

**VARIABILITY STUDIES ON *Quercus leucotrichophora*
A. Camus POPULATIONS IN HIMACHAL PRADESH**

Thesis

by

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(F-2014-24-M)**

submitted to



**Dr. YASHWANT SINGH PARMAR UNIVERSITY OF
HORTICULTURE AND FORESTRY
SOLAN (NAUNI) HP - 173 230 INDIA**

in

**Partial fulfilment of the requirements for the degree
of**

**MASTER OF SCIENCE
(FORESTRY)
FOREST GENETIC RESOURCES**

**DEPARTMENT OF TREE IMPROVEMENT
AND GENETIC RESOURCES
COLLEGE OF FORESTRY
2016**

FRONTISPIECE



BAN OAK TREE (*Quercus leucotrichophora* A. Camus)

FAMILY-FAGACEAE



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CERTIFICATE-I

This is to certify that the thesis titled, “**Variability Studies on *Quercus leucotrichophora* A. Camus Populations in Himachal Pradesh**” submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (FORESTRY) FOREST GENETIC RESOURCES** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173230 is a record of bonafide research work carried out by **Ms Sangeeta Devi (F-2014-24-M)** daughter of Shri Hemraj sharma under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations has been fully acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled, “**Variability Studies on *Quercus leucotrichophora* A. Camus Populations in Himachal Pradesh**” submitted by **Ms Sangeeta Devi (F-2014-24-M)** daughter of Shri Hemraj Sharma to the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) – 173230 India in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (FORESTRY) FOREST GENETIC RESOURCES** has been approved by the Advisory Committee after an oral examination of the student in collaboration with the External Examiner.

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ACKNOWLEDGEMENTS

*Research is an evolving concept. Any endeavour, in this regard is challenging as well as exhilarating. It implies the testing of our nerves. It brings to light our patience, vigour and dedication. First and foremost, I want to thank the **Almighty God** for helping me to accomplish this task. The journey is still continuing with many more destinations to cover. Before I stop, I pray for his blessings to be with me till the end of this life journey.*

*With great reverence, I express my warmest feelings with deep sense of gratitude to the chairperson of my advisory committee, **Dr. H.P. Sankhyan** (Principal Scientist/Professor), Forestry. I have no words to express my heartfelt thanks to him for illuminating guidance, unfailing encouragement, scholarly suggestion, unique supervision, constructive criticism, sympathetic attitude and keen interest during the course of this investigation and in the preparation of this manuscripts. It was a great opportunity for mine to work under his guidance.*

*I seize this opportunity to express my sincere regards to the members of my advisory committee, **Dr. Sanjeev Thakur** (Professor and Head, Department of TIGR), **Dr. S.S. Sharma** (Professor, Department of Basic Sciences) and **Dr.(Mrs) Neerja Rana** (Assistant Professor Department of Basic Sciences) for their perfect guidance and support.*

*I am also grateful to **Dr. Rajan Bawa** (Emeritus Scientist TIGR), **Dr. K.R. Sharma** (Deptt. of Forest Products), **Dr. S.K. Bhardwaj** (Deptt. of Environmental Science), **Dr. R.K. Gupta** (Deptt. of Basic Science), **Dr. I. K. Thakur** (Principal Scientist/Professor TIGR), **Dr. (Mrs.) Tara Gupta** (Principal Scientist/ Professor TIGR), **Dr Anita** (Assistant Professor TIGR) and **Mr. Jaipal Sharma** for their ideological contribution and prized suggestions. 'Thanks' is too small a word to express my deep sense of gratitude to Deptt. of Forest Products and Deptt. of Environmental Science for their sincere, selfless and invaluable help as and when required.*

*Determination, commitment and dedication would have remained fancy words without any meaning if you both didn't implement them in your own life to show me what they really mean. I owe this place to my parents **Mr H.R. Sharma** and **Mrs Promila Sharma**. any and every good quality which seems to be myself is actually theirs. I thank, the supernatural for giving me such caring and sacrificial parents. I thank them from the depth of my existence for all that which helped me to achieve this goal. The perpetual support and tenacity of my grandfather **late shri Mast Ram Sharma** and grandmother **Smt Radha Sharma** has always been a perennial source of inspiration. I place on record my heartiest gratitude towards my brothers and sister **Jitender Sharma**, **Vishal Sharma**, **Love**, **Diksha** my uncle **Mr. Madan Sharma** and aunt **Mrs Niru Sharma**. I would also like to thank **Mr. Rohit Sharma** for boosting up my spirits.*

*I would extend my sincere thanks to my loving friends and seniors **Aditika di**, **Bharti di**, **Shikha Thakur di**, **Shikha Bhagta di**, **Deepika di**, **Mast Ram Negi sir**, **Vinod Kairon sir**, **Leena**, **Purnima**, **Jyoti**, **Arti**, **Jyotsna**, for their co-operation and help during my study.*

*I pay my sincere and cordial regards to the office, laboratory and field staff of the Department of Tree Improvement and Genetic Resources, especially, **Hemkaran ji**, **Bali Dutt ji**, **Ramnath ji** and **Meenkshi Sharma**, other field staff for all the help, co-operation and facilities provided to me while carrying out my research work,*

I sincerely express my gratitude to DPT Computers Nauni, Solan for bringing this manuscript in beautiful shape.

The financial assistance via merit scholarship from university is highly acknowledged.

Needless to say errors and omissions are mine.

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ABBREVIATIONS USED

%	:	Per cent
°C	:	Degree centigrade
amsl	:	Above mean sea level
ANOVA	:	Analysis of Variance
C.D.	:	Critical difference
cm	:	Centimetre
CV	:	Coefficient of Variation
D.B.H.	:	Diameter at breast height
<i>et al</i>	:	co-workers
g	:	grams
GCV	:	Genotypic Coefficient of Variation
m	:	metre
mg	:	Milligram
PCV	:	Phenotypic Coefficient of Variation
RBD	:	Randomized Block Design
S.D	:	Standard Deviation
UHF	:	Dr. Yashwant Singh Parmar University of Horticulture and Forestry
Ve	:	Environmental variance
Vg	:	Genotypic variance
Vp	:	Phenotypic variance

Chapter-1

INTRODUCTION

One of the important and basic requirement for ensuring rapid growth of a country is to explore its natural resources in a sustainable manner. Fortunately India is endowed with a fare proportion of these resources. Forest products including medicinal plants and agriculture raw materials form an important source of existing natural resources. Dependence of man on plants for his existence has been of paramount importance in his life right from the beginning of civilization. Primitive man probably had few needs other then food and shelter. However, civilization has brought with it an ever increasing complexity and has increased requirements of human being to an amazing degree. Periods of distress tentamounting to conditions such as famine have often driven man to fall back on wild plants growing in its surrounding to continue his subsistence (Atal *et al.*, 1980).

Plants are source of a variety of naturally occurring components such as terpenoids, steroids, alkanoids, saponine, essential oil, fatty oils, etc. The three main constituents of human diet consist of carbohydrates, proteins and fats. Amongst the various sources of food, seeds of the plants occupy an important place both for animals as well as human consumption. Seeds contain lipids, fats, oil, proteins and carbohydrates as reserve food material. Most of the knowledge of the chemical composition of seeds is of food cultivated species as these constitute a large share of food supply and also provide huge amount of industrial material. Information on bio-species is relatively scarce. However, search for new oil, fat sources and industrial material is gradually earning more information about the seeds of wild plants. Fatty oils play an important role in agricultural and industrial economy of a nation. Principal edible uses of these are found in cooking oil, frying oil, salad dressing, bakery, cake mix and other non dairy products. Oil apart of its uses in food also find a wide range of industrial applications in the manufacture of soap and detergents, paints and varnishes, cosmetics and lubricants, etc. They are regarded as an important raw material for the manufacture of large number of oleo chemicals in view of hike in price of petroleum products in recent years. Oil and fats are water insoluble hydrophobic substances of vegetable and animal origin, which consist predominantly of glyceryl esters of higher fatty acids called triglycerides. These are usually extracted by expression or solvent extraction methods.

Glyceryl esters which are solid at room temperature are commonly called as fats and those that are liquid at room temperature are called as oils. Deoiled cake the by product rich in protein and carbohydrates along with the presence of some other components, after the removal of the toxic matter can be used as animal feed. In some cases the deoiled cake can be used as fertilizers.

With the rapid growing population and industrialization the increasing demand of oil and fats cannot be met by putting more pressure on arable land which we need for growing food grains. Therefore, we need to look for some other source like forest tree seeds, many forestry species such as *Aleurites fordii*, *Azadirachta indica*, *Calophyllum inophyllum*, *Garcinia indica*, *Madhuca indica*, *Madhuca longifolia*, *Mesua ferrea*, *Melia azedarach*, *Pongamia pinnata*, *Shorea robusta*, *Salvadora oleoides*, *Schleichera oleosa*, *Quercus* spp. and many more are known to contain fats and oil. However, all these species have not been fully exploited due to difficulties in collection of seeds. Food shortage in Himachal Pradesh is estimated to be 1 lakh tones / year (Anonymous, 1976). This deficit can be partially met by the utilization of edible fruits, nuts, seeds of trees growing in the forest. Proper utilization of the forest tree seeds for fats and oil can narrow down the energy gap and can provide a source of saving foreign exchange on one side and on other open avenues for utilization of deoiled cakes for domestic, agricultural land industrial consumption.

Trees are the largest and among the most complex organisms in the world with millions of diverse life forms (Zobel and Talbert 1984). Taxonomically the oaks fall under genus *Quercus* in the family Fagaceae (beech family), which includes more than 400 species and is one of the important tree species in temperate and subtropical plant communities (Koul 1985). In Himachal Pradesh out of total forest area of 37591 km², 921 km² is under the oak covering different species, viz., *Quercus leucotrichophora*, *Quercus glauca*, *Quercus dilatata*, *Quercus semicarpifolia* and *Quercus ilex* (Anonymous, 1991). *Quercus leucotrichophora* locally called as 'ban oak' is a moderate sized to a large evergreen tree with almost rounded crown attaining a height of 20 m and diameter of 60 cm, rarely reaching 30 m in height and 100 cm diameter. The bole is generally irregular and short. The bark is greyish brown, rough with cracks and fissures exfoliating in irregular oblong and sometimes rectangular scales. Branches, petioles and underside/abaxial part of leaves are tomentose. Leaves coriaceous, elliptic-lanceolate, serrate, teeth sharp, mucronate, base acute, blade 7-15

cm × 2.5-5.0 cm, lateral nerves 12-20 pairs, straight, parallel. Young leaves are pinkish and woolly all over, mature dark-green and glabrous above.

Ban oak occurs in the moister and cooler aspects in the western Himalayas between altitudes 800 m to 2300 m on the southern aspects, while the limit is lower by 200 m to 300 m on the northern aspects. It is a tree of temperate climate (Troup, 1921). It is the principal species of the Ban oak Forests of the lower west Himalayas. In its upper zone it is usually associated with *Quercus dilatata*, *Pinus wallichiana* and *Cedrus deodara*, whereas in its lower zone, it is usually associated with *Pinus roxburghii* and *Quercus glauca*. In its natural zone, the maximum shade temperature never exceeds 35°C while at lower limit in sub tropical zone, the temperature may reach about 38°C. The minimum temperature during January drops below freezing point. Total annual rainfall varies from 1000-1800 mm. Summer and autumn months are generally dry. Generally monsoon is helpful, but heavy snowfall is harmful, for the same reason, ban oak is conspicuously absent from Kashmir valley. It grows on wide variety of geological formation and soils; such as shale, gneiss, schist and quartzite. As the moisture requirement of chir pine, its associate is very high, the oak is replaced through regeneration is likely to have further degrading effect on the soil (Raturi and Dabral, 1986). Germination takes place in June- July after the early shower when the temperature is favourable. Germination take place under heavy shade, the seedling also survive under moderate shade, but seeds fail to germinate under heavy sunlight.

Ban oak can be raised either by direct sowing or by planting out nursery raised seedling. Storage of acorn at low temperature and high humidity is advocated (Dent, 1948). When stored in a cool place protected against insect attack, the seeds can be stored well for a year. About 400-800 acorns weight one kg. Fresh seeds gives upto 95 per cent germination, but seed stored up to one year give only 60 per cent germination. Ban oak is successfully raised by direct sowing. The seedling are put into container when the first leave appear, and then left to grow for 18 months before planting out (Noor, 1989).

The acorn contains 65 per cent starch on dry matter basis, but is not fit for either human consumption or cattle feed due to high content of tannin (about 6%). Possibilities exist however of preparing a cattle feed out of acorns after suitable treatment. Oaks have held a prominent place in the human culture. Ban oak forest is important component of Himalayan ecosystem from biodiversity conservation viewpoint, maintenance of soil fertility and recharge of spring water. However, the species is under severe biotic pressure on account of

its multiple uses as fodder, fuel wood, small timber and charcoal. The over exploitation of this species for a long time has led to gradual degradation of its natural stands (Nautiyal *et al.*, 2000).

The present study was concentrated on *Quercus leucotrichophora* because this tree is extensively lopped for fodder in the temperate Himalayas. Oak acorns have been extensively under exploitation as a source of feed for cattle. Uncontrolled and indiscriminate lopping has already done a great damage to the oak forests in the vicinity of habitation. Regeneration of ban oak is poor because of high infestation by insects. However, its seed contain fatty oil that can be used in the Industrial applications in the manufacture of soap, detergents, paint, varnishes, cosmetics, pharmaceutical, plastic, leather, textiles, surface coating and lubricants, etc.

Therefore, the present investigation to study the variation in various morphometric traits, progeny performance traits, physio-chemical parameters of fatty oil and nutritional value of deoiled cake was undertaken with following specific objectives:

- i) To study the extent of variability on morphometric traits.
- ii) To study the variation in progeny performance traits.
- iii) To study the physical and chemical characteristics of fatty oil and nutritional value of deoiled cake.

Chapter-2

REVIEW OF LITERATURE

Variation is the rule of nature and is essential for the long term survival of a species. Variations are the result of continuous environmental selection for generations. The study of variation is first hand information for any breeding programme. It helps to compare the populations and screen the naturally available genetic variation to utilize the best material for future breeding programme, to attain maximum productivity and for further breeding programme. The phenotype of an individual is the result of its genotype, and the environmental effects, or the combination of both.

Quercus leucotrichophora is an important species of Western Himalayas. It is an important evergreen fodder species during the dormant season, viz., December to February. However, very little scientific studies have been carried out on the morphometric and physiochemical traits of the species. Due to lack of sufficient literature available for this species on the above mentioned aspects, work carried out on other related species, literature has been reviewed here under the following sub headings:

- 2.1 Variation in morphometric traits.
- 2.2 Variation in germination parameters and progeny performance traits.
- 2.3 Variation in oil content, physiochemical traits and nutritional value of oiled cake.
- 2.4 Correlation studies.

2.1 VARIATION IN MORPHOMETRIC TRAITS

Variability studies are the prerequisite for the genetic improvement of any tree species under various climatic conditions. Seed sources testing for a particular species are desirable to screen the available variation for higher productivity and future breeding work. Morphometric traits include the plant features which can be observed and measured. They are important in determining growth and development of trees. Literature regarding the morphometric characters is reviewed here under:

Some seed sources show better performance in certain locations than the others and use of seed of a superior provenance in areas, very much different in climatic or edaphic

conditions from their origin, often results in poor performance or failure (Pirags, 1971 and Read, 1971).

Dicke and Bagley (1980) recorded discontinuous variation among provenance of *Quercus macrocarpa* for morphometric characters. They also found high rate of variation in growth characteristics between the sources.

Moura (1983) studied the six provenances of *Eucalyptus urophylla* from different altitude for seed characteristics and reported that among six provenance of *Eucalyptus urophylla*, seed size increases with the increase in altitude of provenance.

Seeds of *Dalbergia sissoo* collected from different seed sources scattered over almost the entire natural range in India were studied for variation in seed morphology and germination parameters. The study revealed significant genetic variation among all seed sources for rate of germination, while as variation observed for seed morphology has been assigned to be geographical. Thus study indicated that the multi-trait selection might be essential in ranking the desired seed source (Vakshaya *et al.*,1992).

Devagiri *et al.* (1998) studied seed source variation in pod and seed traits of *Dalbergia sissoo* in India and Nepal and reported significant variation for pod and seed traits between seed sources. Manga and Sen (1996) while conducting experiments on genetic parameters for seed traits in *Prosopis cineraria* concluded that magnitude of improvement in germination through seed size manipulation depends upon the amount of genetic variability and heritability of the traits.

Badeau and Dupouey (2000) purposed a simple index method, which can help distinguish between *Quercus rober* and *Q. petraea* on the basis of two foliar traits: petiole length and the number of intercalary leaf veins. However, this criteria is not suitable for distinguishing between *Q. petraea* and *Q. pubescens*.

Sankhyan *et al.* (2004) studied the variation in morphometric characters in different species of seabuckthorn in cold deserts of Himachal Pradesh. Different species showed variation in branch, leaf, thorns and fruit characters under natural conditions. As regards the variation with age in both the species it was reported that branch, leaf and fruit characters showed increasing trend up to the age of nine years, thereafter it starts declining. In general, it

was suggested that nine year age is the best age for harvesting the fruits in both the species where all the characters showed maximum value.

Wani (2005) studied morphological variations in progenies of 32 plus trees of *Bauhinia variegata* under greenhouse and field conditions. He revealed that plus trees progeny of Pinjore, Kandaghat and Giripul exhibited outstanding performance for morphological characters, viz., height, diameter, number of branches, leaf area, etc., in comparison to all other superior tree progenies under glasshouse. Whereas, Renuka plus tree showed the best performance of progeny followed by Subathu, Kunihar and Narag under field conditions for the above characters studied.

Mei *et al.* (2007) studied morphometric variation of *Quercus liaotungensis* leaves, they included the five population and 24 morphometric traits of leaf and apical bud were investigated. The analysis of variation shows that variation of all the morphometric traits with in the population were significant, whereas significant differences existed in five indices among population , which resulted from genetic and environmental factors.

Bahar and Singh (2007) conducted studies on seed source variation of *Sapindus mukorossi* by collecting seeds from thirteen localities of Himachal Pradesh, India and observed significant variation in fruit diameter, fruit weight, seed diameter and seed weight among all seed sources.

Bahar (2007) collected bulk seed samples of *Azadirachta indica* from 14 seed sources in southern and western Haryana, India and the composite seed samples were evaluated for variation in seed and germination characteristics. The experimental results of the study revealed significant variation in seed length, seed width, seed weight and per cent germination among all seed sources.

Mir (2011) studied the variation on seed source for fruit, seed morphometric characteristics, seed viability and germination parameters under laboratory condition in *Sapindus mukorossi*. Fruit and seed were collected from different seed sources of Himachal Pradesh. The seed source of Chuwari (Chamba) was found to be the best source in comparison to other seed sources. Among fruit-seed and germination variables, the percent germination showed significant correlation with seed size and weight.

Bayramzadeh *et al.* (2011) studied the morphometric variations of five native oriental beech population grown in the western Caspian region in Guilan province (Astara, Asalem, Fuman, Chere, Shenrud). Eight leaf morphometric traits, including leaf length, leaf width, petiole length, leaf area, leaf dry mass per unit leaf area, leaf thickness and leaf density were measured for 200 trees. The results showed that all measured leaf morphometric traits were remarkably different among the populations, with the exception of distance between veins.

Danquah *et al.* (2011) investigated the pattern of leaf morphometric variation and similarities among the populations of two species of African Mahagonies (*Khaya ivorences* and *Khaya anthotheca*) and suggested that two clusters of populations of *Khaya anthotheca* and one cluster of *Khaya ivorences* were morphologically related.

Mariappan *et al.* (2014) *Caesalpinia sappanis* widely used in traditional medicine and chemical investigation resulted in the isolation of novel and interesting phytochemicals possessing potent biological properties. The most successful tree improvement programme is that where proper seed source were used. The loss from using wrong source can be great and even disastrous. *Caesalpinia sappanis* commonly propagated through seeds discusses seed source variation and increase the seed longevity in suitable storage techniques. The wood of *Caesalpinia sappanis* has already proved export quality of natural dye and has the potential to become a drug to enter into the world market that might provide rich natural resources. In future, more basic research is needed to elucidate the mechanism to appraise the better seed source variations and seed storage behavior and techniques in *Caesalpinia sappanis*.

2.2 VARIATION IN GERMINATION PARAMETERS AND PROGENY PERFORMANCE TRAITS

The literature regarding these parameters is reviewed as hereunder;

Liu *et al.* (1975) while conducting studies on interspecific variation and provenance test in genus *Chamaecyparis*, found that there exist significant differences in germination rates and seed size among the provenances of *Chamaecyparis* species.

Kandya (1978) studied relationship among seed weight and various growth factors in *Pinus oocarpa* seedlings and observed provenance Balize Cayo has highest seed weight (24.54 ± 5.44 mg), height (19.83 ± 0.01 cm), total dry weight (630.10 mg) and root length (19.87 ± 4.22).

Clause *et al.* (1981) studied variation in *Fraxinus americana* and seed of individual white ash parent trees from most of the species range were studied and used to establish a provenance-progeny test. Variation in seed length and length of wing on the seed appeared to be clinal, while ploidy variation accounted for most of the difference in fruit length, seed width, seedling height and date of leaf fall.

Pathak *et al.* (1984) recorded seed weight and germinability of 30 provenances of *Leucaena leucocephala* from India, Philippines and Australia and concluded that character association and inter group differences were highly significant.

