Pod weight (g)

The overall mean population for this character was 0.070 g. The maximum pod weight of 0.077 g was reported in Basti provenance followed by Hanumangarh (0.070 g) and Udamsingh nagar (0.007 g) respectively. The minimum (0.066 g) pod weight was observed in Ferozpur provenance.

Weight of 100 pods (g)

The mean weight of 100-dry pods was found 7.03 g. The maximum pod weight of 7.72 g was observed in Basti provenance followed by Udamsingh Nagar and Hanumangarh provenances.

Seeds per pod

Average number of seeds per pod ranged from 1.2 (Ferozpur and Meerut provenance) to 1.6 (Basti provenance). Lower number of seeds per pod indicated the predominance of single seeded pods. The highest number of seeds were observed in Basti provenance (1.6) followed by Udamsingh Nagar (1.5) and Reasi (1.4).

Seed weight (g)

The overall population mean for seed weight was observed 0.017g. The maximum weight (0.019 g) per seed was found in Ferozpur and Basti provenances followed by Udhamsingh Nagar (0.018 g) and Reasi (0.018 g) provenances.

Seed length (mm)

The maximum seed length of 7.41 mm was found in Basti provenance, whereas a minimum of 6.58 mm of seed length was observed in Hanumangarh provenance.

Seed breadth (mm)

The population mean for this character was found 4.11 mm. The maximum seed breadth (4.42 mm) was found in Ferozpur provenance followed by Reasi, Meerut and Udamsingh nagar provenances. The minimum seed breadth of 3.61 mm was observed in Hanumangarh provenance.

Seed thickness (mm)

The maximum (0.59 mm) seed thickness for this character was found in Basti provenance followed by Reasi (0.58 mm) and Hanumangarh (0.58 mm) provenances.

1000 seed weight (g)

The overall population mean for 1000 seed weight was 18.28 g. The maximum weight for this character (19.40 g) was found in Basti provenance followed by Ferozpur (19.10 g), Udamsingh nagar (18.59 g) and Reasi (18.09 g) provenances.

Coefficient of variability, heritability and genetic advance for pod and seed characters

The data on phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), mean, heritability estimates and genetic advance in percent of mean have been presented in Table 4.3. The magnitude of phenotypic coefficient of variability was higher than the corresponding genotypes for all the characters.

Pod length (cm)

The overall population mean for pod length was 5.00 cm. The genotypic and phenotypic coefficients of variation were 12.37 and 15.62 per cent. The heritability for pod length was observed to be 86.70 percent and the value of genetic advance (% of mean) for pod length was 28.91. This indicates that there may be scope for improvement in this trait through selection. These results suggested that the natural population of *Dalbergia sissoo* has a lot of potential for genetic improvement.

Pod breadth (mm)

The mean value for pod breadth was observed as 7.80 mm. The genotypic and phenotypic coefficients of variation were 10.27 and 13.27 per cent respectively. The heritability for pod breadth was 83.20 percent. The percent gain for pod length was 16.28 per cent.

Pod weight (g)

The population mean for pod weight was found 0.07 g. The GCV and PCV were 11.28 and 14.23 per cent, respectively. The heritability for pod weight was 81.20 per cent. The per cent gain for pod weight was 27.10.

Seeds per pod

The mean value for seeds per pod was observed 1.38. The GCV and PCV were 18.92 and 31.80 per cent, respectively. The heritability for seeds per pod was 66.34 per cent. The genetic advance as percentage of mean was 24.78.

Seed weight (g)

The overall population mean for seed weight was 0.17 g. The GCV and PCV were 11.39 and 14.87 per cent, respectively. The heritability observed for seed weight was 57.80 per cent and per cent gain was 32.89.

Seed length (mm)

The overall population mean for seed length was 7.07 mm. The magnitude of GCV and PCV were 12.40 and 14.50 percent, respectively. The heritability for seed length was observed 84.87 percent and percent gain was 26.56.

Seed breadth (mm)

The overall population mean for seed breadth was 4.11 mm. The GCV and PCV were 10.90 and 17.80 percent, respectively. The heritability was 67.80 percent and percent gain was 17.12.

Seed thickness (mm)

The population mean for seed thickness was 0.57 mm with coefficient of variation 2.28. The magnitude of GCV and PCV were 17.78 and 21.29 percent, respectively. The heritability seed thickness was 82.20 percent. The percent gain was 37.20.

Weight of 100 pods (g)

The population mean for this character was 7.03 g. The GCV and PCV were 12.20 and 16.70 percent, respectively. The heritability was 86.78 percent. The percent gain was 12.90.

Weight of 1000 seeds (g)

The overall population mean for this character was 18.28 g. The GCV and PCV were 22.57 and 26.70 percent, respectively. The heritability for weight of 1000 seeds was 90.12 percent. The percent gain was 42.10.

Table 4.3: Provenance variation for seed and pod characters in *Dalbergia sissoo*

Provenance code	Pod characters				Seed characters					
	Pod length (cm)	**Pod breadth (mm)**	**Pod weight (g)**	**Wt. of 100 pods (g)**	**Seeds per pod**	**Seed weight (g)**	**Seed length (mm)**	**Seed breadth (mm)**	**Seed thickness (mm)**	**Wt of 1000 seeds (g)**
Ferozpur	4.99	7.91	0.066	6.62	1.2	0.019	7.13	4.42	0.57	19.10
Reasi	4.91	7.51	0.069	6.95	1.4	0.018	7.00	4.25	0.58	18.09
Hanumangarh	4.92	7.34	0.070	7.03	1.4	0.016	6.58	3.61	0.58	16.71
Meerut	5.09	7.86	0.068	6.84	1.2	0.017	7.17	4.15	0.56	17.81
Udhamsingh Nagar	4.90	8.14	0.070	7.04	1.5	0.018	7.15	4.13	0.55	18.59
Basti	5.21	8.04	0.077	7.72	1.6	0.019	7.41	4.08	0.59	19.40
Mean	5.00	7.80	0.07	7.03	1.38	0.017	7.07	4.11	0.57	18.28
CV	9.25	16.12	4.67	19.22	9.11	6.00	13.53	19.00	2.28	19.81
CD at 5%	0.51	0.60	0.006	0.92	0.13	0.011	0.10	0.16	0.07	0.65

Table 4.4: Coefficient of variance, heritability and genetic advance for pod and seed characters in *Dalbergia sissoo* Roxb

Name of character	Genotypic Coefficient of Variation	Phenotypic Coefficient of Variation	Heritability	GA%	GAM
Pod length (cm)	12.37	15.62	86.70	28.91	5.00
Pod breadth (mm)	10.27	13.27	83.20	16.28	7.80
Pod weight (g)	11.28	14.23	81.20	27.10	0.07
Seeds per pod	18.92	31.80	66.34	24.78	1.38
Seed weight/seed (g)	11.39	14.87	57.80	32.89	0.17
Seed length (mm)	12.40	14.50	84.87	26.56	7.07
Seed breadth (mm)	10.9	17.80	67.80	17.12	4.11
Seed thickness (mm)	17.78	21.29	82.20	37.20	0.57
Weight of 100 pods (g)	12.20	16.70	86.78	12.90	7.03
Weight of 1000 seeds (g)	22.57	26.70	90.12	42.10	18.28

4.2 Provenance evaluation for seed storability and loss of vigor during storage

Seeds collected from all the ten trees from each of six sites (provenances) were composited. In this way, six composite seed lots arising from six sites (provenances) were stored for 18 months at ambient temperature. The moisture content, seed viability (Tetrazolium test), electrical conductivity, standard germination, seed vigour index-I and seed vigour index-II were worked for the seeds collected from all the six provenances for 18 months at an interval of three months in laboratories of Department of Seed science & Technology and Department of Forestry, Chaudhary Charan Singh Haryana Agricultural University, Hisar. The data for all seed quality parameters was statistically analyzed and presented along with CD at 5% in Table 4.5-4.10.

Moisture content (%)

The data presented in the Table 4.5 revealed that the moisture content decreased significantly during first three months of storage and thereafter, increased significantly in all the provenances from three months of storage to six months of storage. The moisture contents of seeds from all the provenances increased significantly during winter months during both the years.

Seed viability (Tetrazolium test)

The data presented in Table 4.6 revealed that the seed viability decreased significantly with the advancement of storage in all the provenances. The maximum initial seed viability of 94.70% was observed in Udhamsingh Nagar provenance followed by Reasi provenance (92.60%). The reduction in seed viability was observed comparatively more in Udhamsingh Nagar provenance and lesser in Basti provenance.

Electrical conductivity (dSm^{-1})

It was observed that the electrical conductivity as in Table 4.7, increased with the advancement of storage period in all the provenances. The electrical conductivity of seeds from all the six provenances increased significantly in 12-15 months of storage period. The highest initial electrical conductivity (0.355) was observed in Basti provenance followed by Meerut provenance (0.327).

Standard germination (%)

The data presented in Table 4.8 revealed that standard germination decreased with the advancement of storage period in seeds of all the six provenances under study. Seeds of all the provenances showed initial germination percentage of more than 82 per cent and germination after the 18 months of storage was also more than 75% in all the provenances. Germination percent of all the provenances decreased significantly after nine months of storage period.

Table 4.5: Effect of storage period on moisture content in seeds of six provenances of *Dalbergia sissoo.*

Provenance	**Storage period (Months after storage)**							
	Fresh (Feb., 2014)	3 (May,2014)	6 (August,2014)	9 (Nov.,2015)	12 (Feb.,2015)	15 (May,2015)	18 (August,2015)	**CD at 5 %**
Ferozpur	6.60	6.36	6.72	6.58	6.62	6.12	6.47	0.21
Reasi	7.20	6.70	6.95	7.15	7.35	6.76	7.12	0.23
Hanumangarh	6.68	6.41	6.78	6.65	6.70	6.16	6.70	0.26
Meerut	6.72	6.52	6.89	6.86	6.92	6.28	6.51	0.14
Udhamsingh Nagar	6.92	6.66	6.95	7.10	7.46	6.86	7.15	0.24
Basti	6.46	6.11	6.40	7.33	6.98	6.67	6.91	0.25
Mean	6.76	6.46	6.78	6.94	7.00	6.47	6.81	
CD at 5%	0.18	0.13	0.17	0.23	0.15	0.16	0.19	

Table 4.6: Effect of storage period on seed viability (TZ test) in seeds of six provenances of *Dalbergia sissoo*

Provenance	**Seed viability (%)**							**CD at 5%**
	Fresh (Feb.,2014)	3 (May,2014)	6 (August,2014)	9(Nov.,2015)	12 (Feb.,2015)	15 (May,2015)	18 (August,2015)	
Ferozpur	90.00 (78.2)	88.00 (70.1)	86.70 (69.40)	86.30 (69.30)	85.60 (67.60)	84.20 (66.20)	82.90 (66.90)	1.90
Reasi	92.60 (75.6)	91.10 (73.10)	91.20 (72.18)	86.70 (68.70)	83.60 (63.60)	81.80 (64.80)	80.90 (62.70)	1.40
Hanumangarh	88.30 (71.3)	86.90 (69.90)	86.10 (68.10)	85.60 (67.60)	85.20 (67.20)	83.10 (64.10)	79.30 (61.30)	1.67
Meerut	85.10 (66.10)	84.20 (65.20)	83.40 (66.40)	82.30 (65.30)	80.70 (67.70)	84.20 (66.20)	77.80 (60.40)	1.71
Udhamsingh Nagar	94.70 (76.70)	93.30 (75.30)	91.90 (73.90)	90.70 (78.70)	84.80 (66.80)	84.10 (67.10)	81.30 (66.50)	1.30
Basti	86.60 (70.60)	84.80 (66.80)	83.80 (64.80)	83.00 (64.00)	82.30 (65.30)	81.20 (65.20)	80.10 (64.10)	2.03
Mean	89.55 (71.55)	88.75 (72.75)	87.18 (73.18)	85.76 (67.76)	83.70 (64.70)	83.10 (65.10)	80.38 (64.45)	
CD at 5 %	3.34	3.87	3.25	2.46	2.01	1.57	2.87	

The values mentioned in the parenthesis are angular transformed values

Table 4.7: Effect of storage period on Electrical Conductivity (dSm^{-1}) in seeds of six provenances of *Dalbergia sissoo*

Provenance	**Electrical Conductivity(dSm^{-1})**							**CD at 5%**
	Fresh (Feb.,2014)	3 (May,2014)	6 (August,2014)	9(Nov.,2015)	12(Feb.,2015)	15(May,2015)	18(August,2015)	
Ferozpur	0.319	0.325	0.332	0.338	0.348	0.352	0.358	0.23
Reasi	0.308	0.312	0.318	0.321	0.329	0.335	0.339	0.18
Hanumangarh	0.318	0.323	0.330	0.336	0.342	0.350	0.358	0.34
Meerut	0.327	0.333	0.340	0.343	0.351	0.360	0.364	0.27
Udhamsingh Nagar	0.304	0.309	0.315	0.323	0.328	0.336	0.343	0.26
Basti	0.355	0.362	0.368	0.375	0.383	0.391	0.398	0.19
Mean	0.32	0.33	0.33	0.34	0.35	0.35	0.36	
CD at 5%	0.023	0.027	0.031	0.023	0.018	0.033	0.035	