Suri (1984) reported that teak seeds from moist locality were bigger in size and weight as compared to that of dry zone and it was also reported that germination and plant percent are the function of quality of seed rather than size and weight of seed.

Ngulube (1989) worked on genetic variation in seed germination and seedling growth of 24 *Gliricidia sepium* provenances and reported significant differences in seed germination and seedling survival between provenances.

Investigations was carried out to study the pattern of genetic variation and character association in 17 exotic provenances from Australia and one local provenance of *Eucalyptus grandis*. The result revealed the presence of high magnitude variation for height, girth and basal area in the present materials. There were fair differences between phenotypic and genotypic coefficient of variability. Both heritability and genetic advance values were low for all characters (Subramanian *et al.*, 1995).

Mohapatra (1996) from his studies on variability for seedling traits in *Acacia catechu* concluded that significant variation existed in seed length, seed weight, germination index, seedling growth and biomass traits under nursery as well as under field conditions.

Kumar and Bangarwa (1999) studied progeny testing in *Azadirachta indica* collected seed from ten randomly taken trees of neem growing naturally in Hisar. Significant differences were observed among progenies of vigour index and growth parameters in two months old seedlings. The average germination percentage, seedling length, seedling dry matter, vigour index-1, vigour index-2, collar diameter and number of leaves were observed to be 85.55, 48.65%, 576.30 mg, 1194.96, 4841.94, 2.02 mm and 28.28, respectively.

Progeny-6 was found relatively better for vigour index and juvenile growth. Progeny-8 was found relatively better for the same parameters.

Provenance variation in seed parameters and germination of *Grewia optiva* Drummond was carried out by Tyagi *et al.* (1999) in Western Himalayas. The analysis demonstrated genetic variation between the provenances and highly significant correlations between different pairs of characters. A multiple regression analysis showed that seed length and 100-seed weight might be used as the predictors of germination in *Grewia optiva*.

After studying 48 phenotypically superior tree families of *Bauhinia variegata*, Anand (2003) concluded that morphological and biomass traits showed significant variation for seedling height and leaf area.

Todaria *et al.* (2004) while conducting studies on seed source variation on seed germination parameters of *Acacia catechu* reported that variation in seed germination parameters of 20 seed sources collected between 120 to 1300 amsl altitude in Garhwal Himalaya and Siwaliks showed non significant relation with altitude of seed origin. The experiment also concluded that among all temperature regimes, 30/20°C alternative temperature was found most suitable for the seed germination of *Acacia catechu*.

Bhatt and Ram (2005) studied the variation in seed characteristics and germination of *Q. leucotrichophora* A. Camus, a dominant tree species in the Uttranchal Himalaya, along an elevational gradient. Seeds were analysed for seed size, weight, moisture content and germination. Seeds were significantly smaller with low seed weight at high elevation compared to mid elevations. The germination was higher in seeds collected from lower elevation than those from mid and high elevations. The seeds mature earlier at higher elevations indicating an adaptive strategy against the low temperature and frost during winter months. Various seed characteristics support its population in low and mid elevation (below 2000m) than at higher elevations.

Ghildiyal and Sharma (2005) studied the effect of seed size and temperature treatments on germination of various seed sources of *Pinus wallichiana* and *Pinus roxburghii* from Garhwal Himalaya and reported that the large sized seeds in *Pinus wallichiana* (mean germination percentage of 54.66%) and medium sized seeds in *Pinus roxburghii* (mean

germination percentage of 93.33%) have been recorded favorable for getting increased seed germination under laboratory conditions.

Ginwal *et al.* (2005), while studying seed source variation in *Jatropha curcas* for seed germination parameters reported that the variation in seed viability, germination percentage, germination energy and germination value was significant among different seed sources with coefficient of variation of 6.67, 10.03, 11.27 and 27.41 per cent, respectively. Almost a similar trend was noticed in nursery germination percentage, germination energy and germination value with coefficient of variation of 9.26, 9.92 and 21.12 per cent, respectively.

Uniyal *et al.* (2007) studied the effect of seed size on the seedling growth of *Azadirachta indica*. The results revealed that shoot and root length were longer in plants raised from large sized seeds.

Tewari *et al.* (2008) studied seed germination and seedling growth of Bhimal (*Grewia optiva*) in Central India. Observations indicated that acid treatment (H_2SO_4) for 15 min and then soaking in water for 24 hours gave highest (44%) germination, which was significantly higher than other treatments. The treatment produces the highest seedling growth and biomass yield followed by 24 hours seed soaking in ordinary water treatment. Highest 1.32 cm/day increment in plant height and 0.10 cm/day in collar diameter were recorded under acid treatment. Seedlings produced 4.76 to 7.01 g/plant biomass within 120 days of seed sowing.

Rana *et al.* (2009) evaluated progenies of 25 seed sources (plus trees) of *Toona ciliata* under nursery and field conditions. Seedling height, collar diameter and number of leaves indicated significant difference for all characters under nursery conditions.

Singh and Saxena (2009) studied the effect of seed size on germination parameters of *Jatropha curcas* and observed that germination and related parameters were positively correlated with seed size in laboratory as well as in nursery conditions. Large seeds showed remarkable increment in germination percentage (50%), germination speed (100%) and germination energy (72%) over the small seeds in the laboratory. This increment in germination and related parameters for large seeds over the small seeds was even greater in nursery condition.

Venkatesh and Nagarajaiah (2010) while studying the effect of seed size on germination in *Sapindus emarginatus* (Linn.) found that large size seeds possessed higher germination percentage (98%) than the medium (80%) and small size seeds (70%). Similar observations were made in *Sapindus emarginatus* (Linn.) by Suresha *et al.* (2007) and both reported that in *Sapindus emarginatus* (Linn.) biomass production was higher in seedlings produced from larger seeds.

Ahirwar (2012) studied the effect of seed size and weight on seed germination of *Alangium lamarkii* Thwaites. The data revealed that the large size seeds gave maximum (76.00%) germination followed by medium size (74.00%) and small size seeds characterized by low germination percentage (59.00%). It is evident that the germination percentage significantly declined with reduction in size and weight of the seeds.

Sankhyan *et al.* (2015) conducted an experiment, in order to select better seed sources for improved genetic material and quality production of *Sapindus mukorossi*. Twenty four seed sources and two D.B.H. classes from Himachal Pradesh were evaluated on the basis of fruits and seeds morphometric traits and germination parameters in laboratory condition. The study revealed significant variation among different seed sources for all traits, except seed viability while, all morphometric, germination traits in lab condition did not show distinct significant variation between D.B.H. classes. Seed sources which have higher seed weight and seed diameter showed better performance over others, those seed with lower seed weight and seed diameter comparatively. The range of seed sources mean were found appreciably broad for 100 fruits weight 571.00-240.03 g (S16-S21), 100 seed weight 226.05-140.63 g (S16-S3), rind weight 3.45-1.32 g (S16-S21), seed diameter 17.02-12.40 mg (S16-S21) and kernel weight 613.48-352.80 mg (S16-S21) among different seed sources. On other hand among D.B.H. classes the range were 387.58-386.04 g (D2-D1), 100 seed weight 166.62-166.31 g (D2-D1), rind weight 2.22-2.21 g (D2-D1), seed diameter 13.84-13.82 mg (D2-D1) and kernel weight 420.66-417.94 mg (D1-D2). Banjar seed source was found to be superior and best followed by Garsa seed source for all studied traits over all other seed sources.

The Investigation was carried under nursery conditions with the aim to assess the rate of seed germination of bann oak (*Quercus leucotrichophora*). The individual effect of seed size, seed colour and sowing depth was found with the maximum values for germination per cent in large sized (43.89%), dark brown colour seeds (39.44%) when sown at depth 1cm (47.04%), whereas for germination capacity the maximum value was obtained in large sized

(59.44%), dark brown colour seeds (53.33%) when sown at depth 1cm (67.04%). Similar trend was observed in other germination parameters. It was found that effect of interaction for large size (S1) dark brown colour seeds (C2) sown 1cm deep (D1) significantly excelled over other categories in terms of germinability parameter viz., number days for initiation of germination (14.67days) by Thakur and Gupta (2015).

Thakur and Thakur (2015) conducted study on growth characteristics of progenies of *Melia azedarach*. Seeds of *Melia azedarach* were collected from selected mother trees (ortets) one each at twenty seven locations and progenies were raised to study the extent and pattern of variation with respect to growth characters. Site S₂₇ (Nauni) exhibited outstanding performance for these traits of progenies followed by S₁₄ (Ropar) and S₂₃ (Subathu), whereas S₂(Palu upper) showed the lowest values. High heritability with high genetic gain was observed for collar diameter (0.96 and 64.37%), root length (0.93 and 57.72%) and root-shoot length ratio (0.91 and 51.83%). Highly significant and positive genotypic and phenotypic correlations were observed 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).

2.3 VARIATION IN OIL CONTENT, PHYSIOCHEMICAL TRAITS AND NUTRITIONAL VALUE OF DE OILED CAKE

The staple oils of India comprise the materials like sesame, cotton seed, rape-mustard, coconut, sunflower and oil palm. The less known oils of India have been put to different uses depending upon their iodine values, extent of unsaponifiable matter, acid values and other harmful oil associated substances present in them. The oil with high iodine value such as those of tobacco seed, rubber seed and tung seed are mostly used for surface coating.

Karnik *et al.* (1971) studied chemical composition of *Sapindus mukorossi*. The oil was extracted by Soxhlet apparatus using solvent petroleum ether (60-80°C) and reported oil content, refractive index at 30°C, specific gravity at 30°C and saponification value, 38.0 per cent, 1.4730, 0.9106 and 202-204, respectively.

Studies by Marwal *et al.* (1978) for oil evaluation and nutrient content of the acorns of *Quercus ilex* and *Q. leucotrichophora* and by Gul and Khan (1979) for acorns of *Q. dilatata* have shown them to be a suitable feedstuff for livestock and poultry.

Dev *et al.* (1979) while studying chemical composition of *Sapindus mukorossi* reported that refractive index at 24°C, specific gravity at 22°C and saponification value of seed oil were 1.4669, 0.9042 and 197.00, respectively.

Nasir *et al.* (1988) characterized the fixed oil of *Jatropha* species for its fatty acid composition and physico-chemical properties. The physico-chemical contents were, refractive index at 30°C, 1.4675; iodine value 102 and saponification value 196.72.

Seeds of *Pinus roxburghii* were collected from 8 stands at 700 to 1975 m attitude in the Western Himalaya and were studied for variation in seed oil content and oil quality parameters. The experimental results of the study revealed that seed oil content, saponification value and iodine value varied between 42-64 per cent, 210 to 294 and 114 to 120, respectively (Sehgal *et al.*, 1989).

Ginwal *et al.* (2004), while, studying the variation in seed oil content of *Jatropha curcas* of different sources, concluded that the oil content ranged from 33.02 to 39.12 per cent in whole seeds and 47.08 per cent to 58.12 per cent in kernel, across the seed sources.

Sayed *et al.* (2004) studied the physico-chemical characteristics of seed oils of *Mesua ferrea*, collected from different districts of Bangladesh, reported marginal variation in specific gravity (0.9287 to 0.9312), refractive index (1.4690 to 1.4739), saponification value (199.03 to 206.40), and found non significant variation among different seed sources.

Ginwal *et al.* (2005) evaluated ten different seed sources in central India representing the states of Madhya Pradesh and Maharashtra, for oil content variation in *Jatropha curcas* seeds and reported that oil content on both seed and kernel basis varied significantly among different seed sources.

Shah *et al.* (2005) reported that the use of ultrasonication as a pretreatment before aqueous oil extraction was found to be useful for *Jatropha* seed oil extraction. The use of ultrasonication for 10 minutes at pH 9.0 followed by aqueous oil extraction gave a yield of 67 per cent. However, the maximum yield of 74 per cent was obtained by ultrasonification for 5 minutes followed by aqueous enzymatic oil extraction using an alkaline protease at pH 9.0.

Pant *et al.* (2006) conducted a trial to determine the variation in yield and oil content by taking composite sample of six *Jatropha curcas* trees randomly selected from two cultural

site conditions and three altitudinal ranges in Himachal Pradesh, India and reported that non-arable site with low, altitude recorded highest oil content.

Kaushik *et al.* (2006) collected more than one thousand samples of *Jatropha* seeds, presenting twelve states of India, for oil content analysis and reported that oil content varied significantly among different seed sources ranging between 25 to 44 per cent on seed weight basis.

Ruan and Huang (2006) conducted an experiment on seed source variation in *Sapindus mukorossi* and reported that saponification value of oil samples extracted from composite seed samples of Taiwan, India and Vietnam ranged between 173-196 mg KOH/g.

Kaushik *et al.* (2007) assessed variability in seed traits and oil content of 24 accessions of *Jatropha curcas* collected from different agroclimatic zones of Haryana state, India and resulted that there were significant differences ($P < 0.05$) in seed size, 100 seed weight and oil content between accessions. High heritability and genetic gain were recorded for oil content (99.00% and 18.90%) and seed weight (96.00% and 18.00%), respectively, indicating the additive gene action.

Oyekunle *et al.* (2007) assessed the oil extracted from *Jatropha curcas*, for various physical properties and concluded that specific gravity measurement varied between 0.9004 to 0.9113 at 80°C and 0.9125 to 0.9207 at 30°C. Viscosity measurement, in centipoises, ranged between 7.35 to 9.41 at 80°C and 38.44 to 60.34 at 30°C. Refractive index values at 28°C ranged between 1.4646 and 1.4707 and Foidl *et al.* (1996) studied the fuel properties of *Jatropha curcas* oil and observed the specific gravity at 15°C and viscosity at 30°C as 0.920 gm/cm³ and 52.0 centipoises, respectively.

Mukta *et al.* (2009) assessed wide variability in oil content in 75 germplasm of *Pongamia pinnata* collected from Telengana region of Andhra Pradesh, India and concluded that the saponification number (SN), iodine value (IV) and cetane number (CN) of fatty acid methyl esters of oils varied from 183.3 to 200.91, 74.78 to 100.98 and 50.85 to 59.11, respectively. The range of variability found for various biodiesel standards in accessions of *P. pinnata* can be utilized for the establishment of plantations of promising genotypes through clonal means for increased productivity.

Khan *et al.* (2009) while studying the variation in seed oil content of *Prunus armeniaca* from 17 different seed sources, reported that the oil content varied significantly across different seed sources ranging between 40.35 to 52.42 per cent on kernel weight basis.

While Luna *et al.* (2008) conducted an experiment to investigate seed source variations in different morphological traits of seed and oil content among twenty four seed sources of *Jatropha curcas* collected from three states of Northern India, viz., Himachal Pradesh, Jammu and Kashmir and Punjab. The experimental results concluded significant variation for 100 seed kernel weight followed by oil content and weight of 100 seeds.

Properties of seeds and oil extracted from fully ripened *Phoenix canariensis* date seeds and observed the saponification number 191.28, the iodine number 76.66 and the refractive index 1.45 by Nehdi *et al.* (2010).

Mir (2011) studied seed oil content variation in *Sapindus mukorossi* from different seed sources of Himachal Pradesh and reported the oil content on kernel basis 41.55 to 32.62 per cent and on seed basis 18.17 to 10.77 per cent. Oil content parameters were reported as: relative viscosity (22.77 to 22.02), saponification value (187.07 to 144.98 mg KOH/gm), specific gravity (0.9035 to 0.9025) and refractive index (1.4697 to 1.4674).

Aminul Islam *et al.* (2012) conducted an experiment on *Jatropha curcas* and evaluated seed oil from 9 geographical origins and 24 candidate plus trees. Oil extracted by Soxhlet extraction using n-hexane as solvent, concluded that oil content varied from 40.0 to 48.4 per cent among seeds from different origins and 32.1 to 48.8 per cent (w/w) among CPTs. The lowest saponification values were obtained from seed oil of Philippine origin (189.5 mg KOH/g) and CPT-22 (183.3 mg KOH/g oil) from Malaysia. Density, specific gravity, and refractive index of oil showed very little differences among all the seed sources.

Nyakudya *et al.* (2015) studied the potential domestic and industrial usefulness of the *Grewia bicolor* seeds. The *G. bicolor* seeds yielded 4.80 per cent of brownish-orange oil that had an acceptable odour. The seed oil consisted of saturated (20.20%), monounsaturated (25.10%) and polyunsaturated (54.41%) fatty acids. Palmitic acid (11.46%), stearic acid (5.77%), oleic acid (19.33%) and linoleic acid (54.41%) were the main fatty acids in *G. bicolor* seed oil. The oil had a high acid value (0.53 mg KOH/g), iodine value (39.21 g I₂/100 g oil) and saponification value (130.43 mg KOH/g) compared to published data on other

nutritionally and ethnomedicinally important plant seed oils. They conclude that the *G. bicolor* seeds are low oil yielding, whose oil could be used as a potential source of palmitic, stearic, oleic and linoleic acids and may potentially be utilized as an industrial ingredient in the manufacture of soaps, pharmaceutical products, and cosmetics.

Ezekoye and Ezekoye (2016) studied that biodiesel was successfully produced from *Borassus aethiopum* and *Cassia sieberiana* seeds using the trans-esterification method. Results showed that the biodiesels produced have values which compared well with the European Biodiesel Standard. The free fatty acid from *B. aethiopum* oil and *C. sieberiana* oil are 2.68 and 13.97 per cent, respectively, while the iodine values are 47.93 g I₂/100 g and 48 g I₂/100 g, respectively. Also, their saponification values are 201.69 mg KOH/g and 208.56 mg KOH/g, respectively, while their acid values are 5.38 and 28.04, respectively. The calorific value for *B. aethiopum* biodiesel and *C. sieberiana* biodiesel are 42568 and 41427 KJ/kg, respectively, while their fire point are 90 and 50°C, respectively.

2.4 CORRELATION STUDIES

Correlation is one of the basic biometrical tools which help in understanding the nature and degree of association between various traits. It determines the characters on which selection can be relied upon. Therefore, the knowledge of association of different parameters among themselves is of utmost importance.

Jindal *et al.* (1987) studied the inter relationship between shoot dry weight and seven characters of three months old seedlings of *Acacia senegal*. They reported that genotypic correlation coefficients were higher than the corresponding phenotypic ones. Root dry weight and shoot fresh weight were highly correlated with shoot dry weight indicating that selection could be made on these criteria.

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

Selvan (1999) reported in *Acacia catechu* that the phenotypic, genotypic and environmental correlation coefficient between different pairs of seedling traits, viz, seedling height, collar diameter, number of branches and leaf area there were positive and significant

correlation between all the traits except for leaf area with all other traits which was significant with seedling height only at genotypic level.

Tikader and Roy (1999) studied *Morus* species and reported highly significant positive association of number of shoots with length of longest shoot, total shoot length and leaf yield, length of the longest shoot with total shoot length, internodal distances and leaf yield which clearly indicated that these were most important component traits to improve the leaf yields in mulberry.

Thakur *et al.* (2000) reported a positive and significant correlation for number of leaves per plant, leaf length and breadth at genotypic and phenotypic level in *Alnus nitida*.

Anand (2003) reported positive and significant correlation coefficient for dry shoot weight with seedling height, collar diameter, number of nodes, number of leaves, leaf area and fresh shoot weight for forty eight plus tree progenies of *Bauhinia variegata* viz- a- viz maximum direct contributions in the production of dry shoot weight.

Wani (2005) reported genotypic correlation coefficients greater than phenotypic ones for all morphological and biomass traits in *Bauhinia variegata*. Shoot fresh weight gave positive and highly significant correlation at phenotypic, genotypic and environmental level with seedling biomass under phenotypic and genetic control.

Devagiri *et al.* (2007) conducted a study involving 20 seed sources of *Dalbergia sissoo* Roxb. collected from the greater part of its distributional range to understand the variation. Significant positive correlations were observed between growth characters (seedling height, collar diameter and root length).

Lune *et al.* (2008) evaluated forty nine exotic and indigenous clones of poplar for eight morphological traits. Plant height showed positive and significant correlation with diameter.

Wani *et al.* (2008) while working on 32 different seed sources of *Bauhinia variegata* estimated genotypic and phenotypic correlation between various traits and revealed that correlation studies provide better understanding during selection program. They found phenotypic correlation coefficients lower than the corresponding genotypic ones which could be due to the modifying effect of the strong inherent association of characters at genetic level.

Kumaran *et al.* (2010) carried out correlation and path coefficient studies in fifteen seed sources of *Simarouba glauca*. Highly significant positive correlation was observed for height and diameter. Path analysis revealed that height and basal diameter exhibited positive direct effect with volume index.

Gupta *et al.* (2012) recorded maximum positive and significant correlation coefficient (0.959) for basal diameter with volume index in introduced *Salix* species. Principal component analysis through correlation matrix revealed that three out of eight components contributed 85.03 per cent of the overall variation out of which the first principal component ($\lambda=3.086$) explained 38.57 per cent of the variance weighted maximum (0.937) by volume index.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled, “**Variability Studies on *Quercus leucotrichophora* A. Camus Populations in Himachal Pradesh**” was carried out to study magnitude of variation in the morphological traits, progeny performance traits and physiochemical traits to find out the variation among the trees in different diameter classes, variation among different sites, interaction between the trees of different diameter classes and sites in the natural forest conditions, experimental field at Shilli Nursery, Solan (for evaluation of progeny performance) and also in the laboratory of Department of Tree Improvement and Genetic Resources, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry Nauni, Solan, Himachal Pradesh during the years 2014 – 2016. An eco-geographical survey of the populations of *Quercus leucotrichophora* was undertaken during the month of September- October 2014 in jurisdiction of four districts of Himachal Pradesh, viz., Solan, Shimla, Kullu and Chamba areas to identify the sites where species occurs in abundance. During the month of December 2014- January 2015, collection of seeds was done from previously surveyed areas. The details of the experimental sites, experimental methods and the methodologies / techniques followed during the course of investigation have been described in this chapter.