Table 4.8: Effect of storage period on germination in seeds of six provenances of *Dalbergia sissoo*

Provenance	**Storage period (Months after storage)**							**CD at 5%**
	Fresh (Feb.,2014)	3 (May,2014)	6 (August,2014)	9(Nov.,2015)	12(Feb.,2015)	15(May,2015)	18(August,2015)	
Ferozpur	85.8 (78.2)	84.4 (66.2)	83.6 (64.8)	83.1 (62.9)	82.7 (61.2)	80.6 (59.4)	76.8 (55.2)	2.18
Reasi	90.1 (82.3)	88.6 (70.1)	88.7 (70.8)	84.2 (66.4)	81.1 (63.6)	79.3 (61.9)	78.4 (59.8)	1.78
Hanumangarh	86.2 (68.6)	85.5 (65.2)	84.2 (64.6)	83.8 (63.2)	83.1 (62.5)	81.5 (60.7)	80.4 (58.2)	1.10
Meerut	82.6 (64.3)	81.7 (62.5)	80.9 (61.4)	79.8 (59.7)	78.2 (58.4)	77.5 (56.8)	75.3 (54.4)	1.57
Udhamsingh Nagar	91.2 (72.4)	90.8 (70.7)	89.4 (68.2)	88.2 (67.5)	82.3 (62.8)	81.6 (60.2)	78.8 (58.3)	1.39
Basti	84.1 (66.2)	82.3 (64.5)	81.3 (63.5)	80.5 (62.4)	79.8 (61.6)	78.5 (59.8)	77.6 (58.1)	2.05
Mean	86.6 (64.5)	85.5 (62.9)	84.6 (61.2)	83.2 (60.7)	81.2 (58.4)	79.8 (57.1)	77.8 (53.9)	
CD at 5%	3.21	2.65	3.56	2.89	3.48	2.87	1.90	

The values mentioned in the parenthesis are angular transformed values

Table 4.9: Effect of storage period on seed vigour index-I in seeds of six provenances in *Dalbergia sissoo* Roxb.

Provenance	**Storage period (Months after storage)**							**CD at 5%**
	Fresh (Feb.,2014)	3 (May,2014)	6 (August,2014)	9 (Nov.,2015)	12 (Feb.,2015)	15 (May,2015)	18 (August,2015)	
Ferozpur	1011.20	986.20	940.50	930.90	915.30	887.20	860.50	8.20
Reasi	1115.60	1089.50	1075.40	1061.30	989.20	965.20	915.20	7.67
Hanumangarh	995.30	980.35	945.20	925.60	890.20	879.20	856.20	6.45
Meerut	980.20	967.20	955.60	941.30	931.80	915.30	889.50	4.16
Udhamsingh Nagar	1177.50	1136.67	1056.80	1030.20	986.20	956.78	940.56	8.48
Basti	1054.30	989.50	971.60	945.30	930.50	905.20	900.06	5.78
Mean	1055.68	1024.90	990.85	972.43	940.53	918.14	893.67	
CD at 5%	30.78	36.68	68.89	64.87	30.30	48.90	35.67	

Table 4.10: Effect of storage period on Seed vigor index-II in seeds of six provenances in *Dalbergia sissoo*

Provenance	**Storage period (Months after storage)**							CD at 5%
	Fresh (Feb.,2014)	3 (May,2014)	6 (August,2014)	9(Nov.,2015)	12 (Feb.,2015)	15 (May,2015)	18 (August,2015)	
Ferozpur	1500	1468	1434	1412	1390	1366	1337	3.40
Reasi	1612	1565	1534	1505	1447	1430	1412	5.48
Hanumangarh	1470	1446	1424	1350	1323	1309	1234	2.67
Meerut	1550	1539	1518	1478	1444	1426	1325	2.20
Udhamsingh Nagar	1562	1539	1510	1476	1428	1367	1276	3.56
Basti	1495	1430	1403	1387	1347	1323	1311	4.87
Mean	1531.5	1497.8	1470.5	1434.6	1396.5	1370.1	1315.8	
CD at 5%	63.40	57.90	38.79	58.90	45.78	55.55	37.78	

Seed vigour index-I

Results presented in Table 4.9 indicated that seed vigor index-I declined in all the provenances with the advancement of seed storage time. The initial seed vigor-I was found to be highest (1177.50) in Udhamsingh Nagar provenance followed by Reasi (1115.60) provenance. The average vigour-I was 1055.68 which reduced to 893.67, after eighteen months storage period. The vigour index-I significantly reduced after every three months of storage in all the provenances.

Seed vigour index-II

Results presented in Table 4.10 indicated that seedling index-II declined in all the seed lots of six provenances with the advancement passage of time. The initial seed vigor index-II was found maximum (1612) in Reasi provenance followed by the Udhamsingh Nagar (1562) provenance. The initial seed vigor index-II was found minimum (1470) in Hanumangarh provenance. The average vigour-II reduced from 1531.5 to 1315.83 after eighteen months of storage. The vigour index-II reduced significantly in all the six provenances, after every three months of seed storage.

Simple correlation among various seed storability parameter of *Dalbergia sissoo*

The correlation coefficients were estimated among different parameters. The results are presented in Table 4.11. There was significant positive correlation between standard germination % and vigour index-I and II. There was positive association between vigor index by method- I and method-II, which reflected that longer seedlings had a tendency of being heavier. However, a negative correlation was observed in case of electrical conductivity for all the characters under study.

Table 4.11: Simple correlation among various seed storability parameter of *Dalbergia sissoo* Roxb.

Character	Moisture content (%)	Seed viability (TZ-test) (%)	Electrical Conductivity (dSm^{-1})	Standard germination (%)	Seed vigor index-I	Seed vigor index-II
Moisture content (%)						
Seed viability (TZ-test) (%)	0.568**					
Electrical Conductivity (dSm^{-1})	-0.134^{NS}	-0.284^{NS}				
Standard germination (%)	0.367**	0.738**	-0.638**			
Seed vigour index-I	0.324**	0.294*	-0.674**	0.387**		
Seed vigour index-II	0.423**	0.415**	-0.567**	0.286*	0.786**	

At *5 % significant level

At ** 1 % significant level

4.3 Provenance cum Progeny testing

The data on growth characters with respect to analysis of variance, variability, heritability and genetic advance, genotypic and phenotypic correlation coefficients, mean performance of all the sixty progenies for various characters and best progenies from the various provenances have been presented in Table 4.12-4.17.

4.3.1 Analysis of Variance

The analyses of variance for growth characters of sixty progenies in *Dalbergia sissoo* from six provenances at the age of 18 months are presented in Table 4.12. The mean sum of squares due to progenies were highly significant for all the characters *viz*., total height, basal diameter, unforked height, clear bole height, root length, fresh weight, dry weight, total dry biomass, plant straightness, root weight and shoot weight which indicated the presence of ample genetic variation for all the characters under study.

4.3.2 Mean performance of progenies

The mean performance of all the selected sixty progenies from six provenances at the age of 18 months for different characters along with critical difference and general mean at the end of second growing season have been presented along with value of critical difference in Table 4.14. The detail results are being described character wise.

Total height (cm)

The overall population mean for total height was 165.3 cm with range of 114.4 cm to 216.2 cm. fourteen progenies from different provenances were found significantly superior than general mean for total height at the age of 18 months. Progeny of FZP-4 from Ferozpur was found best (216.2 cm) for total height followed by progenies of BST-59 (213.9 cm) and BST-57 (207.6 cm) from Basti provenance.

Basal diameter (cm)

The mean performance of progenies for basal diameter ranged from 1.57 cm to 3.79 cm with general mean of 2.60 cm. The maximum basal diameter (3.79 cm) was found in progeny of BST-60 from Basti provenance followed by progenies FZP-4 (3.78 cm) from Ferozpur provenance, USN-45 (3.49 cm) from Udhamsingh Nagar provenance and FZP-4 (3.49 cm) from Ferozpur provenance. HGR-29 (3.14 cm) from Hanumangarh provenance, MRT-33 (3.42 cm) from Meerut provenance, USN-45 (3.49 cm) and USN-48(3.41 cm) from Udhamsingh Nagar provenance and BST-53 (3.08 cm), BST-57 (3.47 cm), BST-59 (3.49 cm) and BST-60 (3.79 cm) from Basti provenances were found significantly superior than general mean (2.60 cm) for basal diameter. .

Unforked height (cm)

The general mean of population for unforked height was 132.1 cm with a range from 62.2-202 cm. The highest unforked height (202 cm) was observed in BST-59 followed by progenies of FZP-4 (198.0 cm) from Ferozpur provenance, BST-57 (192 cm) from Basti provenance progenies, whereas a minimum of 62.2cm was found in progeny of HGR-22 from Hanumangarh provenance.

Clear bole height (cm)

A range of 7.2 to 16.1 cm was found for clear bole height in all the sixty progenies with a mean value of 11.6 cm. The clear bole height of 16.1 cm was found in progeny of MRT-37 from Meerut provenance followed by progenies of RSI-13 from Reasi and FZP-1 and FZP-5 Ferozpur provenances.

Root length (cm)

General mean for root length was found 75.1 cm with a range from 52.0 to 98.2 cm. The maximum root length was found in progeny FZP-4 from Ferozpur provenance followed by progeny of BST-59 (97.2 cm) from Basti provenance whereas minimum root length was observed in progeny of HGR-22 (52 cm) in Hanumangarh provenance.

Fresh weight (g)

The overall population mean for fresh weight was found 11.0 g with a range from 7.6 to 14.4 g. The highest fresh wait was found in progeny of FZP-4 (14.4 g) from Ferozpur provenance followed by progeny of BST-59 (14.2 g) from Basti provenance.

Total Biomass (dry)

The overall mean for total biomass was 10.3 g with a range of 7.1 to 13.5 g. The highest biomass (dry) was reported in progeny FZP-4 (13.5 g) from Meerut provenance, whereas the minimum total was found in progeny HGR-22 (7.2 g) from Hanumangarh provenance.

Straightness

The population mean for straightness was 3.75 with range from 3.2 to 4.6.Tthirty two progenies were found significantly superior than general mean.

Dry root weight (g)

A range of 2.4 to 4.6 g was observed for root weight with a mean value of 3.5 g. The highest root weight was observed in progeny of FZP-4 (4.6 g) from Ferozpur provenance followed by progenies of BST-59 (4.5 g), BST-57 (4.4 g) and BST-53 (4.2 g) from Basti provenance.

Dry shoot weight (g)

The overall population mean for shoot weight was found 3.8 g. The highest shoot weight (4.8 g) was observed in progenies of BST-59 from Basti provenance and progeny of

FZP-4 from Ferozpur provenance followed by progenies of HGR-29 (4.6 g) from Hanumangarh and in BST-53 (4.6 g) from Basti provenance.

Dry weight (g)

The highest dry weight (13.5 g) per seedling was found in progeny of FZP-4 from Ferozpur provenance followed by progeny BST-59 (13.3 g) from Basti provenance. The minimum dry weight per seedling was found in progeny of HGR-22 from Hanumangarh provenance.

Germination (%)

Germination percent of sixty progenies from six provenances ranged from 62.4 to 88.8 per cent with general mean of 75.6 per cent. The highest germination (88.8%) was observed in progeny of MRT-33 followed by progenies of BST-60 (88.4%) from Basti provenance and USN-45 (86.3%) from Udamsingh Nagar provenance.

4.3.3 Coefficient of variability, heritability and genetic advance

The data on phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), mean, heritability estimates and genetic advance as percentage of mean have been presented in Table 4.13**.** The highest phenotypic coefficient of variation (30.7%) was recorded for clear bole height followed by basal diameter and unforked height with 25.7 and 24.4 per cent of PCV respectively. The phenotypic correlation of variation was found more than 12.2% for all the characters under study. Regarding genotypic coefficient of variation, almost similar trend was observed with highest genotypic coefficient of variation of 28.6 per cent for clear bole height. The magnitude of phenotypic coefficient of variation was higher than the corresponding genotypes for all the characters.

Heritability estimates in broad sense were more than 65% for important growth characters like, total height, basal diameter, unforked height and clear bole height. Heritability estimates were more than 27.4% for all the characters under study. Genetic advances as percentage of mean were found moderate to high ranging from 22.5 for straightness to 58.3 for clear bole height. Simultaneous considerations of all parameters of variability indicated that the characters like total height, basal diameter, unforked height and straightness had sufficiently higher proportion of variation as heritable in the collection of *Dalbergia sissoo* germplasm.

Table 4.12: Analysis of variance for growth characters of sixty progenies of *Dalbergia sissoo* from six provenances

Mean sum of Squares												
Source	d.f.	Total height (cm)	Basal diameter	Unforked height (cm)	Clear bole height (cm)	Root length (cm)	Fresh wt (g)	Dry wt (g)	Total biomass (g)	Plants straightness	Root wt (g)	Shoot wt (g)
Blocks	2	94.47	0.08	41.78	1.90	25.87	6.76	4.39	2.39	0.029	8.40	7.30
Progenies	59	2480.47**	1.41**	1178.76**	64.68**	167.76**	48.67**	23.30**	76.37**	0.810**	17.39**	21.20**
Error	118	163.34	0.09	83.49	2.71	34.78	13.87	6.78	18.30	0.039	7.27	4.78

**Significant at 1 % level of significance

Table 4.13: Mean performance of ***Dalbergia sissoo*** Roxb. progenies for different characters at the end of second (October 2015) growing season (After 18 months)

Progeny Code	Provenance		Progeny characters										
		Total height (cm)	Basal dia. (cm)	Unforked ht. (cm)	Clear bole ht. (cm)	Total Biomass (dry)	Root length (cm)	Fresh wt. (g)/seedling	Dry wt. (g)/seedling	Straightness	Root wt. (g)	Shoot wt. (g)	Germination %
FZP-1	Ferozpur	190.6	2.87	175.5	14.8	11.9	86.6	12.7	8.2	4.1	4.0	4.2	78.5 (62.3)
FZP-2	Ferozpur	160.8	1.98	134.3	7.8	10.0	73.0	10.7	6.9	4.3	3.4	3.5	77.4 (59.1)
FZP-3	Ferozpur	187.7	3.33	167.4	8.0	11.7	85.3	12.5	8.1	3.4	3.9	4.2	74.2 (58.3)
FZP-4	Ferozpur	216.2	3.78	198.0	14.0	13.5	98.2	14.4	9.4	3.8	4.6	4.8	80.4 (61.3)
FZP-5	Ferozpur	190.6	2.95	174.4	14.5	11.9	86.6	12.7	8.4	4	4.1	4.3	73.2 (58.3)
FZP-6	Ferozpur	173.8	2.76	131.5	10.9	10.8	79.0	11.5	7.6	3.7	3.6	4.0	74.3 (58.2)
FZP-7	Ferozpur	140.5	2.22	94.2	9.2	8.7	63.8	9.3	6.3	3	2.9	3.4	82.3 (65.0)
FZP-8	Ferozpur	150.4	1.92	70.0	14.4	9.4	68.3	10.0	6.6	4.3	3.2	3.4	83.4 (65.8)
FZP-9	Ferozpur	178.7	3.12	148.6	13.2	11.1	81.2	11.9	8.0	4.1	3.8	4.2	85.4 (66.9)
FZP-10	Ferozpur	188.1	2.35	164.5	8.2	11.7	85.5	12.5	8.6	4.4	4.0	4.6	83.2 (65.9)
RSI-11	Reasi	151.1	1.92	72.2	22.8	9.4	68.6	10.0	6.7	4	3.2	3.5	80.2 (64.4)
RSI-12	Reasi	160.7	2.85	132.2	7.2	10.0	73.0	10.7	7.3	4.3	3.4	3.9	84.0 (66.2)
RSI-13	Reasi	155.6	2.09	72.2	14.9	9.7	70.7	10.3	7.0	4.2	3.3	3.7	85.3 (67.4)
RSI-14	Reasi	170.3	2.72	131.6	10.8	10.6	77.4	11.3	7.5	3.9	3.6	3.9	82. 4 (63.7)
RSI-15	Reasi	173.9	2.80	94.3	10.9	10.8	79.0	11.5	7.9	4.5	3.7	4.2	83.2 (65.8)
RSI-16	Reasi	162.6	2.45	121.1	12.6	10.1	73.9	10.8	7.3	3.8	3.4	3.9	71.4 (56.7)
RSI-17	Reasi	168.2	2.91	152.2	7.9	10.5	76.4	11.2	7.3	4.2	3.5	3.8	84.5 (67.3)
RSI-18	Reasi	179.8	2.67	170.4	9.8	11.2	81.7	11.9	7.8	4.1	3.8	4.0	72.6 (58.3)
RSI-19	Reasi	145.6	2.43	118.5	10.2	9.1	66.1	9.7	6.4	4.3	3.0	3.4	75.2 (59.3)
RSI-20	Reasi	176.6	2.79	133.7	10.9	11.0	80.2	11.7	8.1	4.4	3.7	4.4	74.2 (59.5)
HGR-21	Hanumangarh	125.7	1.72	104.2	7.9	7.85	57.1	8.3	5.5	3.8	2.6	2.9	76.1 (60.7)
HGR-22	Hanumangarh	114.4	1.57	62.2	10.4	7.1	52.0	7.6	5.2	4.1	2.4	2.8	74.3 (60.2)

HGR-23	Hanumangarh	136.7	2.03	111.4	14.1	8.5	62.1	9.1	6.4	42	2.9	3.5	80.1 (64.0)
HGR-24	Hanumangarh	128.9	2.07	62.5	15.9	8.0	58.5	8.5	5.9	4.2	2.7	3.2	75.2 (60.2)
HGR-25	Hanumangarh	156.7	2.00	72.0	19.8	9.7	71.2	10.4	7.1	4.4	3.3	3.8	76.3 ()61.2
HGR-26	Hanumangarh	134.8	1.98	102.6	14.4	8.4	61.2	8.9	6.4	3.5	2.8	3.6	78.4 (62.0)
HGR-27	Hanumangarh	144.3	2.25	118.5	9.7	9.0	65.5	9.6	6.7	4.1	3.0	3.7	82.2 (64.0)
HGR-28	Hanumangarh	167.3	2.62	128.0	9.1	10.4	76.0	11.1	7.7	4.1	3.5	4.2	78.3 (61.4)
HGR-29	Hanumangarh	187.6	3.14	153.7	8.5	11.7	85.2	12.5	8.5	3.8	3.9	4.6	83.4 (65.5)
HGR-30	Hanumangarh	176.8	2.96	130.7	12.6	11.0	80.3	11.7	7.8	4.1	3.7	4.1	85.4 (67.0)
MRT-31	Meerut	143.7	2.35	120.6	15.0	8.9	65.3	9.5	6.3	3.4	3.0	3.3	85.0 (66.0)
MRT-32	Meerut	165.7	2.86	131.3	9.9	10.3	75.3	11.0	7.3	4	3.5	3.8	80.8 (64.2)
MRT-33	Meerut	198.3	3.42	160.5	9.2	12.3	90.1	13.2	8.6	3.7	4.2	4.4	88.8 (68.7)
MRT-34	Meerut	134.8	2.07	114.6	12.6	8.4	61.2	8.9	5.9	3.5	2.8	3.1	84.2 (65.2)
MRT-35	Meerut	153.2	2.04	68.0	14.4	9.5	69.6	10.2	6.7	2.9	3.2	3.5	82.3 (65.1)
MRT-36	Meerut	176.2	2.98	131.5	9.9	11.0	80.0	11.7	8.0	3.8	3.7	4.3	69.5 (54.2)
MRT-37	Meerut	129.7	2.07	64.4	16.1	8.1	58.9	8.6	5.6	4.2	2.7	2.9	79.3 (63.4)
MRT-38	Meerut	175.7	2.83	133.7	9.8	10.9	79.8	11.7	7.7	3.9	3.7	4.0	80.4 (63.0)
MRT-39	Meerut	160.3	2.81	135.9	8.0	10.0	72.8	10.6	7.1	4.1	3.4	3.7	82.4 (65.7)
MRT-40	Meerut	143.7	2.06	99.2	7.7	8.9	65.3	9.5	6.4	4.3	3.0	3.4	84.2 (66.3)
USN-41	Udamsingh Nagar	139.4	2.24	116.2	9.3	8.7	63.3	9.2	6.1	4.5	2.9	3.2	62.4 (51.2)
USN-42	Udamsingh Nagar	157.3	2.72	132.5	14.4	9.8	71.5	10.4	6.9	4.6	3.3	3.6	77.1 (62.6)
USN-43	Udamsingh Nagar	176.2	2.93	152.5	11.5	11.0	80.0	11.7	7.6	4.2	3.7	3.9	80.4 (63.7)
USN-44	Udamsingh Nagar	147.3	2.34	93.3	10.5	9.2	66.9	9.8	6.3	3.9	3.1	3.2	84.2 (67.8)
USN-45	Udamsingh Nagar	180.9	3.49	148.4	9.8	11.3	82.2	12.0	7.7	4.4	3.8	3.9	86.3 (66.4)

USN-46	Udamsingh Nagar	137.8	2.09	116.2	10.2	8.6	62.6	9.1	6.1	4.6	2.9	3.2	72.3 (58.2)
USN-47	Udamsingh Nagar	168.8	2.66	138.3	7.4	10.5	76.7	11.2	7.3	4.1	3.5	3.8	78.0 (62.0)
USN-48	Udamsingh Nagar	189.7	3.41	151.4	11.9	11.8	86.2	12.6	7.3	3.9	4.0	4.3	80.1 (64.2)
USN-49	Udamsingh Nagar	160.6	2.43	147.5	7.7	10.0	73.0	10.7	7.3	4.3	3.4	3.9	78.3 (61.4)
USN-50	Udamsingh Nagar	134.8	1.79	105.6	10.5	8.4	61.2	8.9	5.9	4	2.8	3.1	72.2 (61.4)
BST-51	Basti	150.5	2.32	123.0	14.2	9.4	68.4	10.0	6.8	3.7	3.2	3.6	70.2 (54.6)
BST-52	Basti	178.9	3.04	158.6	6.9	11.1	81.3	11.9	8.2	4.0	3.8	4.4	82.2 (64.4)
BST-53	Basti	200.7	3.08	166.8	12.9	12.5	91.2	13.3	8.8	3.6	4.2	4.6	78.3 (62.8)
BST-54	Basti	179.2	2.72	170.5	9.2	11.2	81.4	11.9	8.0	4.1	3.8	4.2	76. 6 (60.0)
BST-55	Basti	154.8	2.09	74.2	15.2	9.6	70.3	10.3	6.6	3.9	3.2	3.4	70.0 (52.6)
BST-56	Basti	180.7	2.79	155.5	8.7	11.2	82.1	12.0	8.1	4.1	3.8	4.3	82.0 (64.5)
BST-57	Basti	207.6	3.47	192.0	12.0	12.9	94.3	13.8	9.0	3.2	4.4	4.6	84.3 (66.6)
BST-58	Basti	190.8	2.82	164.6	13.8	11.9	86.7	12.7	8.3	3.5	4.0	4.3	84.2 (65.6)
BST-59	Basti	213.9	3.49	202.0	13.2	13.3	97.2	14.2	9.3	4.3	4.5	4.8	84.4 (68.6)
BST-60	Basti	202.3	3.79	174.4	9.0	12.6	91.9	13.4	9.0	3.8	4.3	4.7	88.4 (69.8)
Mean		165.3	2.6	132.1	11.6	10.3	75.1	11.0	7.3	3.75	3.5	3.8	75.6
Range		114.4- 216.2	1.57-3.79	62.2-202	7.2-16.1	7.1-13.5	52.0-98.2	7.6-14.4	5.2-9.4	2.9-4.6	2.4-4.6	2.8-4.8	62.4-88.8
C.D at 5 %		17.27	0.78	15.51	2.21	3.45	27.31	6.78	3.45	0.27	1.09	1.78	2.82

Note: Figures in parenthesis are angular transformation values.

Table 4.14: Variability, heritability and genetic advance at the age of 18 months in the progenies *Dalbergia sissoo*.

Name of characters	Genotypic Coefficient of Variation(GCV)	Phenotypic Coefficient of Variation(PCV)	h^2 (broad sense)	Genetic advance as percent of mean	Mean	Range
Total height (cm)	15.8	18.7	78.9	29.8	165.3	114.4-216.2
Basal diameter (cm)	22.6	25.7	81.7	41.2	2.6	1.57-3.79
Unforked height (cm)	21.4	24.4	67.3	43.3	132.1	62.5-202.0
Clear bole height (cm)	28.6	30.7	87.5	58.3	11.6	7.2-16.1
Root length (cm)	20.1	22.6	34.7	28.9	75.1	52.0-98.2
Fresh weight (g)	18.4	21.9	36.8	29.6	11.0	7.6-14.4
Total biomass (dry)	19.7	20.8	27.4	27.7	10.3	7.1-13.5
Straightness	11.3	13.8	42.8	22.5	3.7	2.9-4.6
Root weight (g)	10.4	12.2	36.2	23.4	3.5	2.4-4.6
Shoot weight (g)	11.2	13.4	33.4	23.5	3.8	2.8-4.8
Dry weight (g)	19.7	20.8	27.4	27.7	10.3	7.1-13.5

Total height (cm)

The overall population mean for total height was 165.3 cm. The genotypic and phenotypic coefficients were 15.8 and 18.7 percent, respectively. The heritability was 78.9 percent and the value of genetic advance (% of mean) was 29.8, which showed that differences among progenies were due to genetic components. These results suggested that test materials of *Dalbergia sissoo* has lot of potential for improvement of total height through selection.