3.1 EXPERIMENTAL DETAILS

The experimental study was conducted in the jurisdiction of the four districts of Himachal Pradesh, viz., Solan, Shimla, Kullu and Chamba. From each district, two sites were selected where species occurred in abundance. The main aim of the experiment was to study the variation among the trees in different diameter classes, variation in different sites, interaction between trees of three diameter classes and the sites. From each site nine trees were selected, three from each diameter class, viz., less than 30 cm (D1), 30-60 cm (D2) and more than 60 cm (D3), respectively. These trees were marked properly and acorns were collected from these marked trees for the evaluation of progeny performance and physiochemical analysis in the laboratory. Two kg acorns were collected from one site and about eight to nine kg acorns were collected from all sites. The acorns so collected were kept separately with proper identification of concerned site. In nursery total number of seeds

raised were 5400. 75 seeds were sown from one tree in three replications, 225 seeds were sown from one diameter class and total 675 seeds were sown from one site. Rest of the seeds were brought to the laboratory for further analysis.

Sampling Methodology and Analytical Frame of Work:

Number of districts = 4

Number of sites = 8

Diameter classes = 3 (small, medium, large)

Number of treatments = 24

Number of replications = 3

Design employed = RBD (Factorial) in Field and CRD in Laboratory

Study Area with Elevation			
Sr.No.	District	Area	Elevation
1.	Solan	Shilli (S1)	1480 m amsl
		Chail (S2)	2250 m amsl
2.	Shimla	Taklech (S3)	1350 m amsl
		Summer Hill (S4)	2120 m amsl
3.	Kullu	Garsa (S5)	1190 m amsl
		Manikaran (S6)	1760 m amsl
4.	Chamba	Sahu (S7)	1400 m amsl
		Salooni (S8)	1850 m amsl

3.2 EXPERIMENT METHODS

3.2.1 Morphological Characters

A. Tree Height (m)

Tree height was measured from the ground level to apex of leading shoot by Ravi's Multimeter.

B. Diameter at Breast Height (cm)

Diameter of the tree was measured by the help of tree calliper at both axis and average of both the reading was taken into consideration for data analysis.

C. Clean Bole Height (m)

Clean bole height was measured by the help of marked bamboo stick.



Chail-Solan



Summer Hill-Shimla



Sahu-Chamba



Garsa-Kullu

Plate 1. Overview of few sites under study

D. Crown Length (m)

Crown length was measured with the help of Ravi's Multimeter.

E. Crown Width (m)

Crown width was measured by the help of tape at two different axis at ground level.

F. Number of Primary Branches

Number of primary braches was counted manually.

G. Leaf Length (cm)

Leaf length was measured with the help of a scale and the mean expressed in centimetres.

H. Leaf Width (cm)

Leaf width was measured using a scale and the mean expressed in centimetres.

I. Leaf Area (cm²)

Average leaf area of hundred harvested leaves after bringing them into laboratory was measured by the help of leaf area meter.

3.2.2 Germination and Seedling Growth Studies:

A. Number of Days for Initiation of Germination:

Number of days to initial germination was recorded in each line sown.

B. Number of Days for Complete Germination:

Number of days from initial to completion of germination was also recorded for each line.

C. Germination (%):

It was the per cent of the sown seeds germination at a completion of germination which was calculated.

D. Germination Value (GV):

It was an index combining speed and completeness of seed germination. Daily germination counts was recorded and GV was calculated by :

Czabator Method:

$$GV_C = PV \times MDG$$

Where,

GV_C = GV calculated by Czabator (1962) method

PV = The peak value of germination

MDG = Mean daily germination or final daily germination speed

E. Seedling Survival Percentage:

Surviving seedlings in each line were counted at the time of recording seedling traits (height, collar diameter, etc.) in the nursery and the survival per cent was worked out as follows:

$$\text{Survival (\%)} = \frac{\text{Plant count in a bed}}{\text{Number of seeds germinated in bed}} \times 100$$

Other important characteristics of seedling:**A. Seedling length (cm):**

Seedling length (root length + shoot length) was measured with a foot ruler from the root tip to the shoot tip of the seedling.

B. Collar Diameter (cm):

It was measured with a Digital Vernier Calliper at the ground level.

C. Inter-nodal Length (cm):

Inter-nodal distance was measured with a scale (ruler) as the distance between the consecutive leaves on the main axis. It was the average of three observations recorded per seedling.

D. Number of Leaves per seedling:

Total number of leaves per seedling was counted. However, very young and small leaves were ignored.

E. Leaf Area of Seedling (cm²):

Three representative (full grown) leaves per seedling were detached from the seedling and were measured for their area using leaf area meter.

F. Fresh Leaf Biomass of seedling (g):

The whole fresh leaf biomass per seedling was determined by using top pan electric balance.

G. Root Length of Seedling (cm):

Length of tap root was recorded in centimeter using measuring scale by placing in horizontal position on the ground.

H. Shoot Length of Seedling (cm):

It was measured with the help of centimeter scale from leading shoot tip to the collar region of seedling at ground.

I. Root/Shoot Length Ratio:

The root length was divided by the shoot length of the same plant to determine the root/shoot length ratio.

J. Root Fresh Weight (g):

Fresh weight of root was measured using a top pan electric balance after properly surface drying the water washed roots.

K. Shoot Fresh Weight (g):

It was recorded in the same manner as the root fresh weight.

L. Root: Shoot Fresh weight Ratio:

Root fresh weight was divided by the shoot fresh weight of the same plant to determine the ratio.

M. Root Dry Weight (g):

Dry weight of root was measured using a top pan electric balance after drying at 80°C in an oven properly.

N. Shoot Dry Weight (g):

Dry weight of shoot was measured using a top pan electric balance after dried at 80°C in an oven properly.

O. Root: Shoot Dry Weight Ratio:

The root and shoot was dried at 80°C in an oven, and the ratio was calculated by dividing the weight of dry root by the weight of dry shoot of each plant separately.

3.2.3 Oil Content, Oil Physio-chemical traits and nutritional value of deoiled cake

A. Percentage of Seeds to Acorns:

Seed to acorn ratio was estimated by first weighing 100g of seed with acorn on a weighing machine than the same sample was weighing after the removal of outer shell.

B. Percent Oil Content:

Extraction of oil was carried out following the method of Anonymous (1965), in which both seed and kernels was crushed using pestle and mortar. The oil was extracted from powdered sample (known weight) in Soxhlet extraction apparatus with petroleum ether (60-80°C) for six hours without interruption by gently heating it on the heating mantle. Ether was evaporated on a water bath until no odour of ether remained. The oil yield was expressed in terms of percentage of powdered sample.

$$\text{Oil content (\%)} = \frac{\text{Weight of oil extracted from the sample}}{\text{Weight of sample (50 g)}} \times 100$$

C. Specific Gravity:

Specific gravity is a measure of the density of a substance compared to the density of water at constant room temperature. The specific gravity of oil was measured using specific gravity bottles according to standard method (Ranganna, 1997) and was calculated as:

$$\text{Specific Gravity} = \frac{\text{Weight of oil with bottle} - \text{Weight of bottle}}{\text{Weight of water with bottle} - \text{Weight of bottle}} \times 100$$

D. Refractive Index

Refractive index is the degree of deflection of the beam of light that occurs when it passes from one transparent medium to other. It was used as one of the primary objective test procedures to determine the quality of oil as deviations from the established values was indicative of adulteration. The refractive index of oil was determined using Abbe's Refractometer by placing 2-3 drops on the prism and maintaining a temperature of 30°C throughout the measurements (AOAC, 1995).

E. Acid Value

Acid value of seed oil was estimated by titrating a known weight of sample (10g) containing 50 ml neutral solvent (25 ml ether + 25 ml 95% alcohol + 1% phenolphthalein) against 0.1N KOH solution using phenolphthalein as an indicator (Thimmiah, 1999) with continuous shaking until pink colour persisted. The acid value was calculated by using following expression:

$$\text{Acid value (mg KOH/g)} = \frac{\text{Titre} \times \text{Normality of KOH} \times 86.1}{\text{Weight of Sample (g)}}$$

F. Iodine Value

Iodine value was estimated according to Wijs (carbon tetrachloride-acetic acid solvent) method (AOAC, 1995). The oil sample (0.26-0.32 g) was mixed with carbon tetrachloride (25 ml) followed by addition of Wijs solution and then store in dark for one hour. After addition of 15 ml of 15 % KI and 100 ml distilled water, the solution was titrated against 0.1 N Sodium thiosulphate using starch solution as an indicator and titration was continued until blue colour disappeared. The iodine value was then calculated by subtracting the sample titre from the blank titre using following expression:

$$\text{Iodine Value (g I}_2\text{/ 100 g oil)} = \frac{(\text{Blank Titre}-\text{Sample Titre}) \times \text{Normality of Na}_2\text{S}_2\text{O}_3 \times 12.69}{\text{Weight of Sample (g)}}$$

G. Saponification Value:

Saponification value of oil was estimated according to the standard method outlined in AOAC (1995). The oil sample (5.0 g) was mixed with alcoholic potassium hydroxide and the mixture was refluxed for 30 minutes to completely saponify the sample and then was

titrated against 0.5 N HCl using phenolphthalein as indicator. Blank determination was carried out along with sample. The value represents the average molecular weight of the oil and was useful for comparative study of the oil and was useful for comparative study of the fatty acid chain length in oil.

$$\text{Saponification Value} = \frac{28.05 \times (\text{Blank Titre} - \text{Sample Titre})}{\text{Weight of Sample (g)}}$$

H. Unsaponifiable Matter:

Oil sample of 1g was refluxed with 25 ml of N/2 KOH (alcoholic) on a water bath. Most of the alcohol was removed under vacuum. The content was distilled in a separating funnel and was extracted with solvent ether (3x50ml). Combined ether extract was washed with distilled water (3x 25ml) and finally ether was evaporated. The residue was weighed as unsaponifiable matter.

I. Protein Content

Crude protein was determined by Macro-Kjeldahl method (Sankaram, 1966). Ground cake (1g) was digested with conc. H₂SO₄ (25 ml) and digested mixture (20 parts of K₂SO₄ and one part of CuSO₄) in a digestion flask on an electric heater. Heating was continued until light blue colour appeared. After this digestion was further continued for 15 minutes. Flask contents were cooled, transferred into 250 ml volumetric flask and volume was made to the mark with distilled water. Five ml of this digested material was taken in a distillation flask for distillation of ammonia into boric acid solution (10 ml, 0.1 N). To ensure the content of flask to be distinctly alkaline, 40% NaOH (10 ml) was added. When 2/3 volume was made in the Erlenmeyer flask, it was removed from the distillation apparatus and the excess of the acid was back titrated with 0.1 N NaOH using methyl red indicator. Nitrogen was calculated by the following way and content was multiplied by 6.25 to obtain the value of crude protein content.

$$\% \text{ N in sample} = \frac{\text{Titre value} \times 0.0014}{\text{Weight of sample taken (g)}} \times 100$$

$$\text{Crude protein content} = \text{N} \times 6.25$$

J. Starch Content:

The residue left from after the protein content of dry samples was hydrolyzed by adding 5 ml of distilled water and 6 ml of 52 per cent perchloric acid. Contents were stirred for 30 minutes followed by the addition of 20 ml of distilled water. Thereafter, filtered and volume made to 100 ml. Glucose formed in the sample after hydrolysis was determined by phenol-sulphuric acid method of Dubois *et al.*, (1951) and then the starch was calculated by multiplying the glucose with conversion of 0.9 and expressed as mg/g of dry weight.

K. Total Sugar Content:

One gram of cake was extracted with 20-25 ml of boiling alcohol for 10 minutes contents were decanted and the residue was again extracted with 10 ml of boiling alcohol filtered and the two filtrates were combined and volume was made to 50 ml. The alcoholic extract was evaporated to dryness and the residue was dissolved in 3 ml of distilled water and centrifuged at 4000RPM for 15 minutes. The supernatant was used for the estimation of soluble sugars. Total sugars in deoiled samples were estimated by phenol-sulphuric acid method given by Dubois *et al.* (1951). To 1 ml of supernatant (taken in test tube) were added 5% phenol solution (1 ml). The contents were thoroughly mixed and cooled under tap water. The intensity of orange yellow colour was measured at 490 nm. The standard curve prepared from glucose served for the estimation of soluble sugars.

3.3 STATISTICAL ANALYSIS

Statistical analysis was an important tool for collection, evaluation and interpretation of data. The data was analyzed statistically by using RBD factorial in the field and CRD in laboratory. ANOVA (Analysis of Variance) for morphometric traits, progeny performance traits, heritability, genetic gain, correlation and genetic advancement were calculated as described by Panse and Sukhatme (1967) and Chandel (1984).

A. Critical Difference (CD)

In order to compare the mean of various entries, the critical difference was calculated by the formula:

$$CD = S.E \times t_{0.05}$$

$$SE = \sqrt{2MSE/r}$$

Where,

SE	=	Standard Error of the difference of means to be compared.
t	=	Tabulated value of t at 5% levels of significance
r	=	No. of replications
MSE	=	Error mean sum of squares

B. Correlation Coefficient:

Karl Pearson correlation coefficient was determined as:

$$r_{xy} = \frac{\text{CoV}_{xy}}{\sqrt{V_x \cdot V_y}}$$

Where,

r_{xy}	=	Correlation between x and y
V_x	=	Variation of x
V_y	=	Variation of y

C. Variance:

Phenotypic (V_p) and Genotypic (V_g) was calculated as:

V_p	=	$V_g + M_e$	(Phenotypic variance)
M_e	=	Mean sum squares due to error	(Environmental variance)

D. Coefficient of Variability:

Coefficient of variability was worked out by the formulae (Burton and De Vane, 1953).

$$\text{PCV \%} = \sqrt{\frac{V_p}{\bar{X}}} \times 100$$

$$\text{GCV \%} = \sqrt{\frac{V_g}{\bar{X}}} \times 100$$

Where,

PCV and GCV are Phenotypic and Genotypic Coefficients of variation respectively and $\bar{X}$ the population mean of the character.

E. Heritability:

Heritability (Broad Sense) H^2 , was calculated as suggested by (Burton and De Vane, 1953) and Johnson *et al.* (1955).

$$H^2 = \frac{V_g}{V_p} \times 100 \quad (H^2, \text{ expressed as \% age})$$

F. Genetic Advance: (as per Allard, 1960)

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

Where,

$$\begin{aligned} H^2 &= \text{Broad sense heritability} \\ V_p &= \text{Phenotypic variance} \\ K &= \text{Selection Differential at 5\% selection intensity} \end{aligned}$$

G. Genetic Gain:

Genetic gain was calculated as suggested by Johnson *et al.* (1955)

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

Where,

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

Chapter-4

RESULTS AND DISCUSSION

The investigation on “**Variability Studies on *Quercus leucotrichophora* A. Camus Populations in Himachal Pradesh**” was carried out during the years of 2014-2016 to determine the variation among the trees of different diameter classes and sites for morphological, chemical and progeny performance traits/parameters. In all, two experiments were conducted, one each in field and laboratory conditions. A characteristics feature of all living organisms is the immense natural variability present for various characteristics in most populations. A wide range of variability present in the species always provides a better chance of selecting desirable types. The results obtained on different aspects are described under the following headings:

- 4.1 Variation in morphological traits.
- 4.2 Variation in germination traits and progeny performance traits.
- 4.3 Variation in oil content, physical and chemical characteristics of fatty oil and nutritional value of deoiled cake.
- 4.4 Correlation studies.
- 4.5 Variability estimates and genetic parameters.

4.1 VARIATION IN MORPHOLOGICAL TRAITS

4.1.1 Tree Height

Data presented in the Table 1 reveals that maximum mean tree height was depicted by T9 (30.34 m) and minimum by T3 (17.29m). The variation among the sites revealed that maximum mean height was recorded by S7 (28.00 m) and minimum by S1 (17.77 m). S4 (22.74 m), S6 (24.93 m) and S8 (24.23 m) were found statistically at par with site S7. Whereas interaction among the diameter classes revealed that maximum mean height was recorded for D3 (27.31 m) and minimum for D1 (17.86 m). D2 (23.00 m) were found statistically at par with D1. Interaction among the different sites and diameter classes depicted that maximum mean height was of S6D3 (35.90 m) and minimum mean height was of S1D1 (13.55 m). However, non significant interaction was found between different diameter classes and different sites.

Table 1. Variation in the tree height (m) of *Quercus leucotrichophora* in three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	14.24	15.76	10.65	13.55	15.87	24.55	13.00	17.81	20.50	28.90	16.50	21.97	17.77
S2 (Chail)	13.76	17.87	24.45	18.69	15.90	28.80	27.50	24.07	14.60	27.80	22.40	21.60	21.45
S3 (Taklech)	17.98	13.98	24.87	18.94	27.50	16.87	24.00	22.79	13.53	26.60	21.90	20.68	20.80
S4 (Summer-Hill)	20.76	18.90	14.50	18.05	24.76	17.50	27.96	23.41	24.56	25.90	29.80	26.75	22.74
S5 (Garsa)	24.43	16.87	23.80	21.70	26.89	21.90	10.50	19.76	28.50	18.90	24.90	24.10	21.85
S6 (Manikaran)	12.65	16.95	12.45	14.02	28.22	21.60	24.80	24.87	29.00	36.50	42.20	35.90	24.93
S7 (Sahu)	24.76	21.98	15.87	20.87	29.70	23.80	30.65	28.05	27.90	32.84	44.50	35.08	28.00
S8 (Salooni)	15.76	23.65	11.72	17.04	13.66	28.00	27.98	23.21	31.90	24.90	40.50	32.43	24.23
Mean	18.04	18.25	17.29	17.86	22.81	22.88	23.30	23.00	23.81	27.79	30.34	27.31	
CD(0.05)													
Diameter	3.37												
Site	5.51												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

4.1.2 Diameter at Breast Height

The maximum mean value of diameter at breast height was depicted by T7 (60.81cm) and minimum by T2 (21.44cm). Analysis of variation among the sites revealed that maximum mean value of diameter at breast height was depicted by S8 (41.59 cm) and minimum by S1(39.09 cm), whereas interaction among the diameter classes revealed that maximum mean value of diameter at breast height was depicted by D3 (61.01 cm) and minimum by D1 (23.16cm). D2 (36.91 cm) were found statistically at par with D1. Interaction studies between three diameter classes and eight sites showed that maximum mean height was depicted by S5D3 (62.18cm) and minimum by S1D1 (20.20cm). When interaction between mean diameter classes and different was found to be non significant (Table 2).

4.1.3 Clean Bole Height

Perusal of data in Table 3 illustrates highest mean value for clean bole height was recorded by T7 (3.13 m) and minimum by T1 (1.88 m).The variation among the sites revealed that maximum mean value for clean bole height was depicted by S7 (2.94 m) and minimum by S1 (1.78 m). S2 (2.40 m), S3 (2.53 m), S4 (2.29 m), S5 (2.84m) and S6 (2.92 m) and were found statistically at par with site S7.Whereas interaction among the diameter classes revealed that maximum mean value for clean bole height was depicted by D3 (2.78 m) and minimum mean value was depicted by D1(1.95 m). D2 (2.64 m) found statistically at par with D3. Interaction studies between three diameter classes and eight sites showed maximum mean value for clean bole height was depicted by S7D2(3.83 m) and minimum by S1D2 (1.20m) and non significant interaction was found between diameter classes and different sites.