Basal diameter (cm)

The overall range for basal diameter was found from 1.57 to 3.79 cm with mean value of 2.6 cm. The GCV and PCV were 22.6 and 25.7 percent, respectively. The heritability was 81.7 per cent, which can be considered high. The percent gain was 41.2, which is considered to be sufficient showing thereby that there is a possibility for improvement in this trait by selection.

Unforked height (cm)

The range for unforked height was found from 62.5 to 202.0 cm with mean value of 129.0 cm. The GCV and PCV were 21.4 and 24.4 per cent, respectively. The heritability was 67.3 per cent which is considered to be high. The per cent gain was 43.3.

Clear bole height (cm)

The overall population mean for clear bole height was 11.6 cm with a range from 7.2 to 16.1 cm. The GCV and PCV were 28.6 and 30.7 per cent, respectively. The heritability was 87.5 percent which is quite high. The per cent gain was 58.3 which is also quite high, which suggested a great scope for further improvement in this trait by selection.

Root length (cm)

The population mean for root length was 75.1 cm. The range was found from 52.0 to 98.2 cm. The magnitude of GCV and PCV were 20.1 and 22.6 per cent, respectively. The heritability was 34.7 per cent and the per cent gain was 28.9.

Fresh weight (g)

The overall population mean for fresh weight was found 11.0 g with a range from 7.6-14.4 g. The GCV and PCV were 18.4 and 21.9 per cent, respectively. The heritability was 36.8 percent. The percent gain was 29.6.

Total Biomass (g)

The population mean for total biomass was 10.3 g with a range from 7.1 to 13.5 g. The magnitude of GCV and PCV were 19.7 and 20.8 per cent, respectively. The heritability was 27.4 per cent and the per cent gain was 27.7.

Straightness

The population mean for straightness was 3.7 with a range from 2.9 to 4.6. The GCV and PCV were 11.3 and 13.8 per cent, respectively. The heritability was 42.8 per cent. The per cent gain was 22.5.

Root weight (g)

The overall mean for root weight was 3.5 g. The range was observed from 2.4 to 4.6 g. The GCV and PCV were 10.4 and 12.2 per cent, respectively. The heritability was 36.2 per cent and the per cent gain was 23.4.

Shoot weight (g)

The overall population mean for shoot weight was 3.8 g with a range from 2.8 to 4.8 g. The GCV and PCV were 11.2 and 13.4 per cent, respectively. The heritability was 33.4 per cent. The per cent gain was 23.5.

Dry weight (g)

The population mean for dry weight was 10.3 g with a range from 7.1 to 13.5 g. The magnitude of GCV and PCV were 19.7 and 20.8 per cent, respectively. The heritability was 27.4 per cent and the per cent gain was 27.7, respectively.

Superior progenies on the basis of index score analysis

Index score analysis was carried out in sixty progenies of *Dalbergia sissoo* from six provenances by using data for different characters *viz* plant height, basal diameter, unforked height, clear bole height, root length, fresh weight, total biomass, plant straightness, root weight, shoot weight and dry weight. The class intervals for various characters are given in the Table 4.15. One, two, and three index scores were given to various classes of plant height, basal diameter, unforked height, clear bole height, root length, fresh weight, total biomass, plant straightness, root weight, shoot weight and dry weight and have been presented in the Table 4.16. The classification of *Dalbergia sissoo* progenies on the basis of index score analysis is presented in Table 4.17. The index score ranged from 11 to 32 in all the sixty progenies of *Dalbergia sissoo*. Highest score of 32 was observed in progenies of BST-59 from Basti provenance. The progeny of BST-58 ranked second with index score of 31 which indicated the superiority of this progeny for most of the characters under study. The progenies of FZP-10 from Ferozpur provenance, MRT-33 from Meerut provenance, USN-48 from Udamsingh Nagar provenance and BST-53 and BST-60 from Basti provenance ranked third with index score of 30. The progenies of BST-57 (index score 29) from Basti provenance, FZP-3 with index score of 29 from Ferozpur provenance and HGR-29 with index score of 28 from Hanumangarh provenance were found promising for many of the characters.

Table 4.15: Class interval for index scoring for selecting best progenies

Characters	**1**	**2**	**3**
Total height (cm)	≤148.13	148.14-182.06	≥182.07
Basal diameter (cm)	≤2.31	2.32-3.05	≥3.06
Unforked height (cm)	≤108.8	108.9-155.4	≥155.5
Clear bole height. (cm)	≤10.1	10.2-13.0	≥13.1
Total Biomass (dry)	≤9.2	9.3-11.3	≥11.4
Root length (cm)	≤67.4	67.5-82.8	≥82.9
Fresh weight. (g)	≤9.86	9.87-12.12	≥12.13
Dry weight. (g)	≤5.2	9.3-11.3	≥11.4
Straightness	≤3.4	3.5-4.0	≥4.1
Root weight. (g)	≤3.1	3.2-3.8	≥3.9
Shoot weight. (g)	≤3.4	3.5-4.1	≥4.2

Table 4.16: Index scores for different characters in sixty progenies of *Dalbergia sissoo* from six provenances

Progeny Code	Provenance		Progeny characters										
		Total height (cm)	Basal dia. (cm)	Unforked ht. (cm)	Clear bole ht. (cm)	Total Biomass (dry)	Root length (cm)	Fresh wt. (g)	Dry wt. (g)	Straightness	Root wt. (g)	Shoot wt. (g)	Total score
FZP-1	Ferozpur	3	2	3	3	3	3	3	3	3	3	3	32
FZP-2	Ferozpur	2	1	2	1	2	2	2	2	3	2	2	20
FZP-3	Ferozpur	3	3	3	1	3	3	3	3	1	3	3	29
FZP-4	Ferozpur	3	3	3	3	3	3	3	3	2	3	3	32
FZP-5	Ferozpur	3	2	3	3	3	3	3	3	2	3	3	31
FZP-6	Ferozpur	2	2	2	2	2	2	2	2	2	2	2	22
FZP-7	Ferozpur	1	1	1	1	1	1	1	1	1	1	1	11
FZP-8	Ferozpur	2	1	1	3	2	2	2	2	3	2	1	21
FZP-9	Ferozpur	2	3	2	3	2	2	2	2	3	2	3	26
FZP-10	Ferozpur	3	2	3	1	3	3	3	3	3	3	3	30
RSI-11	Reasi	2	1	1	3	1	2	2	2	1	2	2	19
RSI-12	Reasi	2	2	2	1	1	2	2	2	2	2	2	20
RSI-13	Reasi	2	1	1	3	1	2	2	2	2	2	2	20
RSI-14	Reasi	2	2	2	2	1	2	2	2	1	2	2	20
RSI-15	Reasi	2	2	1	2	1	2	2	2	2	2	3	21
RSI-16	Reasi	2	2	2	2	1	2	2	2	1	2	2	20
RSI-17	Reasi	2	2	2	1	1	2	2	2	3	2	2	21
RSI-18	Reasi	2	2	3	1	1	2	2	2	3	2	2	22

RSI-19	Reasi	1	2	2	2	1	2	1	1	3	1	1	17
RSI-20	Reasi	2	2	2	2	1	2	2	2	3	2	3	23
HGR-21	Hanumangarh	1	1	1	1	1	1	1	1	2	1	1	12
HGR-22	Hanumangarh	1	1	1	2	1	1	1	1	3	1	1	14
HGR-23	Hanumangarh	1	1	2	3	1	1	1	1	3	1	2	17
HGR-24	Hanumangarh	1	1	1	3	2	1	1	1	3	1	1	16
HGR-25	Hanumangarh	2	1	1	3	2	2	2	2	3	2	2	22
HGR-26	Hanumangarh	1	1	1	3	1	1	1	1	2	1	2	15
HGR-27	Hanumangarh	1	1	2	1	2	1	1	1	3	1	2	16
HGR-28	Hanumangarh	2	2	2	1	3	2	1	2	3	2	3	23
HGR-29	Hanumangarh	3	3	2	1	3	3	3	2	2	3	3	28
HGR-30	Hanumangarh	2	2	2	2	2	2	2	2	3	2	2	23
MRT-31	Meerut	1	2	2	3	1	1	1	1	1	1	1	15
MRT-32	Meerut	2	2	2	1	2	2	2	2	2	2	2	21
MRT-33	Meerut	3	3	3	1	3	3	3	3	2	3	3	30
MRT-34	Meerut	1	1	2	2	1	1	1	1	2	1	1	14
MRT-35	Meerut	2	1	1	2	2	2	2	2	1	2	3	20
MRT-36	Meerut	2	2	2	1	2	2	2	2	2	2	3	22
MRT-37	Meerut	1	1	1	3	1	1	1	1	3	1	1	15
MRT-38	Meerut	2	2	2	1	2	2	2	2	2	2	2	21
MRT-39	Meerut	2	2	2	1	2	2	2	2	3	2	2	22
MRT-40	Meerut	1	1	1	1	1	1	1	1	3	1	1	13
USN-41	Udamsingh Nagar	1	1	2	1	1	1	1	1	2	1	1	13
USN-42	Udamsingh Nagar	2	2	2	3	2	2	2	2	3	2	2	24
USN-43	Udamsingh Nagar	2	2	2	2	2	2	2	2	3	2	2	23

USN-44	Udamsingh Nagar	1	2	1	2	1	1	1	1	2	1	1	14
USN-45	Udamsingh Nagar	2	3	2	1	2	2	2	2	3	2	2	23
USN-46	Udamsingh Nagar	1	1	2	2	1	1	1	1	3	1	1	15
USN-47	Udamsingh Nagar	2	2	2	1	2	2	2	2	3	2	2	22
USN-48	Udamsingh Nagar	3	3	2	2	3	3	3	3	2	3	2	30
USN-49	Udamsingh Nagar	2	2	2	1	2	2	2	2	3	2	2	22
USN-50	Udamsingh Nagar	1	1	1	2	1	1	1	1	2	1	1	13
BST-51	Basti	2	2	2	3	2	1	1	2	2	2	2	21
BST-52	Basti	2	2	3	1	2	1	1	2	2	2	3	21
BST-53	Basti	3	3	3	2	3	3	2	3	2	3	3	30
BST-54	Basti	2	2	3	1	2	1	1	2	3	2	3	22
BST-55	Basti	2	1	1	3	2	1	1	2	2	2	1	18
BST-56	Basti	2	2	3	1	2	1	1	2	3	2	3	22
BST-57	Basti	3	3	3	2	3	3	2	3	1	3	3	29
BST-58	Basti	3	2	3	3	3	3	2	3	2	3	3	31
BST-59	Basti	3	3	3	3	3	3	2	3	3	3	3	32
BST-60	Basti	3	3	3	1	3	3	2	3	2	3	3	30

Table 4.17: Classification of progenies of *Dalbergia sissoo* at the age of 18 months on the basis of Index scores analysis

												BST-56										
												BST-54										
											BST-52	USN-49										
										MRT-35	BST-51	USN-47										
										RSI-16	MRT-38	MRT-39	USN-45						BST-60			
					USN-46					RSI-14	MRT-32	MRT-36	USN-46						BST-53		BST-59	
		USN-50	USN-44	MRT-37						RSI-13	RSI-17	HGR-25	HGR-30						USN-48		FZP-5	
		USN-41	MRT-34	MRT-31	HGR-27	HGR-23				RSI-12	RSI-15	RSI-18	HGR-28					BST-57	MRT-33		FZP-4	
	FZP-7	HGR-21	MRT-40	HGR-22	HGR-26	HGR-24	RSI-19	BST-55	RSI-11	FZP-2	FZP-8	FZP-6	RSI-20	USN-42		FZP-9		HGR-29	FZP-3	FZP-10	BST-58	FZP-1
Index score	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

CHAPTER-V

DISCUSSION

Dalbergia sissoo is a tree that pays rich dividends because of its multiple uses. It is one of the best timber species of India. Its timber values high for furniture, building constructions and other uses (Tewari, 1994). The wood is hard, heavy, strong, double elastic; seasons well and decay resistant. It is suitable for marine and aircraft grade plywood and is in great demand for veneers. *Dalbergia sissoo* can also be used for paper pulp. It enriches soil through atmospheric nitrogen fixation and rich leaf fall. Its pruned branched are cheap source of firewood. Being protein rich, the leaves of *Dalbergia sissoo* can serve a suitable alternative of cattle fodder during scarcity period. It is a medium to large deciduous tree, native to south Asia. Indigenous to the Indo-Gangetic basin, *Dalbergia sissoo* is a tree of the sub-mountainous regions and alluvial sandy loam. It does not grow well in heavy clay soils, particularly those with hard sub-soil layers. It occurs freely in village lands and cultivated fields. It is the first tree to appear on fresh sand and rock debris brought down by the Himalayan streams, on exposed soils, land slips and sand banks, and on new embankments. With its multiple uses and tolerance to a broad range of climatic and soil conditions, this species deserves much greater considerations for agroforestry plantations than those given in the past. Poor stem form with generally crooked and forked pole results in poor wood quality and constitute a major draw back to *Dalbergia* production (Vidakovic and Ahsan, 1970; Gupta *et al.*, 1992). A great variability, however, exists in growth and stem form of *Dalbergia* (Dogra, 1981). Stem form ranged from crooked and forked to completely straight (Bangarwa, 1996) with a very little proportion of straight trees (Bangarwa *et al.*, 1992).

Though, silviculturists and forest managers have tried to secure the highest possible sustained yield from forests, there is a wide gap between production and requirement. Furthermore, with the increasing population pressure and justifiable aspiration of the people for improved standards of living, particularly in the under developed and developing regions of the world, there is an urgent need to further increase forest production. Intensive forest management activities, such as site preparation or application of fertilizers will never yield maximum returns, unless the genetically best trees are used to the maximum extent in subsequent plantations. As a matter of fact, management practices can show their best impact only after the genetic improvement of forest tree species. Therefore, genetic improvement of tree is an effective component required to be incorporated in field experimentation of trees for desired success in afforestation programmes. Tree improvement is an additional tool of silviculture that deals with the kind and genetic make up of the tree used. Indian forests have not been subjected to the effects of vigorous selection and tree improvement programmes so far. In fact, even the seed collection from the vigorously selected plus trees and further

selection of high quality seeds from such trees are rarely used by foresters in the new plantations. Therefore, the species consists of genetically undifferentiated wild population (Dogra, 1992).

Thus, elucidating the forgoing discussion, present investigation on genotypic and phenotypic variations in *Dalbergia sissoo* Roxb. was planned with a view to (i) to study the extent of phenotypic variation in various geographic sites; (ii) to find out the seed storability and loss of vigour during storage; (iii) to find out the extent of genotypic variation in juvenile growth of various progenies from different geographical sites and (iv) to find out the best seed source of *Dalbergia sissoo* Roxb. for further tree improvement programme. Salient features of the results are being discussed under the following heads:

5.1 Extent of phenotypic variation in various geographical sites

5.2 Provenance evaluation for seed storability and loss of vigor during storage

5.3 Provenance cum progeny testing

5.1 Extent of phenotypic variation in various geographical sites

Selection of best provenance and then selection of individual plus trees from the best provenance form the foundation for seed orchard. Selection of superior provenances or from wild populations of Indian tree species for seed collection and usage, on a large scale, is a practical method that can be immediately adapted to achieve genetic gain. In present study, ten trees of *Dalbergia sissoo* Roxb. were selected at random from natural populations of Ferozpur from Punjab, Reasi from Jammu and Kashmir, Hanumangarh from Rajasthan, Meerut and Basti from Uttar Pradesh and Udham Singh Nagar from Uttrakhand for recording morphological data in order to study phenotypic variation and collection of pod/seeds to work out seed storability and loss of vigor during storage and provenance cum progeny testing to find extent of genetic variation in juvenile growth and to find out best seed sources of *Dalbergia sissoo*. Substantial amount of variability was observed for total tree height, diameter at breast height, clean bole height, unforked height, straightness and crown diameter in natural populations of six diverse provenances *viz;* Ferozpur from Punjab, Reasi from Jammu and Kashmir, Hanumangarh from Rajasthan, Meerut and Basti from Uttar Pradesh and Udham Singh Nagar from Uttrakhand. The maximum variability was observed for unforked height followed by straightness. On overall basis maximum variability was observed in Udham Singh Nagar from Uttrakhand. Zobel *et al*. (1960) conducted studies on loblolly pine throughout its natural range on phenotypic variation and reported considerable variability in important morphological and physiological characteristics, both regionally and locally. Similarly, Khosla *et al.* (1980) made phenotypic variation studies in natural clones of *Populus ciliata* over a restricted geographical area. While reviewing variation in Indian tree species, Dogra (1981) emphasized on survey of phenotypic variation of silvicultural characteristics of tree species in their naturally distributed range. Jatasra and Paroda (1983) reported that in

natural stands of *Prosopis cineraria*, tree height varied from 4 to 22 m with mean values of 9.19 m, stem height and canopy height ranged from 1 to 8 m and 1 to 20 m, respectively. Main stem: canopy ratio (0.56) indicated that canopy grew almost double the height of stem.

In the present study, the total height of the naturally occurring trees of six provenances in *Dalbergia sissoo* exhibited a positive and significant correlation with diameter at breast height, clear bole height, straightness, crown diameter and unforked height. Johar *et al.* (2016) selected plus trees from the naturally occurring *Melia composita o*n the basis of straightness and other economic traits. They reported highly significant and positive correlation between age and other morphological characters *viz.* height clear bole height and GBH.

In the present study on *Dalbergia sissoo*, the phenotypic coefficient of variation (PCV) for seed and pod characters varied from 13.27% for pod breadth to 31.80% for seeds per pod. Regarding genotypic coefficient of variation (GCV), almost similar trend was observed. The difference between PCV and GCV was observed low for all the seed and pod characters. Heritability estimates in broad sense were higher than 57.80% for all the seed and pod characters. The genetic advance as percentage of mean ranged from 12.90 for weight of 100 pods to 42.10 for the weight of 1000 seeds. Sahoo *et al.* (2011) found significant variations among seed and pod characters with high phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and high heritability coupled with high genetic advance for 100 pod weights and 100 seed weight in *Pongamia pinnata*. Genotypic coefficient of variation was found higher than phenotypic correlation and all the characters were found positively correlated with each other. While studying morphometric characters of seventeen seed sources of *Pongamia pinnata*, Kumar (2012) found significant genetic variability among pod, seed and seedling traits with highest number of branches, seed thickness, internodal distance and pod breadth on 100 seed weight, whereas Meena *et al*. (2015) while estimating genetic parameters in pods and seed traits of candidate plus trees of *Tecomella undulata* (SM.) observed considerable variations in all the pod and seed characters like seeds/pod, pod length, and pod width and also concluded that the existence of substantial genetic variation, which can be utilized for further tree improvement programmes of this species. Heritability has an important place in tree breeding as it provides an index of the relative strength of heritability versus environment. Dorman (1976) reported that heritability estimate is important in tree improvement programmes. It is also useful for ranking importance of each trait in cross breeding programmes. Gains from tree breeding programmes depend on the type and extent of genetic variability. The best gains are for characteristics that are strongly under genetic control and have a wide range of variability (Zobel, 1971). Among 1-4 seeded pods, the single seeded ones were found in more than 60% in natural population of

Dalbergia sissoo in the current stage. Earlier, Bangarwa (1993) reported 60-90 % pods as single seeded in natural population of *Dalbergia sissoo.*

5.2 Provenance evaluation for seed storability and loss of vigor during storage

In the present study, the considerable variations in seed viability and germination percentage among different provenances were observed. Germination percentage immediately after collection was quite high. Significant differences were recorded for germination per cent among the different provenances. The germination per cent immediately after collection ranged from 82.6 per cent in Meerut provenance to 91.2 per cent in Udham Singh Nagar provenance with an average of 86.6 per cent. The germination per cent after storage of 18 months varied from 75.3 per cent in Meerut provenance to 80.4 per cent in Hanumangarh provenance with an average of 77.8 per cent. The reduction in germination per cent after storage of 18 months was found minimum in Hanumangarh provenance. Earlier Bangarwa (1993) reported seed storability of twenty provenances of *Dalbergia sissoo* from all over the northern India. Significant differences were found among provenances of low to medium rainfall and high rainfall areas and also between low to medium and high rainfall areas. In general, the germination per cent was relatively higher in provenances from low to medium rainfall areas. Earlier, Mathur *et al.* (1984), Shivkumar and Banerjee (1986) reported considerable variation for germination per cent in the provenances of *Acacia nilotica*. Robbins (1988) found 87 per cent germination from fresh seeds and 70 per cent after two years of storage in *Dalbergia sissoo*. Variations were observed in the storage life of teak seeds within moist type and between moist to very moist type (Emmanuel and Dharmaswamy, 1991).

Dalbergia sissoo is one of the most important leguminous tree species in India, yielding timber, fuel and fodder. Due to the increasing demand of this species for afforestation purposes, it is highly desirable to utilize good quality seed of this species for mass propagation of vigorous seedlings. The knowledge of genetic variability and association among seed quality traits is considered to provide considerable help in the genetic improvement of the species by way of making available reliable information on nature, extent and direction of selection. In the present study on *Dalbergia sissoo*, the moisture contents of seeds from all the provenances increased significantly in winter months during both the years. Seed vigor index-I and seed vigor index-II as well as germination per cent declined in all the provenances with the advancement of seed storage time. The reduction in both vigour index-I and vigour index-II was higher than standard germination for all the provenances during the storage period of eighteen months. Kumar and Bangarwa (2005) in their study on influence of storage period and storage conditions on vigor of Neem, reported that the rate of decrease in seed vigor was higher with the advancement of storage period. The average vigor index-I and vigor index -II was negligible after 60 days of storage. The rate of reduction in vigor indices

was highest in cold storage, whereas it was lowest in cloth bag storage at room temperature.

There was significant positive correlation between standard germination % and vigour index-I and II. There was positive association between vigour index-I and vigour index-II which reflected that longer seedlings had a tendency of being heavier. However, a negative correlation was observed in case of electrical conductivity for all the characters under study. Yadav *et al.* (1998) studied that seeds from five trees of shisham (*Dalbergia sissoo)* in each of eight girth classes *viz*., 0-30, 31-60, 61-90, 91-120, 121-150, 151-180, 181-210 and 211-240 cm inside the existing shisham plantation of CCS Haryana Agricultural University, Hisar were subjected to the measurement of seed quality parameters namely, electrical conductivity (µ mhos/cm/seed), germination (%), viability (%), accelerated ageing (%) and vigor index. Highly significant variation was recorded for seed and electrical conductivity among girth classes. Seed size gave highly positive correlation with seed germination, viability, accelerated ageing and vigor index whereas electrical conductivity was negatively correlated with all the seed quality parameters studied.

5.3 Provenance cum progeny testing

The tree populations under natural forest are generally genetically variable. They must be so in order to survive, grow and reproduce under the different conditions including some hazardous ones and numerous environments that are encountered during a single generation and over generations (Antonovics, 1971; Nienstaedt, 1975). The value of this gift of great variability in forest trees is often under estimated. The proper kind of genetically controlled variation provides the needed conditions for a tree improvement program, giving the necessary tools for large and quick gains from the use of genetics in forestry. As compared to agricultural crops, forest tree populations have been little influenced by human activities until now. In fact, even now, many important forest tree species like shisham have not been paid desired attention for their genetic improvement. Tree breeders are working essentially with wild populations that contain the genes and gene complexes needed for breeding programs. As a matter of fact, most forest tree species have greater variability than species of other organisms; it is reported to be almost double that of other plants (Hameric *et al.*, 1979). Forest tree breeder, therefore, are at a huge advantage by being able to draw on this variability in their breeding programme. However, it is also equally important to maintain and enhance the great store of variation for future use.

Success in the establishment and productivity of forest tree plantations is determined largely by the species used and source of seed within species (Larsen, 1954; Callaham, 1964; Lacaze, 1978). The need to use the best adapted seed source has been recognized in the early years by Tozawa (1924), Wakeley (1954) and Langlet (1967). Till more sophisticated, expensive and long term breeding techniques for further improvement are employed, the use of best seed source is the only available improvement method for fastest, cheapest and immediate gains. The provenance testing is very well developed area in forestry, which

indicates that there exist considerable differences between populations and between trees within populations growing at different sites and even between trees of a single stand. The relative contribution of heredity and environment in the expression of variation may be evaluated by raising seedlings from various seed sources under relatively uniform conditions as in growth chambers, green houses, nurseries or field tests.

Basically, selection exploits the natural variability available within a population of the chosen tree species. The amount and nature of genetic variation in any tree species can be assessed through progeny testing. In provenance cum progeny testing at the age of eighteen months in present study on *Dalbergia sissoo*, the mean sum of squares due to progenies were highly significant for all the characters *viz*., total height, basal diameter, unforked height, clear bole height, root length, fresh weight, dry weight, total dry biomass, plant straightness, root weight and shoot weight which indicated the presence of ample genetic variation for all the characters under study. Gera *et al.* (2001) reported significant variation in plant height, collar diameter and survival among 40 clones of *Tectona grandis* at the age of three and half years. Johar (2016) also reported wide variation in plus tree progenies of *Melia composita* at nursery stage.