4.1.4 Crown Length

Analysis of Table 4 revealed that maximum crown length was recorded by T9 (28.13 m) and T1 (16.17m) depicted the minimum value for the same. The variation among the sites revealed that maximum mean crown length value was depicted by S7 (22.98 m) and minimum by S1 (15.77 m). Whereas interaction among the diameter classes revealed that maximum mean value for crown length was depicted by D3 (24.53 m) and minimum mean value was depicted by D1 (15.90 m). Interaction among the diameter classes and different site

Table 2. Variation in the diameter at breast height (cm) of *Quercus leucotrichophora* in three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	24.40	20.43	15.76	20.20	31.50	34.50	44.50	36.83	60.45	60.20	60.10	60.25	39.09
S2 (Chail)	22.62	24.76	23.65	23.68	30.50	31.40	48.43	36.78	60.65	60.34	60.50	60.50	40.32
S3 (Taklech)	25.86	14.65	24.50	21.67	31.65	32.50	47.80	37.32	61.50	60.87	61.40	61.26	40.08
S4 (Summer-Hill)	29.50	18.98	25.60	24.69	32.70	31.20	42.80	35.57	61.56	62.80	60.60	61.65	40.64
S5 (Garsa)	20.50	16.87	24.80	20.72	33.70	31.90	50.76	38.79	61.45	61.40	63.70	62.18	40.56
S6 (Manikaran)	22.65	24.65	26.70	24.67	34.54	33.50	36.76	34.93	60.10	60.45	60.60	60.38	39.99
S7 (Sahu)	23.76	27.65	23.70	25.04	37.50	32.80	35.80	35.37	60.55	62.90	60.77	61.41	40.60
S8 (Salooni)	27.50	23.50	22.90	24.63	39.80	44.80	34.50	39.70	60.20	60.20	60.90	60.43	41.59
Mean	24.60	21.44	23.45	23.16	33.99	34.08	42.67	36.91	60.81	61.15	61.07	61.01	
CD(0.05)													
Diameter	2.58												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 3. Variation in the clean bole height (m) of *Quercus leucotrichophora* in three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	1.50	1.00	1.40	1.30	0.60	1.50	1.50	1.20	4.50	3.50	0.50	2.83	1.78
S2 (Chail)	1.50	4.00	1.70	2.40	1.50	2.90	3.00	2.47	3.50	2.00	1.50	2.33	2.40
S3 (Taklech)	2.00	1.40	2.40	1.93	2.50	3.00	3.50	3.00	3.00	2.50	2.50	2.67	2.53
S4 (Summer-Hill)	1.50	1.60	2.50	1.87	2.00	3.50	2.40	2.63	2.50	2.00	2.60	2.37	2.29
S5 (Garsa)	2.00	1.40	2.70	2.03	3.50	2.50	2.50	2.83	5.00	3.50	2.50	3.67	2.84
S6 (Manikaran)	2.50	1.80	2.50	2.27	4.00	2.40	3.50	3.30	2.50	3.50	3.60	3.20	2.92
S7 (Sahu)	2.50	2.50	1.50	2.17	3.50	3.50	4.50	3.83	2.50	3.50	2.50	2.83	2.94
S8 (Salooni)	1.50	2.50	1.00	1.67	1.50	2.50	1.50	1.83	1.50	3.50	2.00	2.33	1.94
Mean	1.88	2.03	1.96	1.95	2.39	2.73	2.80	2.64	3.13	3.00	2.21	2.78	
CD(0.05)													
Diameter	0.48												
Site	0.79												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 4. Variation in the crown length (m) of *Quercus leucotrichophora* in three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	12.74	14.76	9.25	12.25	13.26	23.05	11.50	15.94	16.00	25.40	16.00	19.13	15.77
S2 (Chail)	12.26	13.87	22.75	16.29	16.48	25.90	24.50	22.29	11.10	25.80	20.90	19.27	19.28
S3 (Taklech)	15.98	12.58	22.47	17.01	25.00	13.87	20.50	19.79	10.53	24.10	19.40	18.01	18.27
S4 (Summer-Hill)	19.26	17.30	12.00	16.19	22.76	13.00	25.56	20.44	22.06	23.90	27.20	24.39	20.34
S5 (Garsa)	22.43	15.47	21.10	19.67	23.39	16.50	8.00	15.96	23.50	15.40	22.40	20.43	18.69
S6 (Manikaran)	10.15	15.15	9.95	11.75	24.22	21.60	21.30	22.37	26.50	33.00	38.60	32.70	22.27
S7 (Sahu)	22.26	19.48	14.37	18.70	7.50	20.30	26.15	17.98	25.40	29.34	42.00	32.25	22.98
S8 (Salooni)	14.26	21.15	10.72	15.38	12.16	25.50	26.48	21.38	30.40	21.40	38.50	30.10	22.29
Mean	16.17	16.22	15.33	15.90	18.10	19.97	20.50	19.52	20.69	24.79	28.13	24.53	
CD(0.05)													
Diameter	3.40												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number



Diameter class (<30 cm)



Diameter class (30 -60 cm)



Diameter class (>60 cm)

Plate 2. *Quercus leucotrichophora* tree with small diameter class (<30 cm), Medium diameter class (30- 60 cm) and large diameter class (> 60 cm) at Summer hill- Shimla

showed maximum mean value for S6D3 (32.70 m) and minimum for S6D1 (11.75 m), while interaction between mean diameter classes and different sites was found to be non significant.

4.1.5 Crown Width

An appraisal of Table 5 elucidated that maximum mean value for the crown width was recorded by T4 (6.36 m) and minimum by T3 (3.36 m). The variation among the sites revealed that maximum mean value for crown width was showed by S8 (5.52 m) and minimum value for the same was showed by S2 (4.22 m). S3 (4.90 m), S4 (5.12 m), S5 (5.29m), S6 (5.38 m) and S7 (5.24 m) were found statistically at par with site S8. Whereas interaction among the diameter classes revealed that maximum mean value was recorded for D3 (5.40 m) and minimum value for the same recorded for D1 (4.45 m) and D2 (5.13 m) were found statistically at par with D3. Analysis of interaction between three diameter classes and eight sites revealed that maximum value was recorded for S8D3 (7.27 m) and minimum value (3.27 m) was recorded for S8D1. S7D3 (6.20 m) was found statistically at par with S8D3.

4.1.6 Number of Primary Branches

Data appended in Table 6 showed maximum mean number of primary branches was recorded for T6 (11.00) and minimum mean value for the same was recorded for T1 and T7 (9.13). The variation among the sites revealed that maximum mean value for number of primary branches was showed by S6 (11.00) and minimum value for the same by S2 (9.22 m). However, different sites differ non significantly, whereas interaction among three diameter classes revealed that maximum mean value was recorded for D2 (10.25) and minimum value for the same for D3 (9.75) which differed non significantly. For diameter and sites interaction the maximum branching was depicted by S6D1 (13.00) and minimum by S1D2 (8.33) and non significant interaction was found between three diameter classes and eight sites.

4.1.7 Leaf Length

The observation of data presented in Table 7 depicted that the maximum mean value for leaf length was recorded for T5 (15.68 cm) and minimum for T9 (12.57 cm). The different sites showed significant variation with highest mean leaf length for S6 (15.72 cm) and minimum (11.51 cm) for S1. S2 (14.06 cm), S3 (14.70 cm), S4 (14.83 cm), S5 (15.65 cm), S7 (14.20 cm) and S8 (14.36 cm) were found significantly at par with site S6. Interaction

Table 5. Variation in the crown width (m) of *Quercus leucotrichophora* in three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	5.60	4.80	2.50	4.30	6.75	4.60	3.50	4.95	4.30	3.70	2.50	3.50	4.25
S2 (Chail)	4.60	4.20	3.50	4.10	5.60	4.50	2.50	4.20	4.90	4.80	3.40	4.37	4.22
S3 (Taklech)	6.75	4.30	3.70	4.92	4.60	4.50	4.50	4.53	5.60	5.40	4.80	5.27	4.90
S4 (Summer-Hill)	4.90	4.80	2.50	4.07	6.70	6.50	4.80	6.00	5.80	5.60	4.50	5.30	5.12
S5 (Garsa)	5.40	4.80	4.50	4.90	7.60	5.40	3.50	5.50	5.90	5.60	4.90	5.47	5.29
S6 (Manikaran)	5.40	5.30	3.80	4.83	6.30	5.50	4.60	5.47	6.50	5.50	5.50	5.83	5.38
S7 (Sahu)	6.50	5.40	3.60	5.17	6.80	3.70	2.60	4.37	7.60	6.50	4.50	6.20	5.24
S8 (Salooni)	3.50	3.50	2.80	3.27	6.50	5.80	5.80	6.03	9.80	7.50	4.50	7.27	5.52
Mean	5.33	4.64	3.36	4.45	6.36	5.06	3.98	5.13	6.30	5.58	4.33	5.40	
CD(0.05)													
Diameter	0.42												
Site	0.69												
Diameter× Site	1.20												

Where T1 to T9 = Tree Number

Table 6. Variation in the number of primary branches of *Quercus leucotrichophora* in three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	12.00	12.00	7.00	10.33	8.00	9.00	8.00	8.33	10.00	11.00	8.00	9.67	9.44
S2 (Chail)	11.00	7.00	8.00	8.67	9.00	8.00	9.00	8.67	12.00	10.00	9.00	10.33	9.22
S3 (Taklech)	8.00	8.00	12.00	9.33	12.00	12.00	12.00	12.00	9.00	12.00	8.00	9.67	10.33
S4 (Summer-Hill)	6.00	9.00	11.00	8.67	11.00	7.00	11.00	9.67	7.00	11.00	10.00	9.33	9.22
S5 (Garsa)	7.00	12.00	11.00	10.00	8.00	8.00	13.00	9.67	10.00	12.00	11.00	11.00	10.22
S6 (Manikaran)	9.00	15.00	15.00	13.00	9.00	9.00	14.00	10.67	10.00	8.00	10.00	9.33	11.00
S7 (Sahu)	9.00	12.00	8.00	9.67	11.00	12.00	11.00	11.33	8.00	9.00	12.00	9.67	10.22
S8 (Salooni)	11.00	11.00	9.00	10.33	14.00	11.00	10.00	11.67	7.00	10.00	10.00	9.00	10.33
Mean	9.13	10.75	10.13	10.00	10.25	9.50	11.00	10.25	9.13	10.38	9.75	9.75	
CD(0.05)													
Diameter	NS												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 7. Variation in the leaf length (cm) of *Quercus leucotrichophora* in three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	12.56	11.21	11.76	11.84	12.33	10.53	12.22	11.69	10.87	11.43	10.65	10.99	11.51
S2 (Chail)	11.50	14.54	14.78	13.60	16.88	14.88	13.66	15.14	12.88	13.43	13.98	13.43	14.06
S3 (Taklech)	12.80	13.76	12.89	13.15	17.88	17.68	14.55	16.70	14.54	16.87	11.32	14.24	14.70
S4 (Summer-Hill)	11.98	14.78	15.87	14.21	15.78	15.65	15.65	15.69	13.98	16.89	12.87	14.58	14.83
S5 (Garsa)	15.87	15.88	14.88	15.54	15.98	18.98	14.57	16.51	14.09	15.88	14.76	14.91	15.65
S6 (Manikaran)	14.54	16.98	14.87	15.46	14.88	14.77	19.43	16.36	18.67	16.43	10.89	15.33	15.72
S7 (Sahu)	12.67	11.24	12.88	12.26	17.65	16.99	10.88	15.17	15.88	15.76	13.87	15.17	14.20
S8 (Salooni)	16.65	11.65	15.88	14.73	12.89	15.98	15.45	14.77	16.54	11.98	12.21	13.58	14.36
Mean	13.57	13.75	14.23	13.85	15.54	15.68	14.55	15.25	14.68	14.83	12.57	14.03	
CD(0.05)													
Diameter	1.11												
Site	1.82												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

among the three diameter classes depicted maximum mean leaf length value for D2 (15.26 cm) and minimum for D1 (13.85 cm). D3 (14.03 cm) were found statistically at par with D1. Interaction studies between three diameter classes and eight sites showed that maximum mean value for leaf length was depicted by S3D2 (16.70 cm) and minimum by S1D3 (10.65 cm), while interaction between mean diameter classes and different sites was found to be non significant.

4.1.8 Leaf Width

Data appended in the Table 8 revealed that the maximum mean value for the leaf width was depicted by T4 (5.47 cm) and minimum by T6 (4.28 cm). Variation among the eight sites showed significant differences with maximum mean value for leaf width by S6 (5.35 cm) minimum by S2 (4.64cm). S8 (5.15 cm) was found statistically at par with site S6. Interaction among the diameter classes revealed maximum mean value for D3 (5.05 cm) and minimum value for the same was recorded for D2 (4.84 cm). For diameter and sites interaction the maximum mean value for leaf width was depicted by S8D3 (5.49 cm) and minimum by S7D1 and S4D2 (4.33 cm). S6D1 (5.48 cm), S8D1 (5.17 cm), S3D2 (4.98 cm), S6D2 (5.20 cm), S7D2 (5.21 cm), S1D3 (5.04 cm), S4D3 (5.10 cm), S5D3 (5.25 cm), S6D3 (5.38 cm), S7D3 (5.05 cm) and S8D3 (5.49 cm) were found statistically at par with S8D3.

4.1.9 Leaf Area

Perusal of data in Table 9 showed that tree T7 (46.80cm²) had highest and T2 (37.00 cm²) had lowest mean leaf area. However variation among the sites showed significant differences with maximum mean leaf area for S8 (45.30 cm²) minimum for S2 (35.01 cm²). S5 (43.40 cm²) and S7 (42.60 cm²) were found statistically at par with S8. Interaction among the three diameter classes revealed maximum value for D3 (41.29 cm²) and minimum value for D2 (39.62 cm²). For diameter and site interaction the maximum leaf area was depicted by S7D2 (47.43 cm²) and minimum by S6D2 (31.17 cm²) and significant interaction was found between diameter classes and different Sites. S1D1 (44.77 cm²), S2D1 (39.37 cm²), S3D1 (40.63 cm²), S4D1 (38.77 cm²), S5D1 (41.47 cm²), S8D1 (42.10 cm²), S3D2 (39.27 cm²), S5D2 (41.50 cm²), S8D2 (47.13 cm²), S3D3 (39.67 cm²), S4D3 (42.37 cm²), S5D3 (47.23 cm²), S6D3 (42.50 cm²), S7D3 (44.29 cm²) and S8D3 (46.67 cm²) were found statistically at par with S7D2.

Table 8. Variation in the leaf width (cm) of *Quercus leucotrichophora* in three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	5.05	4.84	4.65	4.85	5.50	4.76	4.50	4.92	5.50	5.20	4.41	5.04	4.93
S2 (Chail)	5.45	4.84	3.22	4.50	5.50	4.64	4.50	4.88	5.04	4.48	4.00	4.51	4.64
S3 (Taklech)	5.40	5.00	4.40	4.93	5.50	5.22	4.23	4.98	4.77	4.50	4.50	4.59	4.84
S4 (Summer-Hill)	5.20	4.89	4.66	4.92	4.50	4.50	4.00	4.33	5.40	5.25	4.66	5.10	4.78
S5 (Garsa)	5.08	4.74	4.50	4.77	5.25	4.12	4.00	4.46	5.65	5.25	4.86	5.25	4.82
S6 (Manikaran)	5.99	5.34	5.10	5.48	5.50	5.50	4.60	5.20	5.50	5.43	5.20	5.38	5.35
S7 (Sahu)	4.50	4.25	4.25	4.33	6.50	5.00	4.12	5.21	5.25	5.05	4.86	5.05	4.86
S8 (Salooni)	5.88	5.34	4.30	5.17	5.50	4.60	4.25	4.78	5.65	5.50	5.34	5.49	5.15
Mean	5.31	4.90	4.39	4.87	5.47	4.79	4.28	4.84	5.34	5.08	4.3	5.05	
CD(0.05)													
Diameter	NS												
Site	0.30												
Diameter× Site	0.52												

Where T1 to T9 = Tree Number

Table 9. Variation in the leaf area (cm²) of *Quercus leucotrichophora* in three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	46.80	38.60	48.90	44.77	36.60	41.20	34.40	37.40	39.80	36.90	36.60	37.77	39.98
S2 (Chail)	45.10	36.50	36.50	39.37	35.70	39.90	31.90	35.83	31.70	31.40	26.40	29.83	35.01
S3 (Taklech)	43.70	39.10	39.10	40.63	39.90	41.20	36.70	39.27	41.20	39.90	37.90	39.67	39.86
S4 (Summer-Hill)	41.90	37.20	37.20	38.77	32.10	41.20	38.50	37.27	55.10	39.90	32.10	42.37	39.47
S5 (Garsa)	44.40	35.60	44.40	41.47	45.00	37.60	41.89	41.50	51.90	45.00	44.80	47.23	43.40
S6 (Manikaran)	51.80	31.60	31.60	38.33	30.00	32.10	31.40	31.17	48.60	46.80	32.10	42.50	37.33
S7 (Sahu)	38.70	35.80	33.70	36.07	55.60	48.00	38.70	47.43	55.60	31.40	45.87	44.29	42.60
S8 (Salooni)	43.10	41.60	41.60	42.10	52.80	45.00	43.60	47.13	50.50	55.10	34.40	46.67	45.30
Mean	44.44	37.00	39.13	40.19	40.96	40.78	37.14	39.62	46.80	40.80	36.27	41.29	
CD(0.05)													
Diameter	NS												
Site	5.04												
Diameter× Site	8.73												

Where T1 to T9 = Tree Number

Analysis of data obtained directly from the natural forest the morphological traits revealed that significant differences were found among sites for various traits viz., tree height, clean bole height, crown width, leaf area, leaf length and leaf width. The maximum mean value for the characters such as DBH, crown length, crown width and leaf area were shown by site S8 (Salooni-Chamba), whereas site S6 (Manikaran-Kullu) excelled in number of branches, leaf length and leaf width. Height and clean bole height was maximum in site S7 (Sahu- Chamba). With in diameter classes significant variation found for height, DBH, clean bole height, crown length, crown width, leaf length. Diameter class D3 (>60 cm) excelled in maximum number of characters viz., tree height, clean bole height, crown length, crown width, leaf area, and leaf width.

These finding lend a support to the results obtained by various workers in different species. Farmer and Wilcox (1964) in *Populus deltoides* reported variation in growth rate within stand and also between stands as a result of environmental and site factors. Townsend (1977) revealed significant variation in height, diameter and other parameters among different provenances of *Acer rubrum* at two year age. Dicke and Bagley (1980) revealed discontinuous variation among provenances of *Quercus macrocarpa* for morphometric traits, they found high rate of variation in growth characters between the sources. Comtois *et al.* (1989) recorded the genetic similarity by means of morphological characters like leaf size, leaf shape, etc., in Balsam poplar. Bayramzadeh *et al.* (2011) studied variation in five native Oriental Beech populations grown in the western Caspian region and their result showed that all the measured leaf morphometric traits were remarkably different among the population. Variation in height, diameter and number of branches in *Cedrela* spp (Whitmore, 1971) showed the same variations. Similar variations were reported with respect to leaf dimensions and leaf area in *Juglans nigra* by Dixon (1988). Studies on leaf morphology by Boeger *et al.* (2004) showed similar variations.

Ying and Bagley (1976) reported variation for growth, morphological and physiological traits of Eastern Cottonwood in seven years old plantation of different provenances, which represented the major parts of natural range of species. Nagesh *et al.* (2007) reported seed production areas and seed sources identified for quantitative variation in fruit traits of teak. These variations could be helpful during identification of seeds of different sources and it may have important role in germination. Sankhyan *et al.* (2008) studied morphological variations in *Grewia laevigata* which revealed that some of the traits, viz.,

number of leaves per branch, leaf length and leaf area exhibited variation between the sites but not among the trees.

4.2 VARIATION IN GERMINATION TRAITS AND PROGENY PERFORMANCE TRAITS

4.2.1 Germination and Seedling Growth Studies

4.2.1.1 Number of Days for Initiation of Germination

It is evident from Table 10 (fig 1) that T2 (25.23) showed the maximum mean number of initiation days for germination and minimum mean value was showed by T5 (17.16). The variation among the different sites showed non significant variation with maximum mean days were recorded for site S6 (22.18) and minimum for site S1 (20.97).Whereas interaction among the three diameter classes revealed maximum mean value for D1 (23.90) and minimum for D2 (18.85). D3 (21.16) were found statistically at par with D2. For diameter and site interaction the maximum mean value was showed by S4D1 (25.15) and minimum value by S2D2 (17.34). Non significant interaction was found between diameter classes and different sites.

4.2.1.2 Number of Days for Complete Germination

Data presented in Table 11 (fig 2) indicated that the T1 (52.83) showed maximum mean number of days to complete germination and minimum mean number of days was showed by T5 (36.67) The variation among the eight sites showed significant variation with maximum mean days were recorded for site S3 (49.61) and minimum for site S5 (43.39). S1 (46.73), S2 (46.95), S4 (47.91) and S8 (46.54) were found significant with the maximum. Whereas interaction among the diameter classes revealed maximum mean value for D1 (52.25) and minimum for D2 (39.78). D3 (46.55) were found statistically at par with D2. Interaction studies between three diameter classes and eight sites showed maximum mean value for S3D1 (57.33) and minimum value for S2D2 (36.23). Significant interaction was found between diameter classes and different sites. S1D1 (54.26), S2D1 (56.23), S4D1 (53.46) and S8D1 (52.22) were found statistically at par with S3D1.