In provenance cum progeny testing at the age of eighteen months in present study on *Dalbergia sissoo*, the highest phenotypic coefficient of variation (30.7%) was recorded for clear bole height followed by basal diameter and unforked height with 25.7 and 24.4 percent of PCV, respectively. The phenotypic coefficient of variation was found more than 12.2% for all the characters under study. Regarding genotypic coefficient of variation, almost similar trend was observed with highest genotypic coefficient of variation of 28.6 percent for clear bole height. The magnitude of phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the characters. Heritability estimates in broad sense were more than 65% for important growth characters like, total height, basal diameter, unforked height and clear bole height. Heritability estimates were more than 27.4% for all the characters under study. Genetic advance as percentage of mean were found moderate to high ranging from 22.5 for straightness to 58.3 for clear bole height. Simultaneous considerations of all parameters of variability indicated that the characters like total height, basal diameter, unforked height and straightness had higher proportion of variation as heritable in the collections of *Dalbergia sissoo.* Heritability has an important place in tree breeding as it provides an index of the relative strength of heritability versus environment. Dorman (1976) reported that heritability estimate is important in tree improvement programmes. It is also useful for ranking importance of each trait in cross breeding programmes. Gains from tree breeding programmes depend on the type and extent of genetic variability. The best gains are for characteristics that are strongly under genetic control and have a wide range of variability (Zobel, 1971). Rehman and Hussain (1986) found high broad sense heritability in *Dalbergia sissoo* for growth characters. On the other

hand, a low heritability value on the basis of the parent-progany relationship in *Dalbergia sissoo* was reported by Vidakovic and Siddiqui (1968). High heritability accompanied by high genetic advance for growth parameters have been reported by Solanki *et al.* (1984) in *Prosopis cineraria*. Kedharnath (1982) reported low heritability for height in *Eucalyptus grandis.*

The amount and nature of genetic variation in any tree species can be assessed through progeny testing. In provenance cum progeny testing at the age of eighteen months in present study on *Dalbergia sissoo,* progeny of FZP-4 from Ferozpur was found best (216.2 cm) for total height followed by progenies of BST-59 (213.9 cm) and BST-57 (207.6 cm) from Basti provenance. The maximum basal diameter (3.79 cm) was found in progeny of BST-60 from Basti provenance followed by progenies of FZP-4 (3.78 cm) from Ferozpur provenance, USN-45 (3.49 cm) from Udhamsingh Nagar provenance and FZP-4 (3.49 cm) from Ferozpur provenance. Progenies of FZP-4 from Ferozpur, BST-60, BST-59 and BST-57 from Basti provenance were found promising for total height and basal diameter. Bangarwa (1993) and Dogra *et al.* (2005) in *Dalbergia sissoo;* Solanki *et al.,* (1984) and Dhillon *et al.* (2003) in *Azadirachta indica,* Gera *et al.,* (2004) in *Albizia procera* and Kaushik *et al.* (2011) in *Pongamia pinnata* identified superior progenies on the basis of growth characters.

Anderson (1957) suggested the index score analysis for identification of overall superior genotypes. Bangarwa (2002) identified superior progenies in *Dalbergia sissoo* on the basis of index score analysis. Superior clones were also identified on the basis of index score analysis in *Populus deltoides* (Verma, 2001) and *Eucalyptus tereticornis* (Kumar, 2005).

Index score analysis carried out in sixty progenies of *Dalbergia sissoo* from six provenances revealed that the progeny of BST-59 from Basti provenance, FZP-5, FZP-4 and FZP-1 were found best with highest index score of 32. The progeny of BST-58 from Basti provenance ranked second with index score of 31 which indicated the superiority of this progeny for most of the characters under study. The progenies of FZP-10 from Ferozpur provenance, MRF-33 from Meerut provenance, USN-48 from Udamsingh Nagar provenance and BST-53 and BST-60 from Basti provenance ranked third with index score of 30. The progenies of BST-57 from Basti provenance with index score of 29, FZP-3 from Ferozpur provenance with index score of 29 and HGR-29 from Hanumangarh provenance with index score of 28 were found promising for many of the characters.

In provenance cum progeny testing at the age of eighteen months in present study on *Dalbergia sissoo,* Basti provenance was found best followed by Ferozpur provenance on the basis of growth performance of progenies. Seed sources from Basti and Ferozpur were found superior.

CHAPTER-VI

SUMMARY AND CONCLUSION

Dalbergia sissoo Roxb, a member of plant family leguminosae and the sub-family papilionoideae, is naturally distributed in the foot hills of Himalayas ranging from the Kabul River in Afghanistan to North Eastern India through northern Pakistan, northern India, Nepal, Bhutan and Assam. India, Nepal and Pakistan are well endowed with natural stands of *Dalbergia sissoo* distributed in discrete watersheds of long isolation. Since the species grow on wide range of ecological sites, as a result considerable variation exists in natural population for stem form and other morphological characters. A very high frequency of sissoo in natural populations is with crooked and forked stem with very little proportion of straight trees. These natural populations appear degraded (more number of trees with undesirable traits) due to long history of selective felling (felling of trees with desirable characters).

The present investigation on "Studies on genotypic and phenotypic variations in *Dalbergia sissoo* Roxb." was undertaken with a view to (i) to study the extent of phenotypic variation in various geographic sites; (ii) to find out the seed storability and loss of vigour during storage; (iii) to find out the extent of genotypic variation in juvenile growth of various progenies from different geographical sites and (iv) to find out the best seed source of *Dalbergia sissoo* Roxb. for further tree improvement programme. Salient findings are summarized herewith.

6.1 Extent of phenotypic variation in various geographical sites

6.2 Provenance evaluation for seed storability and loss of vigor during storage

6.3 Provenance cum progeny testing

6.1 Extent of phenotypic variation in various geographical sites

- Substantial amount of variability was observed for total tree height, diameter at breast height, clean bole height, unforked height, straightness and crown diameter in natural populations of six diverse provenances viz; Ferozpur from Punjab, Reasi from Jammu and Kashmir, Hanumangarh from Rajasthan, Meerut and Basti from Uttar Pradesh and Udham Singh Nagar from Uttrakhand.
- The maximum variability was observed for unforked height followed by straightness. On overall basis maximum variability was observed in Udham Singh Nagar from Uttrakhand.
- The total height of the naturally occurring trees of six provenances in *Dalbergia sissoo* exhibited a positive and significant correlation with diameter at breast height, clear bole height, straightness, crown diameter and unforked height.
- Among 1-4 seeded pods, the single seeded ones were found in more than 60 per cent in natural population of *Dalbergia sissoo.*

- The phenotypic coefficient of variation (PCV) for seed and pod characters varied from 13.27% for pod breadth to 31.80% for seeds per pod. Regarding genotypic coefficient of variation (GCV), almost similar trend was observed. The difference between PCV and GCV was observed low for all the seed and pod characters. Heritability estimates in broad sense were higher than 57.80% for all the seed and pod characters. The genetic advance as percentage of mean ranged from 12.90 for weight of 100 pods to 42.10 for the weight of 1000 seeds.

6.2 Provenance evaluation for seed storability and loss of vigor during storage

- The considerable variations in seed viability and germination percentage among different provenances were observed. Germination percentage immediately after collection was quite high. Significant differences were recorded for germination per cent among the different provenances.
- The moisture contents of seeds from all the provenances increased significantly during monsoon season during both the years. Seed vigor index-I and seed vigor index-II as well as germination per cent declined in all the provenances with the advancement of seed storage time.
- The reduction in both vigour index-I and vigour index-II were higher than standard germination for all the provenances during the storage period of eighteen months.
- There was significant positive correlation between standard germination % and vigour index-I and II. There was positive association between vigour index-I and vigour index-II which reflected that longer seedlings had a tendency of being heavier. However, a negative correlation was observed in case of electrical conductivity for all the characters under study.
- The germination per cent immediately after collection ranged from 82.6% in Meerut provenance to 91.2% in Udham Singh Nagar provenance with an average of 86.6 per cent. The germination per cent after storage of 18 months varied from 75.3% in Meerut provenance to 80.4% in Hanumangarh provenance with an average of 77.8 per cent. The reduction in germination per cent after storage of 18 months was found minimum in Hanumangarh provenance.

6.3 Provenance cum progeny testing

- The mean sum of squares due to progenies were highly significant for all the characters *viz;* total height, basal diameter, unforked height, clear bole height, root length, fresh weight, dry weight, total dry biomass, plant straightness, root weight and shoot weight which indicated the presence of ample genetic variation for all the characters under study.
- The highest phenotypic coefficient of variation (30.7%) was recorded for clear bole height followed by basal diameter and unforked height with 25.7 and 24.4 per cent of PCV, respectively. The phenotypic coefficient of variation was found more than

12.2% for all the characters under study. Regarding genotypic coefficient of variation, almost similar trend was observed with highest genotypic coefficient of variation of 28.6 percent for clear bole height. The magnitude of phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the characters.

- Heritability estimates in broad sense were more than 65% for important growth characters like, total height, basal diameter, unforked height and clear bole height. Heritability estimates were more than 27.4% for all the characters under study. Genetic advance as percentage of mean were found to be moderate to high ranging from 22.5 for straightness to 58.3 for clear bole height. Simultaneous considerations of all parameters of variability indicated that the characters like total height, basal diameter, unforked height and straightness had higher proportion of variation as heritable in the collections of *Dalbergia sissoo.*
- Progeny of FZP-4 from Ferozpur was found best (216.2 cm) for total height followed by progenies of BST-59 (213.9 cm) and BST-57 (207.6 cm) from Basti provenance. The maximum basal diameter (3.79 cm) was found in progeny of BST-60 from Basti provenance followed by progenies of FZP-4 (3.78 cm) from Ferozpur provenance, USN-45 (3.49 cm) from Udhamsingh Nagar provenance and FZP-4 (3.49 cm) from Ferozpur provenance. Progenies of FZP-4 from Ferozpur, BST-60, BST-59 and BST-57 from Basti provenance were found promising for total height and basal diameter.
- Index score analysis carried out in sixty progenies of *Dalbergia sissoo* from six provenances revealed that the progeny of BST-59 from Basti provenance, FZP-1, FZP-4 and FZP-5 were found best with highest index score of 32. The progeny of BST-58 from Basti provenance ranked second with index score of 31 which indicated the superiority of this progeny for most of the characters under study. The progenies of FZP-10 from Ferozpur provenance, MRF-33 from Meerut provenance, USN-48 from Udamsingh Nagar provenance and BST-53 and BST-60 from Basti provenance ranked third with index score of 30. The progenies of BST-57 from Basti provenance with index score of 29, FZP-3 from Ferozpur provenance with index score of 29 and HGR-29 from Hanumangarh provenance with index score of 28 were found promising for many of the characters.
- Based on growth performance of progenies, Basti provenance was found best followed by Ferozpur provenance. Seed sources from Basti and Ferozpur were found superior.

BIBLIOGRAPHY

Anderson, E. 1957. A semigraphical method for the analysis of complex problems. *Proceedings of National Academy of Sciences,* **43**: 923-927.

Antonovics. 1971. The effects of a heterogeneous environment on the genetics of natural populations. *Am. Science,* **59** (5): 593-595.

Bagchi, S.K. and Kulkarrni, H.D. 1987. A note on seedling abnormality frequency in the half sib progenies of *Santalum album. Indian Forester,* **113** : 650-651.

Bagchi, S.K., Choubey, A.K. and Kulkarni, H.D. 1987. Variability analysis among half sib seedlings of *Santalum album* L. *Indian Forester,* **113**: 370-374.

Bangarwa, K.S. 1993. Studies on provenance variations, progeny testing and reproductive biology in *Dalbergia sissoo*. Ph.D. Thesis submitted in the Department of Plant Breeding, CCS H.A.U., Hisar, 165 p.

Bangarwa, K.S. 1996. Sissoo breeding, Agriculture and Forestry Information Centre. 146 p.

Bangarwa, K.S. 2002. Plus tree selection and progeny testing for establishment of first general seed orchard in *Dalbergia sissoo* Roxb. *Indian Journal of Agroforestry*, **4**: 122-131.

Bangarwa, K.S. and Singh, V, P. 2001. Provenance variation for seed and pod characters in *Dalbergia sissoo* Roxb. *Forage Research,* **27**(3): 201-212.

Bangarwa, K.S. and Singh, V.P. 1998. Phenotypic variation in natural populations of *Dalbergia sissoo* Roxb. *Biodiversity Forest Special,* pp. 171-182.

Bangarwa, K.S., Hooda, M.S. and Puri, S. 1992. An ideal plus tree in *Dalbergia sissoo* Roxb. for Agroforestry. *In: MPTS for Agroforestry System* (Eds. Pathak, P.S., Roy, R.D. and Singh, P.). *Range Management Society of India,* IGFRI, Jhansi, India, pp. 111-114.

Bangarwa, K.S., Singh, V.P. and Tomar, R.P.S. 1995. Progeny testing for seed quality parameters in *Dalbergia sissoo* Roxb. *Seed Science & Technology*, **23**: 253-257.

Burley, J. 1965. Genetic variation in *Picea sitchensis* (Bong) Carr. Abstr. of thesis, in Dissert. Abstract, **26**(4): 1847

Burley, J. 1987. Strategies for genetic improvement of agroforestry trees. *In: Agroforestry for Rural needs* (Eds. P.K. Khosla and D.K. Khurana), ISTS, Solan, India. pp. 253-256.

Burton, G.W., 1952. Quanntitative inheritance in grasses. In: Proceedings of the 7th International Grassland Congress,**1**:277-283.

Callaham, R.Z. 1964. Provenance research: Investigation of genetic diversity associated with geography. *Unasylva,* **18**: 40-50.

Champion, H.G. and Seth, S.K. 1968. A revised survey of the forest type of India. New Delhi : Govt, of India Press.

Chaturvedi, M.D. 1956. The friendly shisham. *Indian Farming,* **6**(2): 19-20.

Chauhan, P.S. 1987. Silvi-genetical approaches in productivity *of Populus ciliata* Wall, ex Royal. Ph.D. thesis submitted to Dr. Y.S.Parmer University of Hort. and Forestry, Solan (HP).

Chauhan, Y. S. and Shams, P.M. 2008. Seed germination and morphological traits of seed/pod of *Delonix regia* Bojer. Rafin. *Annals of Forestry*, **16**(2): 255-260.

Costa, R.B., Resende, M.D.V., Contini, A.Z., Rao, R.A.R. and Martins, W.J. 2005. Genetic evaluation of *Leucaena leucocephala* Lam. De wit progenies in indigenous reserve, in Caarapo city, MS. Seropedica, Brazil: *Inst itudo de Florestas,* **4**(1): 72-76.

Devagiri, G.M., Dhiman, R.C., Thapliyal, R.C., Patil, C.S.P. and Kumar, N. 2004. Genetic analysis of traits related to seed germination and vigour among provenances of shisham (*Dalbergia sissoo* Roxb.). *Annals of Forestry,* **12**(2): 161-171.

Dhillon, G.P.S., Gill, R.I.S., Kaur, N. and Singh, B. 2008. Variation in seed parameters, germination behavior and seedling traits among different seed sources of *Jatropha curcas* Linn. *Annals of Forestry,* **16**(1): 1-7.

Dhillon, R. S. 1992. Studies on phenotypic variation and provenance evaluation of *Dalbergia sissoo Roxb*. In Haryana. M.Sc. Thesis, CCS Haryana Agricultural University, Hisar, India.

Dhillon, R.S., Bisla, S.S., Arya, S. and Hooda, M.S. 2003. Genetic variation, heritability and correlation for growth parameters in *Azadirachta indica* A. Juss. *Annals of Forestry,* **11**(2): 215-221.

Dogra, A.S., Nautiyal, S., Nautiyal, D.P. and Singh, S. 2005. Evaluation of field performance of 34 progenies of *Dalbergia sissoo* in Punjab. *Annals of Forestry*, **13**(2): 199-209.

Dogra, P.D. 1981. Forest genetics research and application in Indian forestry-I, II. *Indian Forester,* **107**: 190-219.

Dogra, P.D. 1992. Priorities in forest tree genetics: unrealized tree improvement and breeding potential in Indian forestry. *In: Status of Indian Forestry* (P.K.Khosla, ed), ISTS, Solan: pp. 243-259.

Dorman, K.W. 1976. The Genetics and Breeding of Southern Pines. Agriculture Handbook No.471. USDA, US Forest Service, Washington, D.C.

Emmanuel, C.J.S.K., Kapoor, M.L. and Sharma, V.K. 1992. Three decades of forest genetics and tree improvement. *Indian Forester,* **118**: 489-500.

Emmanuel, CJ.S.K. and Dharamaswamy, S.S. 1991. Short note : seed source variation in storage life of teak seeds. *Silvae Genetica,* **40**: 249-250.

Finkeldey R. and Hattemer H.H. 2006. *Tropical Forest Genetics*. Springer Berlin Heidelberg.

Gera, M., Awadhiya, A,. and Gera, N. 2016. Provenance trail of *Dalbergia sissoo* Roxb. *Indian Forester,* **142**(3): 213-220.

Gera, M., Gera, N. and Sharma, S., 2001. Establishment of variability in growth characters of forty clones of *Tectona grandis*. *Indian Forester*, **127**: 639-643.

Gera. M., Gera, N. and Ginwal, H.S. 2004. Performance of eleven seed source/provenances of *Albizia procera* Roxb, under semi-arid region of Central India. *Annals of Forestry,* **12**(1): 73-80.

Ginwal, H.S., Phartyal, S.S., Rawat P.S. and Srivastava, R.L. 2005. Seed source variation in morphology, germination and seedling growth of *Jatropha curcas* Linn. in central India. *Silvea Genetica*, **54**(2): 76-80.

Gupta, G., Dwivedi, A.K. and Shik Kumar, P. 1992. Forest tree improvement programmes in Uttar Pradesh. *Indian Forester,* **118**: 389-393.

Gupta, V.K. and Patil, B.D. 1988. Genetic variability and path analysis in Leucaena. *Indian Journal of Agricultural Sciences,* **58:** 483-484.

Gurunathan, N., Ahlawat, S.P. and Rajarajan. K. 2014. Performance of different accessions of *Pongamia pinnata*. *Indian Forester,* **140**(9): 837-840.

Hameric, J.L., Metton, Y.B. and Linhart, Y.B. 1979. Levels of genetic variation in trees: Influence of life history characteristics. Proc. Symp. On sozymes of N. Amer. For. Trees, Berkeley, Calif,: pp. 35-41.

Hooda, M.S., Dhillon, R.S., Dhanda, S., Kumari, S., Dalal, V. and Jattan, M. 2009. Genetic divergence studies in plus trees of *Pongamia pinnata*, Karanj. *Indian Forester,* **135**: 1069-1079.

Huang, S.N. 1989. A note on genetic variation in seeds and seedling of five provenances of *Acacia auriculiformis*. *Tropical Forest Science*, **1**: 401-404.

Hussain, R.W. and Abbas, S.H. 1974. Volume tables for shisham in irrigated plantations of the Punjab. For. Mens. Br., Div. of For. Res., Leaflet No. 26, PFI, Peshawar : 30 p.

International Seed Testing Association. 1985. International rules for seed testing.Proceedings of *International Seed Testing Association*. **31**:1-52.

Jatasra, D.S. 1982. Germplasm collection of *Prosopis cineraria* from the Indian desert. *Forage Research*, **8**: 1-9.

Jatasra, D.S. and Paroda, R.S. 1983. Evaluation of *Prosopis cinceria* germplasm from desert. Trans. Isdt & Ucds, **8**: 138-142.

Jindal, S.K., Kackar,N.L. and Solanki, K.R. 1987. Germplasm collection and genetic variability in Rohida *Tecomela undulata* (Sm.) in western Rajasthan. *Indian Forester,* **10**: 52-55.

Jindal, S.K., Singh, M., Solanki, K.R. and Kackar, N.L. 1991. Variability, and changes in genetic parameters of height in juvenile progenies of *Tecomella undulata* (Sm.) Seem. *Tree Sciences,* **10**: 25-28.

Johnson, H.W. Robinson, H.F. and Comstock, R.E. 1955. Estimates of genetic and environmental variability in soyabean. *Agronomy Journal*. **47**:314-318.

Johar, V., Sharma, K.B., Rachana and Kumar, P. 2016. Plus tree selection and progeny testing of Burma Dek (*Melia composite* Wild.). *Indian Journal of Ecology*. **43**(1): 364-367.

Kackar, N.L., Solanki, K.R. and Jindal, S.K. 1986a. Variation for morphological characters in *Prosopis cineraria* in natural stands. *Myforest,* **22**: 129-134.

Kackar, N.L., Solanki, K.R. and Jindal, S.K. 1986b. Variation in fruit and seed characters of *Prosopis cineraria* in Thar desert. *Indian Forester,* **9**: 113-115.

Kala, S. and Kumaran, K. 2012. Genetic divergence studies among the progenies of plus trees in *Bixa orellan*a L. *Indian Forester,* **138**(9): 828-834.

Kaushik, N., Kumar, K., Kumar, S., Beniwal, R.S. and Suman. 2011. Variability assessment in *Pongamia pinnata* (L.) Pierre germplasm collected from Haryana, India. *Range Management and Agroforestry,* **32(**1): 56-60.

Kaushik, N., Mann, S and Kumar, K. 2011a. Variability in growth characters among progenies of *Pongamia pinnata* (L.) Pierre. *Range Management and Agroforestry,* **32**(2): 131-134.

Kedarnath, S. 1982. A Plus tree selection- a tool in forest tree improvement. In: Khosla, P.K. (Ed.) Improvement of Forest Biomass. Indian Society of Tree Science, H.P. University, Solan (India). pp. 13-20.

Kedharnath, S. 1982b. Plus tree selection - a tool in forest tree improvement. In : Improvement of Forest Biomass (P.K.Khosla, eds), ISTS, Solan : pp. 13-20.

Kedharnath, S., Chetty, R. and Rawat, M.S. 1960. Estimation of genetic parameters in teak (*Tectona grandis*) without raising progenies. *Indian Forester,* **86**: 238-245.

Khosla, P.K.., Sagwal, S.S., Khurana, D.K. and Sareen., T.S. 1980. Phenotypic variation in natural stands of *Pinus roxburghii Silvicultura,* **16**: 36 p.

Khurana,D.K. and Khosla, P.K. 1980. Provenance site-interaction trial on *Populus ciliata* wall ex Royle. IUFRO Symposium on Fast Growing Trees Brazil. *Silvicultura*, **16** : 102 p.

Kumar, R. 2005. Studies on genetic variability among different clones and invitro propagation in Eucalyptus tereticornis Smith. Ph.D. Thesis submitted to CCS Haryana Agricultural University, Hisar. 182 p.

Kumar, R. 2012. Genetic variability and association studies in *Pongamia pinnata* L. Pierre. *Range Management and Agroforestry,* **33**(2): 129-132.

Kumar, R. and Bangarwa, K.S. 1996. Seed storability in A*zadirachta indica* A. Juss. *Annals of Biology,* **12**(1): 62-66.

Kumar, R. and Bangarwa, K.S. 2005. Influence of storage periods and storage conditions on vigour of neem (*Azadirachta indica*) seeds. *Environment and Ecology,* **23**(3): 428-431.

Kumar, Rakesh. 2012. Genetic variability and association studies in *Pongamia pinnata* (L.) Pierre. *Range Management and Agroforestry,* **33**(2): 129-132.

Lacaze, J. F. 1978. Advances in species and provenance selection. *Unasylva*, **30**: 17-20.

Ladoffe, S.S. and Maghembe, 3.A. 1988. Performance of teak provenances seventeen years after planting at Longuza, *Tanzania. Silvae Genetica,* **37**: 175-178.

Langlet, O. 1967. Regional Intraspecific variousness. IUFRO Congress, Munchen, Germany, Vol. III : pp. 435-458.

Larsen, C.S. 1954. Provenance testing and forest tree breeding. Proc. 11 throng. IUFRO, Rome :467-473.

Lush, J.L. 1949. Heritability of quantitative characters in farm animals. Proceedings of the 8th International Genetic Congress., Hereditas (Supple): 356-357.

Madoffe, S. S. and Maghembe, J.A. 1988. Performance of teak provenances seventeen years after planting at Longuza, Tanzania. *Silvae Genetica*, **37**: 175-178.

Mathews, J.D. 1961. A programme ol forest genetics and tree breeding Research, Report to Govt, of India, reproduced for FAO publication No. 1349.

Mathur, R.S., Sharma, K.K. and Rawat, M.M.S. 1984. Germination behaviour of various provenances of *Acacia nilotica. Indian Forester*, **110**: 435-449.

Meena, D., Singh, A. and Rawal, C. 2015. Estimation of genetic parameters in pods and seed traits of candidate plus trees of *Tecomella undulata* (SM.) Seem. *Indian Forester*, **141** (7): 748-754.

Moore, R.P.(ed), 1985. Handbook of Tetrazolium Testing. ISTA, Zurich, Switzerland.

Neil, P.E. 1990. *Dalbergia sissoo* provenance testing in Nepal. Nitrogen Fixing Tree Research Report. **8**: 130-132.

Ngulube, M.R. 1989. Genetic variation in seed germination and seedling growth of 24 *Gliricidia sepium* provenances. *Forest Ecology and Management*, **28**:1-6.

Nienstaedt, H. 1975. Adaptive variation -Manifestations in Tree species and uses in forest management and tree improvement. Proc. 15th Can. *Tree Improvement Association*, Part 2: 11-23.