4.2.1.3 Germination (%)

Data in Table 12 (fig 3) showed that T6 (72.42) had the maximum mean value for germination percentage and T2 (55.12) had minimum mean value. The variation among eight

Table 10. Variation in the number of days for initiation of germination of *Quercus leucotrichophora* seeds from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	23.33	24.88	24.67	24.29	18.73	17.45	18.65	18.28	20.67	18.98	21.33	20.33	20.97
S2 (Chail)	21.67	26.43	25.00	24.37	20.15	15.00	16.87	17.34	21.33	20.76	21.99	21.36	21.02
S3 (Taklech)	22.33	24.88	23.33	23.51	19.87	15.90	16.78	17.52	22.13	19.87	25.67	22.56	21.20
S4 (Summer-Hill)	25.99	26.78	22.67	25.15	21.90	16.98	18.90	19.26	19.67	19.67	22.33	20.56	21.65
S5 (Garsa)	21.88	25.70	22.33	23.30	20.16	16.50	17.87	18.18	21.67	19.87	23.33	21.62	21.03
S6 (Manikaran)	22.67	22.33	23.98	22.99	22.51	18.95	22.16	21.21	22.67	21.60	22.76	22.34	22.18
S7 (Sahu)	21.00	25.98	22.98	23.32	18.88	16.65	21.45	18.99	23.33	17.67	23.33	21.44	21.25
S8 (Salooni)	21.00	24.88	26.99	24.29	19.98	19.87	20.33	20.06	20.78	17.98	18.56	19.11	21.15
Mean	22.48	25.23	23.99	23.90	20.27	17.16	19.13	18.85	21.53	19.55	22.41	21.16	
CD(0.05)													
Diameter	1.12												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 11. Variation in the number of days for complete germination of *Quercus leucotrichophora* seeds from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	56.25	50.19	56.35	54.26	39.62	38.88	42.32	40.27	50.24	37.07	49.65	45.65	46.73
S2 (Chail)	56.56	55.3	56.83	56.23	42.05	33.87	32.77	36.23	53.44	39.63	52.08	48.38	46.95
S3 (Taklech)	57.11	57.56	57.31	57.33	40.86	37.74	38.68	39.09	55.9	47.42	53.9	52.41	49.61
S4 (Summer-Hill)	56.76	51.04	52.57	53.46	54.03	35.89	40.7	43.54	50.47	38.24	51.45	46.72	47.91
S5 (Garsa)	47.91	49.64	47.04	48.20	42.05	33.61	40.1	38.59	46.87	37.98	45.35	43.40	43.39
S6 (Manikaran)	48.35	46.36	49.17	47.96	41.3	39.17	43.06	41.18	48.53	40.6	47.44	45.52	44.89
S7 (Sahu)	48.48	47.83	45.69	47.33	36.87	37.48	42.73	39.03	46.94	38.85	46.91	44.23	43.53
S8 (Salooni)	51.22	52.44	56.01	53.22	41.95	36.72	42.22	40.30	50.46	41.53	46.34	46.11	46.54
Mean	52.83	51.30	52.62	52.25	42.34	36.67	40.32	39.78	50.36	40.17	49.14	46.55	
CD(0.05)													
Diameter	1.88												
Site	3.07												
Diameter× Site	5.31												

Where T1 to T9 = Tree Number

Table 12. Variation in the germination (%) of *Quercus leucotrichophora* seeds from three diameter classes among different sites

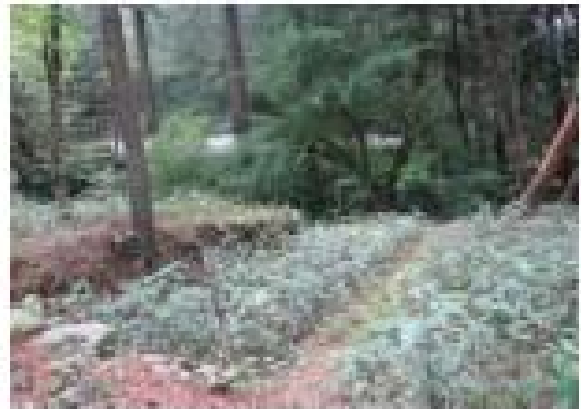
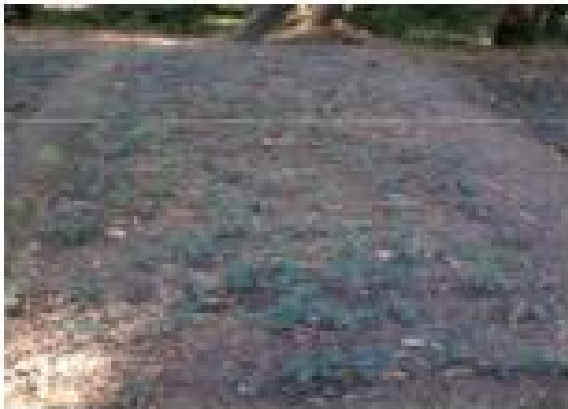
Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	60.55 (51.09)	56.65 (48.82)	52.89 (46.66)	56.70 (48.86)	68.98 (56.15)	65.16 (53.82)	69.87 (56.71)	68.00 (55.56)	65.89 (54.26)	62.98 (52.52)	54.89 (7.81)	61.25 (51.53)	61.98 (51.98)
S2 (Chail)	54.87 (47.79)	54.00 (47.29)	56.67 (48.83)	55.18 (47.97)	75.16 (60.11)	71.89 (57.98)	73.28 (8.87)	73.44 (58.99)	65.98 (54.32)	69.17 (56.27)	58.89 (50.12)	61.79 (53.57)	64.43 (53.30)
S3 (Taklech)	57.33 (49.21)	51.99 (46.14)	57.87 (49.53)	55.73 (48.29)	72.19 (58.17)	59.87 (50.69)	69.10 (56.23)	67.05 (55.03)	68.87 (56.09)	71.29 (57.60)	68.76 (56.02)	51.34 (56.57)	64.14 (52.30)
S4 (Summer-Hill)	60.87 (51.28)	58.98 (50.17)	62.76 (52.39)	60.87 (51.28)	65.45 (54.00)	55.87 (48.37)	65.90 (54.27)	62.41 (52.21)	63.90 (53.07)	60.71 (51.18)	70.89 (57.35)	55.57 (53.87)	62.81 (52.45)
S5 (Garsa)	52.67 (46.53)	58.76 (50.05)	52.56 (46.47)	54.66 (47.68)	72.17 (58.16)	75.36 (60.24)	77.76 (61.86)	75.10 (60.09)	51.68 (45.96)	64.89 (53.66)	70.55 (57.13)	62.37 (52.25)	64.04 (53.34)
S6 (Manikaran)	61.89 (51.88)	51.56 (45.89)	54.98 (47.86)	56.14 (48.54)	75.14 (60.09)	72.17 (58.16)	75.77 (60.51)	74.36 (59.59)	69.00 (56.17)	64.98 (53.72)	71.90 (57.99)	52.98 (55.96)	66.38 (54.70)
S7 (Sahu)	51.78 (46.02)	55.34 (48.07)	51.79 (46.03)	52.97 (46.70)	62.78 (52.40)	73.90 (59.28)	76.98 (61.33)	71.22 (57.67)	69.87 (56.71)	65.89 (54.26)	70.87 (57.34)	68.88 (56.10)	64.36 (53.49)
S8 (Salooni)	60.45 (51.03)	53.65 (47.09)	61.89 (51.88)	58.66 (50.00)	69.87 (56.71)	67.94 (55.51)	70.67 (57.21)	69.49 (56.48)	72.90 (58.63)	66.98 (54.93)	69.78 (56.65)	69.89 (56.74)	66.01 (54.49)
Mean	57.55 (49.35)	55.12 (47.94)	56.43 (48.71)	56.36 (48.67)	70.22 (56.97)	67.77 (55.51)	72.42 (58.37)	70.13 (56.95)	66.01 (54.40)	65.86 (54.27)	67.07 (55.05)	66.31 (54.57)	
CD(0.05)													
Diameter	2.49												
Site	NS												
Diameter× Site	7.03												

Where T1 to T9 = Tree Number

*Values in the brackets are transformed values



Nursery bed preparation for the evaluation of progeny performance



Seedling growth after one year

Plate 3. Experimental field under progeny performance of *Quercus leucotrichophora*

sites showed non significant variation with the maximum mean value for germination by site S6 (66.38) and minimum by S1 (61.98). Interaction among the diameter classes revealed maximum value for D2 (70.13) and minimum for D1 (56.36). D3 (66.31) were found statistically at par with D1. Interaction studies between three diameter classes and eight sites showed maximum mean value for S5D2 (75.10) and minimum for S7D1 (52.97) and significant interaction was found between diameter classes and different sites. S2D2 (73.44), S6D2 (74.36), S7D2 (71.22), S8D2 (69.49), S7D3 (68.88) and S8D3 (69.89) were found statistically at par with S5D2.

4.2.1.4 Germination Value

Data appended in Table 13 (fig 4) showed that maximum mean germination value was showed by T7 (7.52) and minimum by T1 (5.54). The variation among the sites showed non significant variation with maximum mean germination value in site S8 (7.44) and minimum value in S6 (5.64). Interaction among the diameter classes revealed maximum means value for D3 (7.18) and minimum for D1 (5.97). D2 (6.38) and were found statistically at par with D3. Interaction studies between three diameter classes and eight sites showed maximum mean value for S2D3 (9.18) and minimum mean value for S5D1 (4.49). Significant interaction was found between diameter classes and different sites. S4D1 (7.09), S8D1 (8.01), S1D2 (7.10), S3D2 (7.12), S5D2 (7.91), S8D2 (7.75), S3D3 (8.16) S4D3 (8.55) and S7D3 (7.74) were found statistically at par with S2D3.

4.2.1.5 Seedling Survival Percentage

Seedling survival has been expressed in percentage in Table 14 (fig 5) and it was found that maximum mean percentage was showed by T4 (81.10) and minimum by T1 (62.14). The variation among the sites showed significant variation with maximum mean value for Site S7 (75.83) and minimum mean value for S1 (69.18). S8 (75.30) and S6 (73.36) were found significantly at par with site S7. Interaction among the diameter classes revealed maximum value for D2 (80.65) and minimum for D1 (63.85). D3 (73.61) and were found significantly at par with D1. Interaction studies among three diameter classes and eight sites showed that maximum mean value for survival percentage was showed by S7D2 (84.37) and minimum S1D1 (55.68). Significant interaction was found between diameter classes and different sites. S2D2 (80.03), S3D2 (79.04), S5D2 (79.46), S6D2 (83.58) and S8D2 (83.74) were found significantly at par with S7D2.

Table 13. Variation in the germination value of *Quercus leucotrichophora* seeds from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	4.56	7.98	5.20	5.91	7.97	4.56	8.76	7.10	3.98	4.98	6.57	5.18	6.06
S2 (Chail)	4.98	7.18	5.98	6.05	3.89	5.65	4.99	4.84	9.79	8.97	8.79	9.18	6.69
S3 (Taklech)	4.90	4.67	4.43	4.67	8.79	4.67	7.89	7.12	8.59	7.98	7.90	8.16	6.65
S4 (Summer-Hill)	5.40	8.29	7.58	7.09	8.76	5.78	4.63	6.39	9.87	8.98	6.80	8.55	7.34
S5 (Garsa)	6.10	3.87	3.50	4.49	6.78	8.97	7.98	7.91	9.79	4.60	4.67	6.35	6.25
S6 (Manikaran)	4.56	8.67	4.98	6.07	5.46	4.99	4.76	5.07	5.67	5.76	5.89	5.77	5.64
S7 (Sahu)	5.90	5.49	4.98	5.46	4.67	4.60	5.34	4.87	5.65	9.76	7.80	7.74	6.02
S8 (Salooni)	7.90	7.76	8.37	8.01	5.25	9.04	8.97	7.75	6.78	8.98	3.87	6.54	7.44
Mean	5.54	6.74	5.63	5.97	6.45	6.03	6.67	6.38	7.52	7.50	6.54	7.18	
CD(0.05)													
Diameter	0.93												
Site	NS												
Diameter× Site	2.63												

Where T1 to T9 = Tree Number

Table 14. Variation in the percentage seedling survival of *Quercus leucotrichophora* seedling from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	52.89 (46.66)	56.18 (48.55)	57.98 (49.59)	55.68 (48.27)	77.42 (61.63)	76.55 (61.04)	74.00 (59.34)	75.99 (60.67)	71.99 (58.05)	78.67 (62.49)	76.90 (61.27)	75.85 (60.60)	69.18 (56.51)
S2 (Chail)	54.78 (47.74)	59.09 (50.24)	61.90 (51.88)	58.59 (49.95)	77.33 (61.57)	82.89 (65.57)	79.87 (63.34)	80.03 (63.49)	77.80 (61.89)	79.98 (63.42)	74.70 (59.80)	77.49 (61.70)	72.04 (58.38)
S3 (Taklech)	63.98 (53.12)	59.78 (50.64)	61.89 (51.88)	61.88 (51.88)	78.90 (62.65)	76.33 (60.89)	81.89 (64.81)	79.04 (62.79)	69.77 (56.65)	72.90 (58.63)	72.89 (58.62)	71.85 (57.97)	70.93 (57.54)
S4 (Summer-Hill)	60.99 (51.35)	62.57 (54.26)	65.89 (54.26)	63.15 (52.63)	79.60 (63.15)	80.66 (63.91)	76.68 (61.12)	78.98 (62.73)	76.98 (61.33)	76.50 (61.00)	71.00 (57.42)	74.83 (59.92)	72.32 (58.43)
S5 (Garsa)	66.67 (54.74)	66.89 (54.87)	72.98 (58.68)	68.85 (56.10)	80.17 (63.56)	78.33 (62.26)	79.88 (63.35)	79.46 (63.05)	70.00 (56.79)	73.98 (59.33)	65.19 (53.84)	69.72 (56.65)	72.68 (58.60)
S6 (Manikaran)	64.89 (53.66)	62.89 (52.47)	71.90 (57.99)	66.56 (54.71)	85.99 (68.02)	82.78 (65.48)	81.98 (64.88)	83.58 (66.13)	61.90 (51.88)	73.98 (59.33)	73.90 (59.28)	69.93 (56.83)	73.36 (59.22)
S7 (Sahu)	65.98 (54.32)	66.80 (54.82)	75.09 (60.06)	69.29 (56.40)	87.70 (69.47)	84.60 (66.89)	80.81 (64.02)	84.37 (66.79)	74.50 (59.67)	75.90 (60.60)	71.09 (57.47)	73.83 (59.25)	75.83 (60.81)
S8 (Salooni)	66.90 (54.88)	64.50 (53.43)	68.9 (56.10)	66.77 (54.80)	81.67 (64.65)	85.55 (67.66)	83.99 (66.41)	83.74 (66.24)	70.81 (57.30)	78.90 (62.65)	76.50 (61.00)	75.40 (60.32)	75.30 (60.45)
Mean	62.14 (52.06)	62.34 (52.16)	67.07 (55.06)	63.85 (53.09)	81.10 (64.34)	80.96 (64.21)	79.89 (63.41)	80.65 (63.99)	71.72 (57.94)	76.35 (60.93)	72.77 (58.59)	73.61 (59.16)	
CD(0.05)													
Diameter	1.89												
Site	3.09												
Diameter× Site	5.36												

Where T1 to T9 = Tree Number

*Values in the brackets are transformed values

The germination and seedling growth characters, viz., number of days for complete germination, seedling survival percentage were recorded significant among various sites. Site S6 (Manikaran-Kullu) recorded maximum mean value for number of days for initial germination and germination percentage. Site S8 (Salooni-Chamba) recorded maximum mean value for germination percentage and S7 (Sahu-Chamba) excelled in seedling survival percentage. With in diameter classes significant variation were recorded for number of days for initiation of germination, number of days for complete germination, germination percentage, germination value and seedling survival percentage. Diameter class D2 (30-60 cm) excelled in germination percentage and seedling survival percentage.

These finding lend a support to the results obtained by Ngulube (1989) in *Gliricidia sepium* who reported significant differences in seed germination between provenances. Seeds of *Dalbergia sissoo* collected from different seed sources scattered over almost the entire natural range in India were studied for variation in seed morphology and germination parameters. The study revealed significant genetic variation among all seed sources for rate of germination (Vakshasya *et al.*, 1992). Some seed sources show better performance in certain locations than the others and use of seed of a superior provenance in areas, very much different in climatic or edaphic conditions from their origin, often results in poor performance or failure (Pirags, 1971 and Read, 1971).

Mohapatra (1996) in *Acacia catechu* recorded significant variation in germination index in nursery and field condition. White *et al.* (1990) analyzed the genetic variation in six provenances of *Dalbergia sissoo* and observed substantial differences for survival, form, growth and vigour in the seedlings. Kumar and Bangarwa (1999) studied progeny testing in *Azadirchta indica* collected seed from ten randomly taken trees of neem growing naturally in Hisar. Significant differences were observed among progenies for vigour index and growth parameters in two months old seedlings. Hooda *et al.* (2009) in *Pongamia pinnata* reported significant variation for germination percentage. Kumar and Tokey (1996) reported significant variation in seed germination and seed growth in *Albizia lebbek*. Singh and Pokhariyal (2001) in *Dalbergia sissoo* reported significant variation in seed traits and germination parameters among different seed sources as in our present findings.

Figure 1 Variation in the number of days for initiation of germination of *Quercus leucotrichophora* seeds from three diameter classes (D) among different sites (S)

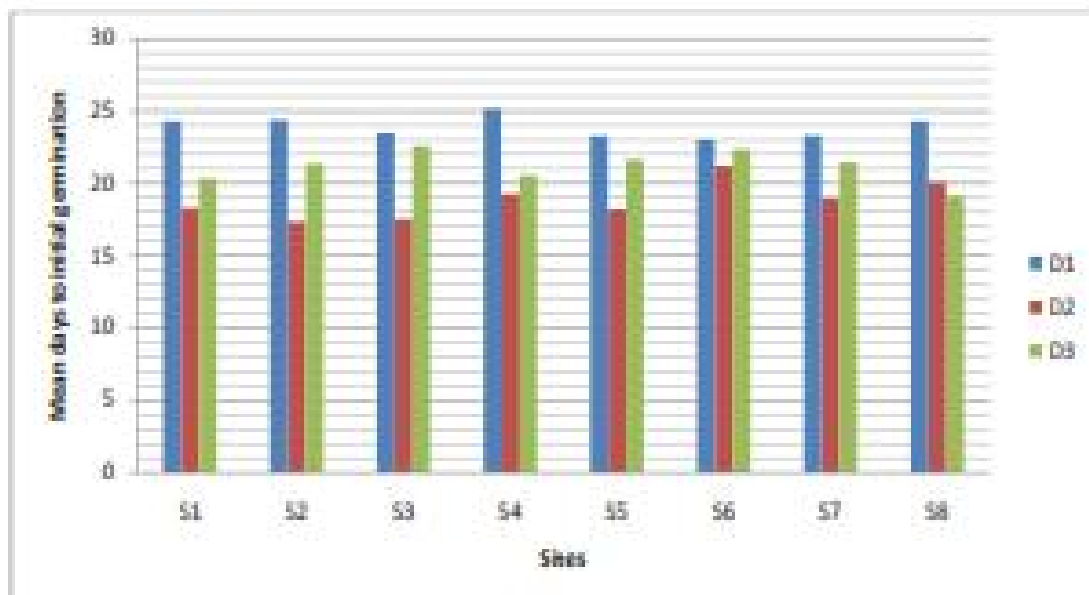


Figure 2 Variation in the number of days for complete germination of *Quercus leucotrichophora* seeds from three diameter classes (D) among different sites (S)

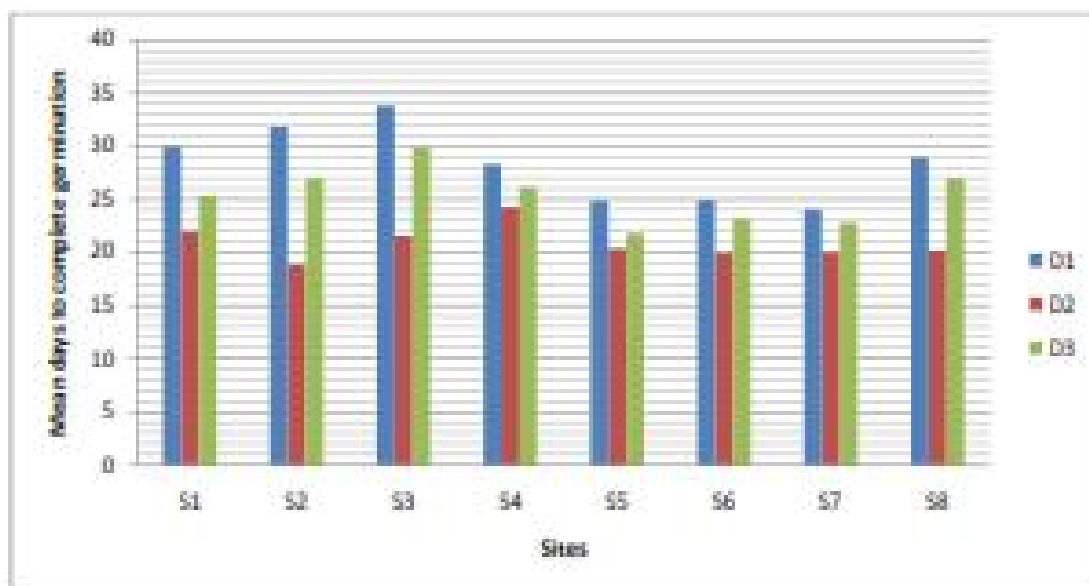


Figure 3. Variation in the germination (%) of *Quercus leucotrichophora* seeds from three diameter classes (D) among different sites (S)

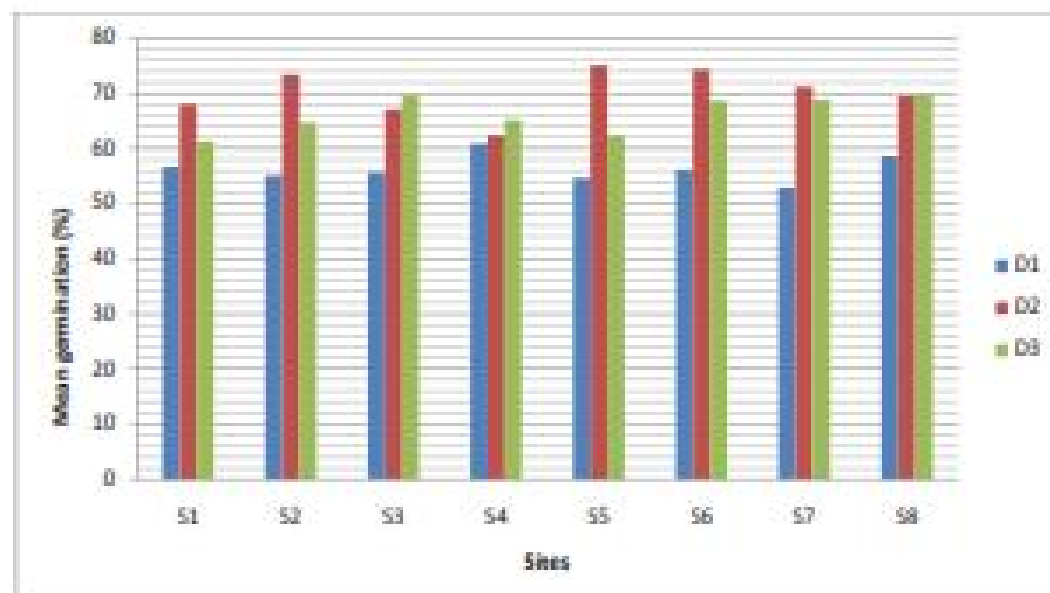


Figure 4. Variation in the germination value of *Quercus leucotrichophora* seeds from three diameter classes (D) among different sites (S)