Panse, U.G. and Sykhatme, M.U. 1967. Statistical methods for agricultural workers. Second Edition ICAR, New Delhi.

Panwar, G.S. and Srivatsava, S.K. 2015. Seed germination and seed storage behaviour of *Eremostachys superba*: An endangered medicinal and ornamental herb of India. *Indian Forester*, **141**(7): 762-765.

Puri, D.N., Gupta, R.K. and Dhyani, S.K. 1989. Screening for promising *Leucaena* provenances for Doon valley. *Indian Forester*, **115**: 900-904.

Rao, D.V. 1984. Provenance trial of Eucalyptus. *Indian Forester*, **110**: 28-34.

Rao, H.S. 1950. Genetics' and forest tree improvement. *Indian Forester*, **77**: 635-647.

Rawat, M.S., Uniyal, D.P. and Vakshasya, R.K. 1987. Guidelines for the establishment of provenance trials of *Acacia nilotica, Azadirachta indica ,Albizia procera, Dalbergia sissoo, Tamarindus indicus, Madhuca latifolia and Salix tetrasperma.* Indo- Danish Project on Seed Procurement and *Tree Improvement Centre,* Dehradun.

Rehman, S.A. and Hussain, A. 1986. Growth and- heritability estimates among 6-yeais old tree geographic source of shisham (*D. sissoo*) Pakistan 3. *Forests,* **36**: 67-72.

Rehman, S.A., Hussain, A. and Ameen, S. 1988. Results of early selection of *Acacia* and in *Prosopis* species/seed sources. Pakistan. *Journal of Forestry*, **38**: 109-117.

Robbins, A.M.J. 1988. Storage of sissoo seeds. Kathmandu, Nepal; Forest Research and Information Centre, Forest Survey and Research. Office, Deptt. of Forest. *Bano Ki Janakari,* **2**(1): 57-59.

Sagwal, S.S. 1985. Clonal selection of poplar in Palam Valley of Himachal Pradesh. *Indian Journal of Forestry*, **8**: 173-175.

Sah, A.K., Bhandari, A.S., Chaubey, O.P. and Jamaluddin. 1988. Frost tolerance of tree species used in wasteland afforestation in Madhya Pradesh. *Journal of Tropical Forestry*, **4**(2): 188-190.

Sahoo, D.P., Rout, G.R., Das, S., Aprajita, S. and Mahapatra, A.K. 2011. Genotypic variability and correlation studies in pod and seed characteristics of *Pongamia pinnata* L. Pierre in Orissa, India. *International Journal of Forestry Research*, 6 p.

Sharma R.C., Pal M. and Singh, R. 2010. Performance of shisham *(Dalbergia sissoo* Roxb.) provenances against ganoderma root rot. *Indian Forester*, **136**(5): 588-593.

Sheikh, A.H. and Matin, M.A., 2007. Seed morphology and germination studies of *Dalbergia sissoo* Roxb. in Central Himalaya. India. *Tropical Agriculture Research and Extension*, **11**: 39-44.

Sheikh, M.I. 1989. *Dalbergia sissoo* Roxb. Its Production, Management and Utilization in Pakistan. GCP/RAS/111/NET. Field Document No.21. FAO Publication.

Sindhu, H.C., Veerendra and Sharma, C.R. 1990. Variation studies in sandal (*Santalum album* L.). Time of emergence and seedling vigour. *Indian Forester*. **116**(7):568-571.

Singh, B. and Bhatt, B.P., 2008a. Provenance variation in pod, seed and seedling traits of *Dalbergia sisso* Roxb. In Central Himalaya, India. *Tropical Agriculture Reasearch and Extension*, **11**:39:44.

Singh, B. and Bhatt, B.P., 2008b. Germination behaviour of *Dalbergia sissoo* as affectes by seed sopurce and temperature. *Indian Jornal of forestry*, 3 (4): 565-570.

Shiv Kumar, P. and Banerjee, A.C. 1986. Provenance trials of *Acacia nilotica. Journal of Tree Science*, **5**: 53-56.

Sofi, A.H. and Singh, O., 2011. Variation in seed germination and nursery growth among families of *Dalbergia sisso* Roxb. *Annals of Forestry*, **19**(1):69-74.

Solanki, K.R., Muthana, K.D., Jindal, S.K. and Arora, C.D. 1984. Variability, heritability and correlations for growth parameters in *Prosopis cineraria*. *Journal of Tree Science*, **3**: 86-88.

Surendran, C. and Chandrasekhran, P. 1984. Heritability variation and genetic gain estimates in half sib progenies of *Eucalyptus tereticornis*. *Journal of Tree Sciences.* **3**: 1-4.

Suri, P.N. and Seth, S.K. 1959. Tree planting practices in Temperate Asia. Burma-India-Pakistan, Rome, FAO. Forest Development Paper 14.

Tewari, D.N. 1994. A monograph on *Dalbergia sissoo* Roxb. International Book Distributors, Dehradun.

Thakur, I.K. and Thakur,S. 2015. Variability, heritability, genetic gain, genetic advance and correlation in growth characteristics of progenies of *Melia azedarach*. *Indian Forester*, **141**(3): 247-253.

Tozowa,M. 1924. Necessity of provenance test and the urgent need of a test plantation network. *Journal of Korean Forestry Association*, **22**: 1-5.

Venkatesh, C.S. 1969. The early growth of certain half sib progenies of *Bombax ceiba* L. Paper contributed to the FAO sponsored Second World Consultation of Tree Breeding. Washington DC.

Venkatesh, C.S. and Vakshasya, R.K. 1977. Effect of selfing, crossing and interspecific hybridization in *Eucalyptus camaldulensis*. Third World Consultation on Forest Tree Breeding, Canberra

Verma, R.C. 2001. Studies on genetic variation and clonal testing in *Populus deltoides* Bartr. Ex Marsh. Ph. D. Thesis, CCS Haryana Agricultural University, Hisar. 139 p.

Vidakovic, M. and Ahsan, J. 1970. The inheritance of crooked bole in *Dalbergia sissoo* Roxb. *Silvae Genetica*, **19**: 94-98.

Vidakovic, M. and Siddiqui, K.M. 1968. Heritability of height and diameter growth in *Dalbergia sissoo* using one parent progeny test. *Pakistan Journal of Forestry*, **18**: 75-94.

Volkar, P.W., Dean, C.A., Tibbits, W.B. and Ravenwood, I.C. 1990. Genetic parameters and gain expected from selection in *Eucalyptus globulus* in Tasmania. *Silvea Genetica*, **39**: 18-21.

Wakeley, P.C. 1954. The relation of geographic race to forest tree improvement. *Journal of Forestry*, **52**: 653 p.

Wright, J.W. 1976. Introduction to Forest Genetics. Academic Press, New York.

Yadav, S.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.

Zobel, B. and Talbert, J. 1984. Applied Forest Tree Improvement. Jhon Willey and sons, New York. 505 p.

Zobel, B., Thorbjornsen, E. and Henson, F. 1960. Geographic site and individual tree variation in wood properties of Loblollypine. *Silvae Genetica*, **9**: 149-158.

Zobel, B.J, Barber,J., Brown, C.L. and Perry, T.O. 1958. Seed orchards; their concept and management *Journal of Forestry*, **56**: 815-825.

Zobel, B.J. 1971. The genetic improvement of southern pines. *Scientific American*, **225**: 94-103.

Zobel,B.J. 1952. The genetic approach for improving wood qualities of the southern pines. *Journal of Forestry*, **2**: 45-47.

ABSTRACT

Title of Thesis	:	Studies on genotypic and phenotypic variations in *Dalbergia sissoo* Roxb.
Name of degree holder	:	SANJAY KHAJURIA
Admission No.	:	2012A63D
Title of degree	:	Doctor of Philosophy
Name and Address of Major Advisor	:	Dr. K.S. Bangarwa Major Advisor (Professor & Head) Department of Forestry CCS Haryana Agricultural University, Hisar
Degree awarding University/ Institute	:	CCS Haryana Agricultural University, Hisar-125004 (Haryana), India.
Year of award of degree	:	2016
Major Subject	:	Forestry
Total No. of Pages in the Thesis	:	66 + vi
No. of words in the abstract	:	Approx. 457

Key words : *Dalbergia sissoo*, phenotypic variation, genotypic variation, provenance, heritability and progeny.

The present investigation entitled "Studies on genotypic and phenotypic variations in *Dalbergia sissoo* Roxb." was carried out in three broad experiments *viz;* extent of phenotypic variation in various geographical sites, provenance evaluation for seed storability and loss of vigor during storage and provenance cum progeny testing. Substantial amount of variability was observed for total tree height, diameter at breast height, clean bole height, unforked height, straightness and crown diameter in natural populations of six diverse provenances viz; Ferozpur from Punjab, Reasi from Jammu and Kashmir, Hanumangarh from Rajasthan, Meerut and Basti from Uttar Pradesh and Udham Singh Nagar from Uttrakhand. The maximum variability was observed for unforked height followed by straightness. However, on the overall basis, maximum variability was observed in Udham Singh Nagar from Uttrakhand. The considerable variations in seed viability and germination percentage among different provenances were also observed. Germination percentage immediately after collection was quite high. Significant differences were recorded for germination per cent among the different provenances. The germination per cent immediately after collection ranged from 82.6% in Meerut provenance to 91.2% in Udham Singh Nagar provenance with an average of 86.6 per cent. The germination per cent after storage of 18 months varied from 75.3% in Meerut provenance to 80.4% in Hanumangarh provenance with an average of 77.8 per cent. The reduction in germination per cent after storage of 18 months was found minimum in Hanumangarh provenance. The mean sum of squares due to progenies were highly significant for all the characters *viz*., total height, basal diameter, unforked height, clear bole height, root length, fresh weight, dry weight, total dry biomass, plant straightness, root weight and shoot weight which indicated the presence of ample genetic variation for all the characters under study. The magnitude of phenotypic coefficient of variation was higher than the corresponding genotypic coefficient of variation for all the characters. Heritability estimates in broad sense were more than 65% for important growth characters like, total height, basal diameter, unforked height and clear bole height. Index score analysis carried out in sixty progenies of *Dalbergia sissoo* from six provenances revealed that the progeny of BST-59 from Basti provenance, FZP-1, FZP-4 and FZP-5 from Firozepur provenance were found best with highest index score of 32 followed by progeny of BST-58 from Basti provenance with index score of 31 and the progenies of FZP-10 from Ferozpur provenance, MRF-33 from Meerut provenance, USN-48 from Udamsingh Nagar provenance and BST-53 and BST-60 from Basti provenance with index score of 30. Progenies of FZP-4 from Ferozpur, BST-60, BST-59 and BST-57 from Basti provenance were found promising for total height and basal diameter. Based on growth performance of progenies, Basti provenance was found best followed by Ferozpur provenance. Seed sources from Basti and Ferozpur were found superior.

MAJOR ADVISOR **DEGREE HOLDER**

HEAD OF THE DEPARTMENT

CURRICULUM VITAE

Name	:	Sanjay Khajuria
Date of birth	:	January 01, 1977
Place of birth	:	Jammu
Mother's name	:	Smt. Maya Devi
Father's name	:	Sh. Hans Raj
Permanent address	:	VPO:-Billawar,District- Kathua,
Mobile	:	09419125917
E-mail	:	khajuriascientiest@gmail.com

Academic qualifications

Degree	University/ Board	Year of passing	Division	Subjects
B. Sc. Ag (Hons.)	Dr. B.R.A U, Agra	2000	First	All Agricultural subjects
M.Sc. Forestry	Dr. B.R.A.U, Agra	2002	First	Major-Forestry, Minor-Agro-Forestry
Ph.D Forestry	CCSHAU, Hisar	2016	First	Major-Forestry, Minor-Seed Science & Technology
ARS	ASRB, New Delhi	2003	Qualified	Forestry

Citation : Awarded with Young Scientiest Award for Ph.D Research paper by the Plant society of India at Ahemdabad, Gujrat on February 2015

Participated in National seminars at GBPUAT, Pantnagar (U.K), Ahemdabad (GUJRAT), CCSHAU, Hisa r(Haryana),

List of publications :
Research paper- 19, Scientific articles- 72, Technical Bulletins- 12, Pamphlets- 6, Abstracts- 54, Radio talks- 64, TV Talks- 42, Fellow and Editorial member of various National and International scientific societies, Participated in many National and International Seminars and Undergone various Training programmes.

Sanjay Khajuria

UNDERTAKING OF COPYRIGHT

I, Sanjay Khajuria, Adm. No. 2012A63D, undertake that I give copyright to the CCS HAU, Hisar of my thesis entitled **"Studies on genotypic and phenotypic variations in *Dalbergia sissoo* Roxb"**.

I also undertake that patent, if any, arising out of the research work conducted during the program shall be filled by me only with due permission of the competent authority of CCS HAU, Hisar.

Signature of the student