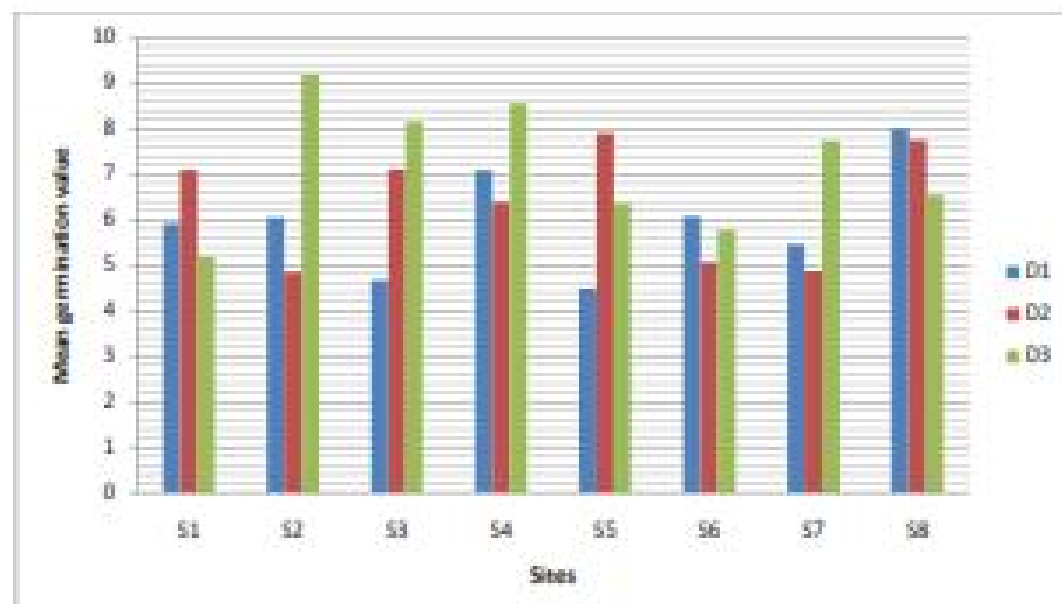
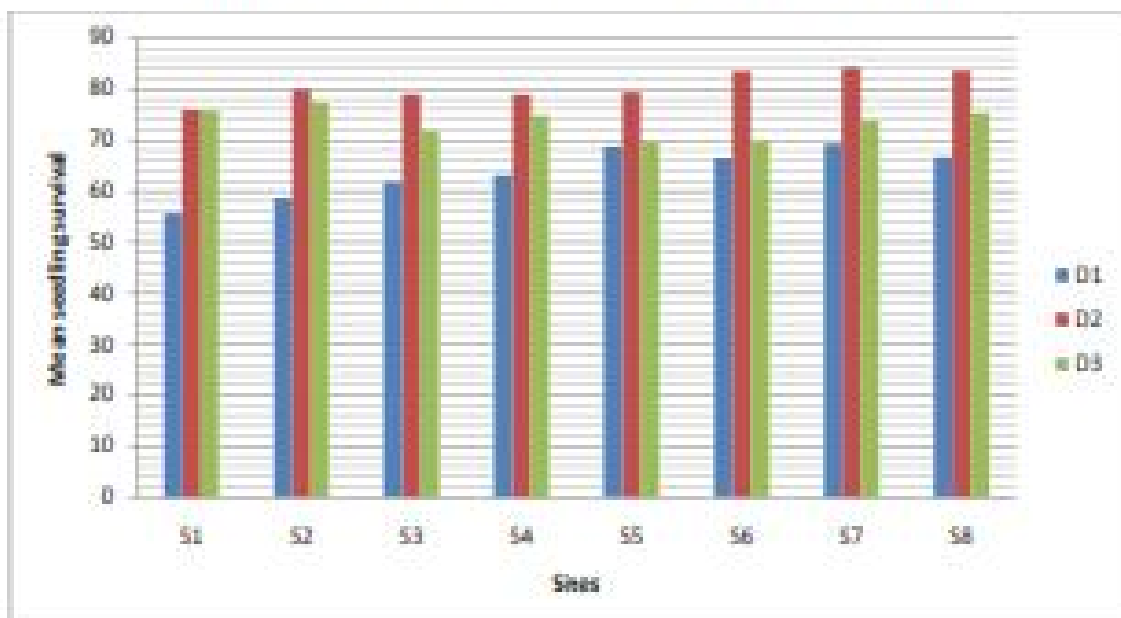


Figure 5. Variation in the percentage seedling survival of *Quercus leucotrichophora* seedling from three diameter classes (D) among different sites (S)



4.2.2 Variation in Progeny Performance Traits

4.2.2.1 Seedling length

An appraisal of Table15 elucidated that maximum mean value for the seedling length was attained by T5(26.08 cm) and minimum value was recorded for T1(22.61 cm).Variation among the different sites showed non significant variation with maximum mean length of 25.24 cm in sites S4 and minimum value for the same was recorded in S1 (23.05 cm). Interaction among the three diameter classes depicted maximum mean value for the diameter class D3 (24.96 cm) and minimum for D1 (22.83 cm). D2 (24.89 cm) and were found statistically at par with D3. Interaction studies between diameter classes and different site showed maximum mean value for S2D3 (27.48 cm), whereas S6D1 (19.98 cm) recorded the minimum mean value. Non significant interaction was found between diameter classes and different sites.

4.2.1.2 Collar Diameter

Perusal of data in Table16 depicted that maximum mean value for the collar diameter was depicted by T7 (0.37 cm) and minimum mean value for the same was recorded in T1 and T2 (0.23 cm).Variation among the different sites showed non significant variations with maximum mean collar diameter for site S4 and S7 (0.30 cm each) and minimum value for S6 (0.25 cm). Variation among the three diameter classes was significant and maximum mean value was recorded by D3 (0.35 cm) and minimum for D1 (0.23 cm). D2 (0.26 cm) were found statistically at par with D1. Interaction between three diameter classes and eight sites showed maximum value for S7D3 (0.46 cm) and minimum value for S8D1 (0.20 cm). Non significant interaction was found between diameter classes in different sites.

4.2.1.3 Inter-nodal Length

An appraisal of Table17 elucidated that maximum mean value for the inter-nodal length was attained by T8 (3.05 cm) and minimum mean value for the same by T1 (1.94 cm).Variation among the sites showed non significant variation with maximum mean height by site S6 (2.99 cm) and minimum value by site S1 (2.22 cm). Interaction among the three diameter classes recorded maximum mean value for the diameter class D3 (3.03 cm) and minimum for D1 (2.04 cm). D2 (2.72 cm) were found statistically at par with D1. Interaction between three diameter classes and eight sites showed maximum mean value for S6D3 (3.72 cm) while S5D1 (1.79 cm) recorded the minimum mean value. However, non significant interaction was found between diameter classes and different sites.

Table 15. Variation in the seedling length (cm) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	20.20	20.12	22.53	20.95	24.56	22.74	22.85	23.38	21.63	26.96	25.85	24.81	23.05
S2 (Chail)	22.63	22.54	21.52	22.23	25.63	28.43	22.63	25.56	25.96	28.75	27.74	27.48	25.09
S3 (Taklech)	24.74	22.10	20.63	22.49	24.23	24.54	23.63	24.13	26.96	21.10	22.95	23.67	23.43
S4 (Summer-Hill)	26.32	24.74	27.09	26.05	21.21	25.52	24.85	23.86	27.63	27.32	22.52	25.82	25.24
S5 (Garsa)	24.65	25.43	22.03	24.04	25.88	25.52	25.41	25.60	22.65	22.74	25.52	23.64	24.43
S6 (Manikaran)	19.53	17.52	22.88	19.98	22.52	28.32	26.41	25.75	22.08	25.96	27.63	25.22	23.65
S7 (Sahu)	21.38	22.63	23.21	22.41	23.21	25.97	25.52	24.90	23.96	23.85	25.63	24.48	23.93
S8 (Salooni)	21.43	26.63	25.44	24.50	24.31	27.63	25.74	25.89	25.63	23.96	24.01	24.53	24.98
Mean	22.61	22.71	23.17	22.83	23.94	26.08	24.63	24.89	24.56	25.08	25.23	24.96	
CD(0.05)													
Diameter	1.14												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 16. Variation in the collar diameter (cm) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	0.36	0.24	0.18	0.26	0.25	0.36	0.25	0.29	0.37	0.35	0.25	0.32	0.29
S2 (Chail)	0.32	0.25	0.26	0.28	0.16	0.25	0.26	0.22	0.47	0.32	0.24	0.34	0.28
S3 (Taklech)	0.37	0.14	0.15	0.22	0.29	0.25	0.39	0.31	0.42	0.23	0.35	0.33	0.29
S4 (Summer-Hill)	0.18	0.27	0.36	0.27	0.32	0.25	0.13	0.23	0.29	0.43	0.43	0.38	0.30
S5 (Garsa)	0.15	0.25	0.29	0.23	0.24	0.29	0.32	0.28	0.36	0.19	0.37	0.31	0.27
S6 (Manikaran)	0.19	0.22	0.21	0.21	0.19	0.24	0.31	0.25	0.29	0.34	0.29	0.31	0.25
S7 (Sahu)	0.11	0.30	0.21	0.21	0.36	0.22	0.12	0.23	0.44	0.46	0.48	0.46	0.30
S8 (Salooni)	0.19	0.17	0.25	0.20	0.22	0.35	0.32	0.30	0.29	0.41	0.32	0.34	0.28
Mean	0.23	0.23	0.24	0.23	0.25	0.28	0.26	0.26	0.37	0.34	0.34	0.35	
CD(0.05)													
Diameter	0.04												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 17. Variation in the inter-nodal length (cm) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	1.50	2.50	1.50	1.83	1.50	3.50	2.50	2.50	1.50	2.50	2.98	2.33	2.22
S2 (Chail)	1.50	1.50	2.50	1.83	2.65	2.50	2.50	2.55	2.43	2.50	3.50	2.81	2.40
S3 (Taklech)	2.50	2.32	1.50	2.11	2.76	2.40	3.00	2.72	2.55	2.00	3.23	2.59	2.47
S4 (Summer-Hill)	2.32	2.43	1.75	2.17	2.75	2.50	1.50	2.25	2.42	3.50	3.50	3.14	2.52
S5 (Garsa)	1.50	2.32	1.54	1.79	3.50	2.80	2.75	3.02	3.54	4.32	2.50	3.45	2.75
S6 (Manikaran)	3.21	1.75	1.98	2.31	3.12	3.21	2.50	2.94	3.75	3.87	3.54	3.72	2.99
S7 (Sahu)	1.65	1.65	2.55	1.95	1.50	3.21	3.65	2.79	3.75	2.98	3.21	3.31	2.68
S8 (Salooni)	1.32	2.50	3.21	2.34	2.43	4.12	2.50	3.02	3.50	2.76	2.43	2.90	2.75
Mean	1.94	2.12	2.07	2.04	2.53	3.03	2.61	2.72	2.93	3.05	3.11	3.03	
CD(0.05)													
Diameter	0.38												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

4.2.1.4 Number of Leaves per seedling

Observation of data in Table 18 depicted that maximum mean value for leaves per seedling was recorded in T7 (10.68) and minimum in T1 (8.18). Variation among the sites showed non significant variations with maximum mean leaves per seedling by site S4 (10.60) and minimum value by site S3 (8.98). Variation among the diameter classes was significant and maximum mean value was recorded by D2 (10.31) and minimum by D1 (8.56). D3 (10.01) were found statistically at par with D2. Interaction between three diameter classes and eight sites showed maximum mean value for S4D2, S8D2 and S2D3 (11.42) and minimum value for S1D1 (7.25). Non significant interaction was found between three diameter classes and different sites.

4.2.1.5 Leaf Area of seedling

Perusal of data for leaf area in Table 19 noticed that T4 (12.49 cm²) had highest and T6 (9.08 cm²) had lowest mean value for leaf area. However, variation among the different sites showed significant variations with maximum mean leaf area for S8 (11.38 cm²) and minimum for S7 (9.83 cm²). S1 (11.25 cm²), S2 (11.06 cm²) and S3 (10.94 cm²) were found statistically at par with S8. Interaction among the diameter classes revealed maximum value for D3 (10.78 cm²) and minimum value for D1 (10.40 cm²). For diameter and sites interaction significant interaction was found between three diameter classes and different sites and maximum mean value for leaf area was recorded by S1D1 (12.73 cm²) and minimum value by S7D1 (8.32 cm²). S8D1 (11.24 cm²), S2D2 (11.61 cm²), S3D2 (11.17 cm²), S8D2 (11.94 cm²), S3D3 (11.50 cm²) and S7D3 (11.45 cm²) were found statistically at par with S1D1.

4.2.1.6 Fresh Leaf Biomass of seedling

The observation of data represented in Table 20 depicted that the maximum mean value for the fresh leaf biomass was recorded for T1 (2.25 g) and minimum for T3 (1.64 g). The different sites showed non significant variation with highest mean fresh leaf biomass for S3 (2.08g) and minimum for S6 (1.85 g). Interaction among the three diameter classes depicted maximum mean fresh leaf biomass value for D2 and D3 (2.05) and minimum mean value for D1 (1.89 g). For diameter and site interaction the maximum value was recorded for S3D3 (2.32 g) and minimum value for S6D1 (1.40). Non significant interaction was found between three diameter classes and different sites.

Table 18. Variation in the number of leaves per seedling of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	6.77	6.98	8.00	7.25	11.87	7.00	10.98	9.95	11.00	8.00	10.65	9.88	9.03
S2 (Chail)	7.19	8.67	8.79	8.22	8.91	6.00	11.00	8.64	12.90	11.36	10.00	11.42	9.42
S3 (Taklech)	6.98	8.56	9.87	8.47	9.71	10.87	9.80	10.13	8.02	9.00	8.00	8.34	8.98
S4 (Summer-Hill)	11.98	9.71	10.00	10.56	10.91	11.98	11.36	11.42	10.98	11.52	7.00	9.83	10.60
S5 (Garsa)	11.75	7.00	11.26	10.00	8.97	11.00	10.70	10.22	10.98	10.00	9.00	9.99	10.07
S6 (Manikaran)	8.77	9.17	7.00	8.31	10.71	11.65	8.65	10.34	9.87	11.87	10.87	10.87	9.84
S7 (Sahu)	5.00	7.90	8.91	7.27	10.00	9.81	11.25	10.35	9.88	9.82	8.90	9.53	9.05
S8 (Salooni)	6.98	7.63	10.59	8.40	11.26	12.00	11.00	11.42	11.79	11.91	7.00	10.23	10.02
Mean	8.18	8.20	9.30	8.56	10.29	10.04	10.59	10.31	10.68	10.44	8.93	10.01	
CD(0.05)													
Diameter	0.93												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 19. Variation in the leaf area of seedling (cm²) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	13.00	12.65	12.54	12.73	11.98	9.87	9.76	10.54	13.65	9.76	8.00	10.47	11.25
S2 (Chail)	13.54	9.87	9.54	10.98	12.98	10.98	10.87	11.61	10.98	10.87	9.87	10.57	11.06
S3 (Taklech)	11.87	9.65	8.98	10.17	12.87	11.09	9.54	11.17	12.87	12.65	8.98	11.50	10.94
S4 (Summer-Hill)	11.50	9.98	9.54	10.34	12.98	9.87	9.76	10.87	10.65	9.98	9.87	10.17	10.46
S5 (Garsa)	11.09	9.98	7.76	9.61	13.87	9.76	6.99	10.21	11.98	9.87	9.83	10.56	10.13
S6 (Manikaran)	11.65	9.08	8.65	9.79	11.56	10.70	6.87	9.71	12.98	9.76	9.08	10.61	10.04
S7 (Sahu)	9.76	8.43	6.76	8.32	11.70	10.49	6.98	9.72	12.98	10.87	10.49	11.45	9.83
S8 (Salooni)	12.98	10.98	9.76	11.24	11.98	11.98	11.87	11.94	11.98	10.98	9.87	10.94	11.38
Mean	11.92	10.08	9.19	10.40	12.49	10.59	9.08	10.72	12.26	10.59	9.50	10.78	
CD(0.05)													
Diameter	NS												
Site	0.90												
Diameter× Site	1.56												

Where T1 to T9 = Tree Number

Table 20. Variation in the fresh leaf biomass of seedling (g) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	2.34	1.87	1.65	1.95	0.99	1.98	2.54	1.84	2.98	1.98	1.77	2.24	2.01
S2 (Chail)	2.43	2.12	2.21	2.25	1.87	2.54	1.87	2.09	2.01	1.76	1.82	1.86	2.07
S3 (Taklech)	2.98	1.98	1.22	2.06	1.87	1.76	1.98	1.87	1.99	2.98	1.98	2.32	2.08
S4 (Summer-Hill)	1.98	2.21	1.22	1.80	2.71	2.98	1.09	2.26	2.01	1.87	2.13	2.00	2.02
S5 (Garsa)	2.87	1.21	2.32	2.13	1.87	2.13	1.87	1.96	1.98	1.90	1.09	1.66	1.92
S6 (Manikaran)	1.98	1.22	1.00	1.40	2.98	1.98	1.77	2.24	1.99	1.87	1.87	1.91	1.85
S7 (Sahu)	2.12	2.12	1.65	1.96	2.01	1.76	1.82	1.86	2.98	1.50	2.09	2.19	2.01
S8 (Salooni)	1.32	1.54	1.87	1.58	2.98	1.76	1.99	2.24	1.99	1.65	2.98	2.21	2.01
Mean	2.25	1.78	1.64	1.89	2.16	2.11	1.87	2.05	2.24	1.94	1.97	2.05	
CD(0.05)													
Diameter	NS												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

4.2.1.7 Root Length of seedling

The observation in Table 21 depicted that the maximum mean value for the root length was recorded for T5 (12.98 cm) and minimum for T1 (10.56 cm). The different sites showed non significant variation with highest mean root length for S6 and S7 (11.96 cm) and minimum (11.02 cm) for S8. Interaction among the three diameter classes showed maximum mean value for root length for D2 (12.04 cm) and minimum mean value for D1 (11.18 cm). For diameter and site interaction the maximum value was recorded by S6D2 (13.72 cm) and minimum value by S8D1 (9.98 cm). Non significant interaction was found between three diameter classes and eight sites.

4.2.1.8 Shoot Length of seedling

The observation of data in Table 22 depicted that the maximum mean value for the shoot length was recorded for T9 (14.18 cm) and minimum value for T2 (10.78 cm). The different sites showed significant variation with highest shoot length mean value for S4 (14.16 cm) and minimum (11.94 cm) for S1. S2 (13.25), S5 (12.59) and S8 (13.95) were found significantly at par with maximum. Interaction among the three diameter classes found maximum mean value for D3 (13.58 cm) and minimum for D1 (11.65 cm). D2 (12.84 cm) were found significantly at par with D3. For diameter and sites interaction the maximum value was recorded by S4D3 (15.80 cm) and minimum value by S1D1 (9.71 cm). Non significant interaction was found between three diameter classes and eight sites.

4.2.1.9 Root : Shoot Length Ratio

Perusal of data in Table 23 depicted that T2 (1.13) had highest and T9 (0.79) had lowest mean root : shoot length ratio. However variation among the different sites showed non significant differences with maximum root : shoot length ratio for S6 (1.04) minimum for S4 and S8 (0.81). Whereas interaction among the diameter classes revealed maximum value for D1 (0.99) and minimum value for D3 (0.86). Interaction studies among the three diameter classes and eight sites showed maximum mean value for S1D1 (1.16) and minimum value for S4D3 (0.65). Non significant interaction was found between diameter classes and different sites.

Table 21. Variation in the root length of seedling (cm) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	9.87	10.87	12.98	11.24	11.32	12.98	9.87	11.39	9.98	11.09	10.98	10.68	11.10
S2 (Chail)	10.98	11.98	11.98	11.65	10.98	12.98	11.98	11.98	12.98	12.88	9.87	11.91	11.85
S3 (Taklech)	12.09	12.76	9.87	11.57	12.98	11.98	12.98	12.65	11.09	10.23	9.08	10.13	11.45
S4 (Summer-Hill)	11.98	12.98	12.88	12.61	10.98	10.98	9.87	10.61	8.98	11.34	9.76	10.03	11.08
S5 (Garsa)	12.98	11.09	10.23	11.43	14.54	12.98	9.76	12.43	12.87	9.98	12.09	11.65	11.84
S6 (Manikaran)	9.87	8.98	11.34	10.06	12.54	15.65	12.98	13.72	11.32	12.98	11.98	12.09	11.96
S7 (Sahu)	9.76	12.87	9.98	10.87	12.67	13.43	11.98	12.69	10.98	12.98	12.98	12.31	11.96
S8 (Salooni)	6.98	13.98	8.99	9.98	9.88	12.87	9.87	10.87	12.98	11.98	11.65	12.20	11.02
Mean	10.56	11.94	11.03	11.18	11.99	12.98	11.16	12.04	11.40	11.68	11.05	11.38	
CD(0.05)													
Diameter	NS												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 22. Variation in the shoot length of seedling (cm) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	10.33	9.25	9.55	9.71	13.24	9.76	12.98	11.99	11.65	15.87	14.87	14.13	11.94
S2 (Chail)	11.65	10.56	9.54	10.58	14.65	15.45	10.65	13.58	12.98	15.87	17.87	15.57	13.25
S3 (Taklech)	12.65	9.34	10.76	10.92	11.25	12.56	10.65	11.49	15.87	10.87	13.87	13.54	11.98
S4 (Summer-Hill)	14.34	11.76	14.21	13.44	10.23	14.54	14.98	13.25	18.65	15.98	12.76	15.80	14.16
S5 (Garsa)	11.67	14.34	11.80	12.60	11.34	12.54	15.65	13.18	9.78	12.76	13.43	11.99	12.59
S6 (Manikaran)	9.66	8.54	11.54	9.91	9.98	12.67	13.43	12.03	10.76	12.98	15.65	13.13	11.69
S7 (Sahu)	11.62	9.76	13.23	11.54	10.54	12.54	13.54	12.21	12.98	10.87	12.65	12.17	11.97
S8 (Salooni)	14.45	12.65	16.45	14.52	14.43	14.76	15.87	15.02	12.65	11.98	12.36	12.33	13.95
Mean	12.05	10.78	12.14	11.65	11.96	13.10	13.47	12.84	13.17	13.40	14.18	13.58	
CD(0.05)													
Diameter	1.07												
Site	1.74												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 23. Variation in the root:shoot length ratio of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	0.96	1.18	1.36	1.16	0.85	1.33	0.76	0.98	0.86	0.70	0.74	0.76	0.97
S2 (Chail)	0.94	1.13	1.26	1.11	0.75	0.84	1.12	0.90	1.00	0.81	0.55	0.79	0.93
S3 (Taklech)	0.96	1.37	0.92	1.08	1.15	0.95	1.22	1.11	0.70	0.94	0.65	0.76	0.98
S4 (Summer-Hill)	0.84	1.10	0.91	0.95	1.07	0.76	0.66	0.83	0.48	0.71	0.76	0.65	0.81
S5 (Garsa)	1.11	0.77	0.87	0.92	1.28	1.04	0.62	0.98	1.32	0.78	0.90	1.00	0.97
S6 (Manikaran)	1.02	1.05	0.98	1.02	1.26	1.24	0.97	1.15	1.05	1.00	0.77	0.94	1.04
S7 (Sahu)	0.84	1.32	0.75	0.97	1.20	1.07	0.88	1.05	0.85	1.19	1.03	1.02	1.02
S8 (Salooni)	0.48	1.11	0.55	0.71	0.68	0.87	0.62	0.73	1.03	1.00	0.94	0.99	0.81
Mean	0.89	1.13	0.95	0.99	1.03	1.01	0.86	0.97	0.91	0.89	0.79	0.86	
CD(0.05)													
Diameter	NS												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

4.2.1.10 Root Fresh Weight

The observation of data represented in Table 24 depicted that the maximum mean value for the root fresh weight was recorded for T7 (2.62 g) and minimum value for T1 (1.93 g). The sites showed significant variation with highest mean value for root fresh weight for S5 (2.84 g) and minimum (1.82 g) for S7. S1 (2.46 g), S3 (2.45 g) and S4 (2.52 g) were found significantly at par with S5. Interaction among the three diameter classes found maximum value for D3 (2.46 g) and minimum mean value for D1 (2.20 g). Interaction between three diameter classes and eight sites showed maximum mean value for S1D3 (2.96 g) and minimum value for S8D2 (1.22 g). S1D1 (2.42 g), S2D1 (2.17 g), S3D1 (2.40 g), S4D1 (2.80 g), S1D2 (2.67 g), S2D2 (2.42 g), S3D2 (2.52 g), S4D2 (2.36 g), S5D2 (2.69 g), S6D2 (2.92 g), S1D3 (2.28 g), S2D3 (2.42 g), S3D3 (2.43 g), S4D3 (2.39 g), S5D3 (2.87 g), S6D3 (2.40 g), S7D3 (2.21 g), S8D3 (2.71 g) and S5D3 (2.87 g) were found significantly at par with S1D3. Significant interaction was found between three diameter classes and different sites.

4.2.1.11 Shoot Fresh Weight

The observation of data represented in Table 25 depicted that the maximum mean value for the shoot fresh weight was recorded for T7 (2.83 g) and minimum value for T3 (1.84 g). The eight sites showed non significant variation with highest mean shoot fresh weight for S1 and S3 (2.40 g) and minimum (2.22 g) for S5. Interaction among the three diameter classes found maximum mean value for D3 (2.38 g) and minimum mean value for D1 (2.27 g). For diameter and site interaction the maximum value was recorded for S3D3 (2.69 g) and minimum value for S8D1 (2.00 g). S1D1 (2.30 g), S2D1 (2.58 g), S3D1 (2.26 g), S5D1 (2.41 g), S7D1 (2.40 g), S4D2 (2.66 g), S1D2 (2.32), S4D2 (2.66 g), S6D2 (2.42 g), S8D2 (2.52 g), S1D3 (2.58 g), S4D3 (2.33 g), S7D3 (2.45 g), S8D3 (2.50 g) were found statistically at par with S3D3. Significant interaction was found between diameter classes and different sites.

4.2.1.12 Root : Shoot Fresh Weight Ratio

Perusal of data in Table 26 noticed that T6 (1.36) had highest and T1 (0.71) had lowest mean root : shoot fresh weight ratio. However variation among the eight sites showed significant differences with maximum mean root : shoot fresh weight ratio value for S5 (1.34) and minimum for S7 (0.79). S4 (1.16) and S1 (1.08) were found significantly at par with S5. Whereas interaction among the three diameter classes revealed maximum value for D3 (1.06)

Table 24. Variation in the root fresh weight (g) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	2.05	2.25	2.95	2.42	2.50	2.75	2.75	2.67	3.05	1.75	2.05	2.28	2.46
S2 (Chail)	2.25	1.75	2.50	2.17	2.25	2.50	2.50	2.42	2.75	2.25	2.25	2.42	2.33
S3 (Taklech)	2.50	2.75	1.95	2.40	3.05	2.25	2.25	2.52	2.05	3.23	2.02	2.43	2.45
S4 (Summer-Hill)	1.95	3.50	2.95	2.80	1.59	1.75	3.75	2.36	1.75	2.76	2.65	2.39	2.52
S5 (Garsa)	2.95	2.95	2.98	2.96	2.62	1.95	3.50	2.69	2.98	2.98	2.65	2.87	2.84
S6 (Manikaran)	0.99	1.95	0.99	1.31	3.05	2.75	2.95	2.92	2.76	2.02	2.42	2.40	2.21
S7 (Sahu)	1.25	2.25	1.85	1.78	1.75	1.69	0.99	1.48	2.25	2.25	2.12	2.21	1.82
S8 (Salooni)	1.50	1.95	1.76	1.74	0.95	0.95	1.75	1.22	3.34	2.65	2.15	2.71	1.89
Mean	1.93	2.42	2.24	2.20	2.22	2.07	2.56	2.28	2.62	2.49	2.29	2.46	
CD(0.05)													
Diameter	NS												
Site	0.49												
Diameter× Site	0.85												

Where T1 to T9 = Tree Number

Table 25. Variation in the shoot fresh weight (g) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	2.65	2.25	2.00	2.30	2.95	2.5	1.5	2.32	3.25	2.50	1.99	2.58	2.40
S2 (Chail)	2.75	2.75	2.25	2.58	2.50	1.99	1.99	2.16	2.50	1.99	1.95	2.15	2.30
S3 (Taklech)	3.02	2.25	1.50	2.26	2.25	2.25	2.25	2.25	3.05	2.52	2.50	2.69	2.40
S4 (Summer-Hill)	2.65	2.05	1.75	2.15	3.25	2.99	1.75	2.66	2.50	2.50	1.99	2.33	2.38
S5 (Garsa)	2.99	2.75	1.50	2.41	2.50	2.02	1.99	2.17	2.52	2.25	1.50	2.09	2.22
S6 (Manikaran)	2.75	1.75	1.75	2.08	3.05	2.25	1.95	2.42	2.75	1.99	1.95	2.23	2.24
S7 (Sahu)	2.75	2.50	1.95	2.40	2.50	2.02	1.99	2.17	3.05	2.25	2.05	2.45	2.34
S8 (Salooni)	2.01	2.00	1.99	2.00	3.05	2.5	2.02	2.52	3.02	2.50	1.99	2.50	2.34
Mean	2.70	2.29	1.84	2.27	2.76	2.32	1.93	2.33	2.83	2.31	1.99	2.38	
CD(0.05)													
Diameter	NS												
Site	NS												
Diameter× Site	0.43												

Where T1 to T9 = Tree Number

Table 26. Variation in the root:shoot fresh weight ratio of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	0.77	1.00	1.48	1.08	0.85	1.10	1.83	1.26	0.94	0.70	1.03	0.89	1.08
S2 (Chail)	0.82	0.64	1.11	0.86	0.90	1.26	1.26	1.14	1.10	1.13	1.15	1.13	1.04
S3 (Taklech)	0.83	1.22	1.30	1.12	1.36	1.00	1.00	1.12	0.67	1.28	0.81	0.92	1.05
S4 (Summer-Hill)	0.74	1.71	1.69	1.38	0.49	0.59	2.14	1.07	0.70	1.10	1.33	1.05	1.16
S5 (Garsa)	0.99	1.07	1.99	1.35	1.05	0.97	1.76	1.26	1.18	1.32	1.77	1.42	1.34
S6 (Manikaran)	0.36	1.11	0.57	0.68	1.00	1.22	1.51	1.25	1.00	1.02	1.24	1.09	1.00
S7 (Sahu)	0.45	0.90	0.95	0.77	0.70	0.84	0.50	0.68	0.74	1.00	1.03	0.92	0.79
S8 (Salooni)	0.75	0.98	0.88	0.87	0.31	0.38	0.87	0.52	1.11	1.06	1.08	1.08	0.82
Mean	0.71	1.08	1.24	1.01	0.83	0.92	1.36	1.04	0.93	1.08	1.18	1.06	
CD(0.05)													
Diameter	NS												
Site	0.27												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

and minimum value for D1 (1.01). Interaction between three diameter classes and eight sites showed maximum mean root : shoot fresh weight ratio for S5D3 (1.42) and minimum value for S8D2 (0.52). Non significant interaction was found between diameter classes and different sites.

4.2.1.13 Root Dry Weight

The observation of data represented in Table 27 depicted that the maximum mean value for the root dry weight was recorded for T8 (1.11 g) and minimum value for T1 (0.82g). The sites showed significant variation for root dry weight with highest mean value for S3 (1.18 g) and minimum (0.76 g) for S8. S1 (1.09 g), S2 (1.06 g), S4 (1.07 g), S5 (1.17 g) and S6 (0.97 g) were found significantly at par with S3. Interaction among the three diameter classes found maximum value for D3 (1.05 g) and minimum mean value for D1 (0.99 g). Interaction studies between three diameter classes and eight sites showed maximum mean value for S3D3 (1.31 g) and minimum value for S8D2 (0.47 g). Non significant interaction was found between diameter classes and different sites.

4.2.1.14 Shoot Dry Weight

Data in Table 28 revealed that maximum mean value for shoot dry weight was recorded in T7 (1.36 g) and minimum value in T9 (0.81 g). The eight sites showed non significant variation with highest mean value for S3 (1.11 g) and minimum (0.95 g) for S6. Interaction among the three diameter classes found maximum mean value for D3 (1.06 g) and minimum mean value for D1 (1.00 g). Interaction studies between three diameter classes and eight sites showed maximum mean value for S3D3 (1.25 g) and minimum mean value for the same by S1D2 (0.83 g). S1D1 (1.04 g), S2D1 (1.05 g), S3D1 (1.06 g), S5D1 (1.02 g), S4D2 (1.22 g), S5D2 (1.06 g), S5D2 (1.09 g), S8D2 (1.07 g), S3D3 (1.13 g), S4D3 (1.06 g), S7D3 (1.24 g) and S8D3 (1.13 g) were found statistically at par with S3D3. However, Significant interaction was found between three diameter classes and different sites.

4.2.1.15 Root : Shoot Dry Weight Ratio

Data appended in Table 29 showed that maximum mean value for root : shoot dry weight was recorded for T3 (1.37) and minimum value for T1 (0.71). However, variation among the different sites showed significant differences with maximum mean value for root : shoot dry weight ratio for S5 (1.28) and minimum for S7 (0.77). S1 (1.23) was found significantly at par with S5. Whereas interaction among the diameter classes revealed

Table 27. Variation in the root dry weight (g) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	1.02	0.99	1.25	1.09	1.01	1.25	1.20	1.15	1.57	0.65	0.89	1.04	1.09
S2 (Chail)	1.05	0.69	1.05	0.93	1.02	1.12	1.10	1.08	1.25	1.12	1.10	1.16	1.06
S3 (Taklech)	1.02	1.25	0.95	1.07	1.42	1.05	1.02	1.16	0.99	1.99	0.95	1.31	1.18
S4 (Summer-Hill)	0.88	1.25	1.30	1.14	0.64	0.95	1.54	1.04	0.87	0.98	1.25	1.03	1.07
S5 (Garsa)	0.95	1.25	1.55	1.25	1.25	0.95	1.42	1.21	0.98	1.21	0.98	1.06	1.17
S6 (Manikaran)	0.45	0.85	1.35	0.88	1.44	1.05	1.20	1.23	0.79	0.92	0.69	0.80	0.97
S7 (Sahu)	0.54	1.05	0.81	0.80	0.78	0.79	0.34	0.64	1.02	1.02	0.72	0.92	0.79
S8 (Salooni)	0.66	0.88	0.75	0.76	0.35	0.35	0.72	0.47	1.15	1.02	0.97	1.05	0.76
Mean	0.82	1.03	1.13	0.99	0.99	0.94	1.07	1.00	1.08	1.11	0.94	1.05	
CD(0.05)													
Diameter	NS												
Site	0.25												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 28. Variation in the shoot dry weight (g) of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	1.21	1.01	0.89	1.04	1.35	0.65	0.49	0.83	1.52	1.02	0.85	1.13	1.00
S2 (Chail)	1.10	1.05	1.01	1.05	1.02	0.85	0.80	0.89	1.12	0.93	0.79	0.95	0.96
S3 (Taklech)	1.45	1.05	0.69	1.06	1.01	1.01	0.99	1.00	1.56	1.10	1.10	1.25	1.11
S4 (Summer-Hill)	1.05	0.99	0.89	0.98	1.42	1.39	0.84	1.22	1.23	1.08	0.88	1.06	1.09
S5 (Garsa)	1.25	1.15	0.66	1.02	1.32	1.01	0.85	1.06	1.12	0.99	0.59	0.90	0.99
S6 (Manikaran)	0.99	0.89	0.85	0.91	1.35	1.02	0.90	1.09	0.98	0.89	0.69	0.85	0.95
S7 (Sahu)	1.12	1.01	0.92	1.02	1.05	0.88	0.85	0.93	1.87	1.12	0.72	1.24	1.06
S8 (Salooni)	0.98	0.89	0.85	0.91	1.30	1.01	0.89	1.07	1.45	1.05	0.88	1.13	1.03
Mean	1.14	1.01	0.85	1.00	1.23	0.98	0.83	1.01	1.36	1.02	0.81	1.06	
CD(0.05)													
Diameter	NS												
Site	NS												
Diameter× Site	0.24												

Where T1 to T9 = Tree Number

Table 29. Variation in the root:shoot dry weight ratio of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	0.84	0.98	1.40	1.08	0.75	1.92	2.45	1.71	1.03	0.64	1.05	0.91	1.23
S2 (Chail)	0.95	0.66	1.04	0.88	1.00	1.32	1.38	1.23	1.12	1.20	1.39	1.24	1.12
S3 (Taklech)	0.70	1.19	1.38	1.09	1.41	1.04	1.03	1.16	0.63	1.81	0.86	1.10	1.12
S4 (Summer-Hill)	0.84	1.26	1.46	1.19	0.45	0.68	1.83	0.99	0.71	0.91	1.42	1.01	1.06
S5 (Garsa)	0.76	1.09	2.35	1.40	0.95	0.94	1.67	1.19	0.88	1.22	1.66	1.25	1.28
S6 (Manikaran)	0.45	0.96	1.59	1.00	1.07	1.03	1.33	1.14	0.81	1.03	1.00	0.95	1.03
S7 (Sahu)	0.48	1.04	0.88	0.80	0.74	0.90	0.40	0.68	0.55	0.91	1.00	0.82	0.77
S8 (Salooni)	0.67	0.99	0.88	0.85	0.27	0.35	0.81	0.47	0.79	0.97	1.10	0.96	0.76
Mean	0.71	1.02	1.37	1.04	0.83	1.02	1.36	1.07	0.81	1.09	1.19	1.03	
CD(0.05)													
Diameter	NS												
Site	0.31												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

maximum mean value for D2 (1.07) and minimum mean value for D1 (1.04). Interaction studies between three diameter classes and eight sites showed maximum mean value for root : shoot dry weight ratio by S1D2 (1.71) and minimum value by S8D2 (0.47). Non significant interaction was found between diameter classes and different sites.

Various progeny performance traits like leaf area, shoot length, root fresh weight, root : shoot fresh weight ratio, root dry weight, root : shoot dry weight ratio recorded significant differences among various sites. The site S4 (Summer Hill- Shimla) excelled in seedling length, collar diameter, number of leaves per seedling and shoot length whereas site S6 (Manikaran – Kullu) excelled in inter-nodal length, root length, root : shoot length ratio. With in diameter classes significant variation recorded for characters, viz., seedling height, collar diameter, inter-nodal length, number of leaves per seedlings and shoot length. Diameter class > 60 cm excelled for maximum of the characters viz., seedling length, collar diameter, inter-nodal length, leaf area, shoot length, root fresh weight, shoot fresh weight, root : shoot fresh weight ratio, root dry weight and shoot dry weight.

Similar findings have also been observed by different workers in other species. Ngulube (1989) in *Gliricidia sepium* provenances reported significant differences in seedling growth between provenances. Mohapatra (1996) studied the variation in seedling traits in *Acacia catechu* and recorded that significant differences exist in the seedling growth and biomass traits under nursery as well as under field condition. Anand (2003) in *Bauhinia variegata* recorded significant variation for seedling length and leaf area. Rana *et al.* (2009) studied the progenies of *Toona ciliata* under nursery condition and they recorded significant difference for Seedling length, collar diameter, number of leaves under nursery condition. Sankhyan *et al.* (2008) studied the morphological variation in *Grewia laevigata* and they recorded that some of the characters like number of leaves per seedling, nodal length, leaf length and leaf area exhibited variation between the sites. The seed source and provenance variation in nursery and field is essentially genetic in origin (Snieszko and Stewart, 1989).

Rehman *et al.* (1988) observed differences among the seed source of *Acacia* spp. and *Prosopis* spp. for height growth and survival under nursery conditions. Veerendra and Sharma (1990) revealed that characters like collar diameter, root length, shoot length and number of leaves per seedling varied significantly among different seed sources of *Santalum album* but seedling length showed non-significant differences. Bimlendra *et al.* (1992) studied details related to root and shoot growth in many species including *Melia azedarach* and

observed variations among different growth characteristics while Jaswal (1992) revealed that the growth parameters in *Grewia optiva* seedlings for height, collar diameter, leaf area, length and dry weight of root and shoot and their respective ratio showed significant variations among seed sources.

Dhillon *et al.* (2009) conducted study by raising 11 tree progenies of *Melia azedarach* the difference among progenies for collar diameter and plant height was significant at nursery stage. The plant height and diameter at the age of 1, 3, 5 and 7 years also varied significantly among progenies. Rehman *et al.* (1988) observed differences among the seed source of *Acacia* spp. and *Prosopis* spp. for height growth and survival under nursery conditions.

4.3 VARIATION IN PHYSICAL AND CHEMICAL CHARACTERISTICS OF FATTY OIL AND NUTRITIONAL VALUE OF DE-OILED CAKES

4.3.1 Percentage of Seeds to Acorns

It is evident from the data represented in Table 30 (fig 6) that percentage of seeds to acorn varied significantly in different sites and diameter classes. The maximum mean value was showed by T9 (80.46%) and minimum by T1 (75.80%). Among the eight sites maximum mean value was recorded for site S7 (80.83%) and minimum value for S5 (75.51%). Site S2 (79.72%), S3 (78.98%), S6 (78.84%) and S8 (79.68%) were found significantly at par with site S7. Interaction among the diameter classes revealed maximum mean value for D3 (80.15%) and minimum value for D1 (76.48%) D2 (77.80%) and were significantly at par with D1. Interaction studies between three diameter classes and eight sites showed maximum mean value for S6D3 (82.77%) and minimum for S4D1 (70.52%). S3D1 (79.25%), S7D1 (80.01%), S8D1 (79.91%), S3D2 (79.25%), S7D2 (80.40%), S8D2 (79.80%), S2D3 (82.55%), S4D3 (80.60%), S5D3 (81.07%), S7D3 (82.07%) and S8D3 (79.32%) were found significantly at par with S6D3. Significant interaction was found between diameter classes and different sites.

4.3.2 Percent Oil Content

Data in Table 31(fig 7) revealed that T8 (13.56%) had the maximum mean value for oil content and minimum mean value for the same was showed by T2 (11.22%). The variation among the sites showed non significant variation with maximum mean value by site S5 (12.56%) and minimum by S1 (11.54%). Interaction among the diameter classes revealed maximum value for D3 (13.02%) and minimum mean value for D1 (11.31%). D2 (12.07%) and were found significantly at par with D1. Interaction studies between three diameter



Seed of *Quercus leucotrichophora*



Powdered sample



Oil sample of Garsa (best proven) site

Plate 4. Seeds, powdered sample and oil sample of Garsa (best proven) site of *Quercus leucotrichophora*

Table 30. Variation in the percentage of seeds to acorns of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	75.43	71.45	76.54	74.47	75.45	77.87	81.67	78.33	71.55	76.98	74.66	74.40	75.73
S2 (Chail)	76.67	77.45	78.65	77.59	80.32	80.40	76.34	79.02	80.98	81.98	84.70	82.55	79.72
S3 (Taklech)	78.43	79.67	79.65	79.25	78.99	78.88	79.88	79.25	79.63	81.09	74.63	78.45	78.98
S4 (Summer-Hill)	69.55	70.45	71.55	70.52	76.98	74.66	77.99	76.54	80.25	80.45	81.09	80.60	75.89
S5 (Garsa)	70.55	71.25	72.45	71.42	72.45	75.98	73.69	74.04	81.09	83.98	78.13	81.07	75.51
S6 (Manikaran)	77.54	78.95	79.63	78.71	73.67	74.63	76.79	75.03	80.63	81.90	85.78	82.77	78.84
S7 (Sahu)	79.55	80.23	80.25	80.01	80.45	81.09	79.65	80.40	85.68	75.56	84.98	82.07	80.83
S8 (Salooni)	78.65	80.55	80.54	79.91	81.90	77.63	79.88	79.80	77.87	80.40	79.69	79.32	79.68
Mean	75.80	76.25	77.41	76.48	77.53	77.64	78.24	77.80	79.71	80.29	80.46	80.15	
CD(0.05)													
Diameter	1.27												
Site	2.07												
Diameter× Site	3.59												

Where T1 to T9 = Tree Number

Table 31. Variation in the percent oil content of seeds of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	11.65	10.50	10.50	10.88	11.65	11.50	11.90	11.68	11.54	12.88	11.78	12.07	11.54
S2 (Chail)	10.50	11.65	10.60	10.92	10.54	11.65	11.50	11.23	10.65	13.65	13.80	12.70	11.62
S3 (Taklech)	10.87	10.00	11.54	10.80	13.01	14.67	12.45	13.38	12.87	13.76	13.50	13.38	12.51
S4 (Summer-Hill)	10.76	11.80	10.60	11.05	11.98	12.65	10.65	11.76	11.65	14.98	14.98	13.87	12.22
S5 (Garsa)	11.65	10.70	12.55	11.63	12.65	11.98	11.54	12.06	13.29	13.99	14.68	13.99	12.56
S6 (Manikaran)	10.50	12.65	11.25	11.47	11.45	13.99	12.76	12.73	11.89	12.65	13.40	12.65	12.28
S7 (Sahu)	11.50	11.98	12.65	12.04	10.60	10.14	13.89	11.54	11.87	13.65	12.50	12.67	12.09
S8 (Salooni)	13.50	10.50	11.09	11.70	13.90	11.12	11.50	12.17	13.98	12.93	11.65	12.85	12.24
Mean	11.37	11.22	11.35	11.31	11.97	12.21	12.02	12.07	12.22	13.56	13.29	13.02	
CD(0.05)													
Diameter	0.64												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

classes and eight sites showed maximum mean value for oil content for S5D3 (13.99%) and minimum value for S3D1 (10.80%). Non significant interaction was found between diameter classes and different sites.

4.3.3 Specific Gravity

Data pertaining to the specific gravity of oil is presented in Table 32 (fig 8). None of the considered factors showed any significant variation. The value ranges between 0.907-0.908 for three diameter classes and for eight sites and their interaction.

4.3.4 Refractive Index

The perusal of data in Table 33 (fig 9) revealed that the refractive index of oil also did not vary in all the treatment and combinations. The value ranges between 1.457-1.458 for three diameter classes in eight sites and their interaction.

4.3.5 Acid Value

The data presented in Table 34 (fig 10) revealed that the maximum mean acid value was showed by T9 (13.44) and minimum by T2 (11.90). The variation among the sites showed non significant variation with maximum mean value for Site S4 (13.15) and minimum mean value for the same by S5 (12.06). Interaction among the diameter classes revealed maximum value for D3 (13.24) and minimum mean value for D1 (12.05). D2 (12.61) was found significantly at par with D1. Interaction between the three sites and eight sites showed maximum mean value for S4D3 (14.25) and minimum mean value for S5D1 (11.70). However, non significant interaction was found between diameter classes and different sites.

4.3.6 Iodine Value

It is evident from Table 35 (fig 11) that the maximum mean iodine value was recorded for T7 (80.62) and minimum mean value for T1(76.44).The variation among the sites showed non significant variation with maximum mean value was showed by site S8(80.38) and minimum mean value for the same by S1(76.58). Interaction among the diameter classes revealed maximum value for D3 (80.17) and minimum mean value for the same by D1 (77.10). D2 (79.54) were found significantly at par with D3. Interaction studies between three diameter classes and eight sites showed maximum mean value for iodine by S8D2 (83.19) and minimum by S5D1 (73.56). Non significant interaction was found between diameter classes and different sites.

Table 32. Variation in the specific gravity of seed oil of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	0.908	0.908	0.907	0.908	0.907	0.907	0.908	0.907	0.908	0.908	0.908	0.908	0.908
S2 (Chail)	0.908	0.908	0.908	0.908	0.908	0.907	0.908	0.908	0.908	0.908	0.907	0.908	0.908
S3 (Taklech)	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908
S4 (Summer-Hill)	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908
S5 (Garsa)	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908
S6 (Manikaran)	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908
S7 (Sahu)	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908
S8 (Salooni)	0.908	0.907	0.908	0.908	0.908	0.908	0.907	0.908	0.908	0.908	0.908	0.908	0.908
Mean	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	0.908	
CD(0.05)													
Diameter	NS												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 33. Variation in the refractive index of seed oil of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458
S2 (Chail)	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458
S3 (Taklech)	1.458	1.457	1.458	1.458	1.457	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458
S4 (Summer-Hill)	1.458	1.458	1.458	1.458	1.457	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458
S5 (Garsa)	1.457	1.458	1.458	1.458	1.457	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458
S6 (Manikaran)	1.457	1.458	1.458	1.458	1.457	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458
S7 (Sahu)	1.457	1.458	1.458	1.458	1.457	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458
S8 (Salooni)	1.457	1.458	1.458	1.458	1.457	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458
Mean	1.457	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	1.458	
CD(0.05)													
Diameter	NS												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 34. Variation in the acid value of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	12.76	11.60	12.89	12.42	11.63	12.87	11.98	12.16	13.43	12.89	13.90	13.41	12.66
S2 (Chail)	11.98	11.67	11.50	11.72	11.98	11.98	13.56	12.51	11.65	12.67	14.99	13.10	12.44
S3 (Taklech)	10.80	12.87	11.54	11.74	12.65	13.45	12.78	12.96	12.98	12.54	12.98	12.83	12.51
S4 (Summer-Hill)	11.90	11.79	11.90	11.86	11.28	12.76	15.98	13.34	13.98	14.87	13.90	14.25	13.15
S5 (Garsa)	11.98	11.67	11.45	11.70	11.67	11.98	11.54	11.73	12.76	12.87	12.65	12.76	12.06
S6 (Manikaran)	12.90	11.65	12.67	12.41	12.45	11.65	12.45	12.18	13.99	13.98	12.56	13.51	12.70
S7 (Sahu)	12.78	12.98	11.50	12.42	12.98	12.98	13.92	13.29	12.59	12.67	13.98	13.08	12.93
S8 (Salooni)	10.67	10.98	14.87	12.17	13.90	11.65	12.61	12.72	11.65	14.76	12.56	12.99	12.62
Mean	11.97	11.90	12.29	12.05	12.32	12.42	13.10	12.61	12.88	13.41	13.44	13.24	
CD(0.05)													
Diameter	0.59												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Figure 6 Variation in the percentage of seeds to acorns ratio of *Quercus leucotrichophora* from three diameter classes (D) among different sites (S)

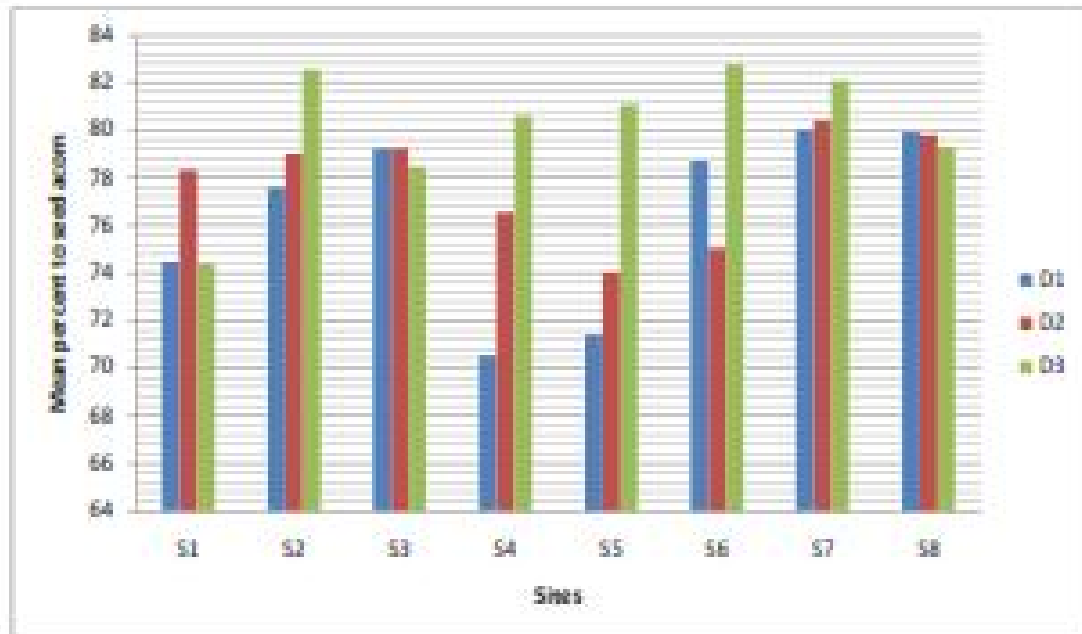


Figure 7 Variation in the percent oil content of seeds of *Quercus leucotrichophora* from three diameter classes (D) among different sites (S)

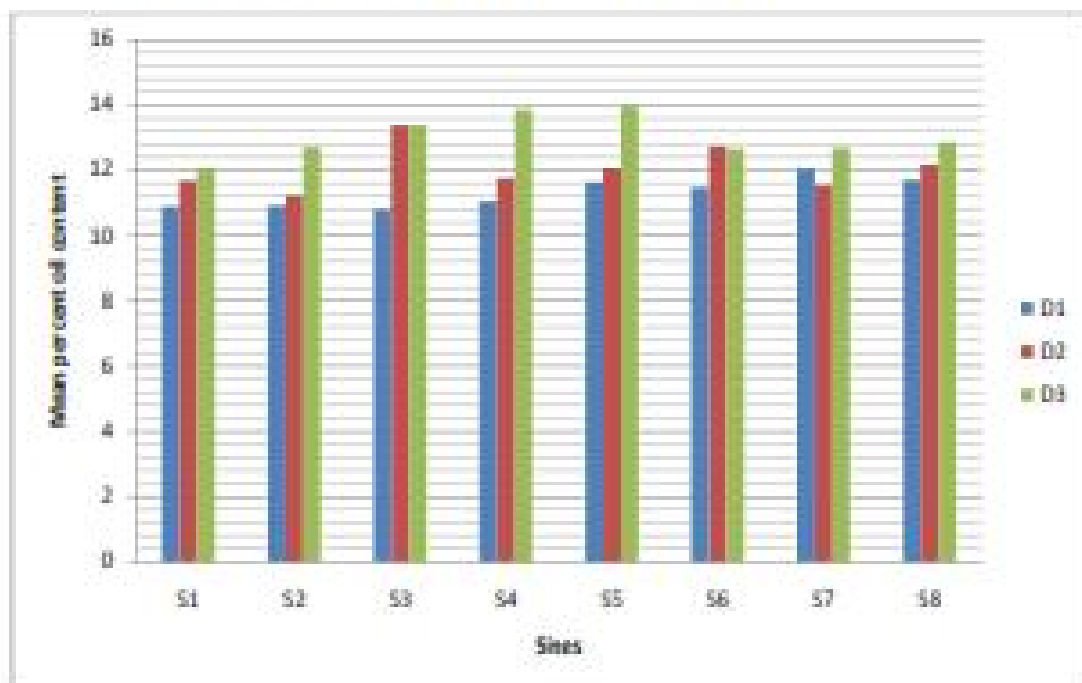


Figure 8 Variation in the specific gravity of seed oil of *Quercus leucotrichophora* from three diameter classes (D) among different sites (S)

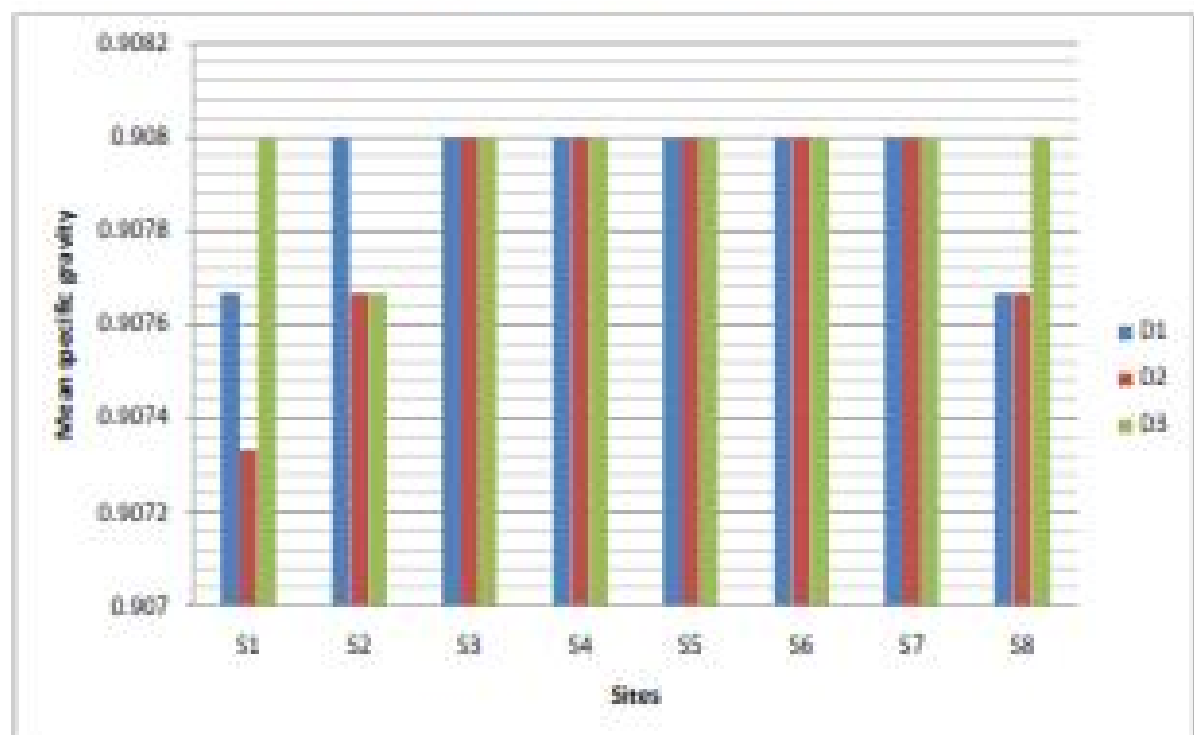


Figure 9 Variation in the refractive index of seed oil of *Quercus leucotrichophora* from three diameter classes (D) among different sites (S)

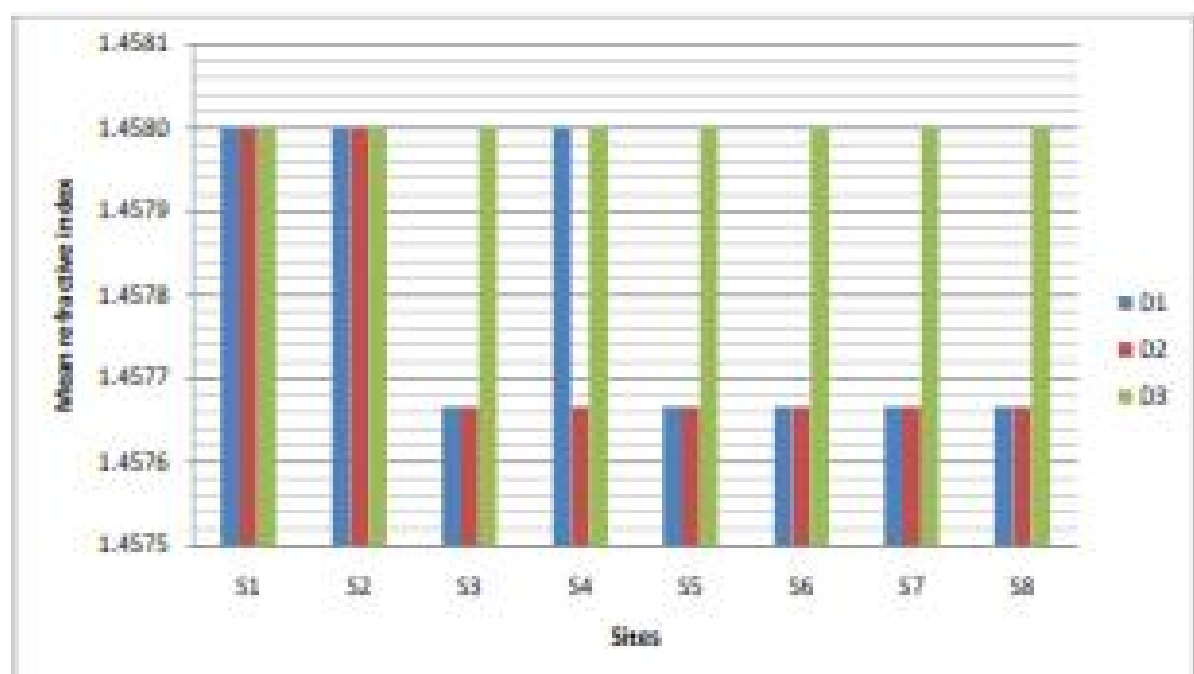


Figure 10 Variation in the acid value of *Quercus leucotrichophora* from three diameter classes (D) among different sites (S)

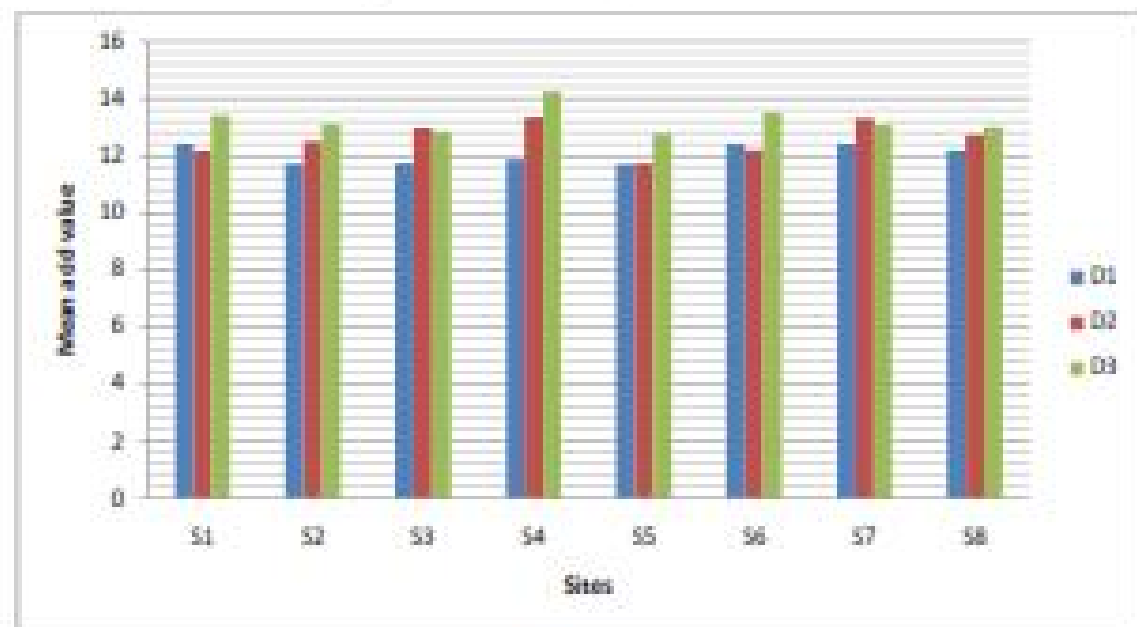


Figure 11 Variation in the iodine value of *Quercus leucotrichophora* from three diameter classes (D) among different sites (S)

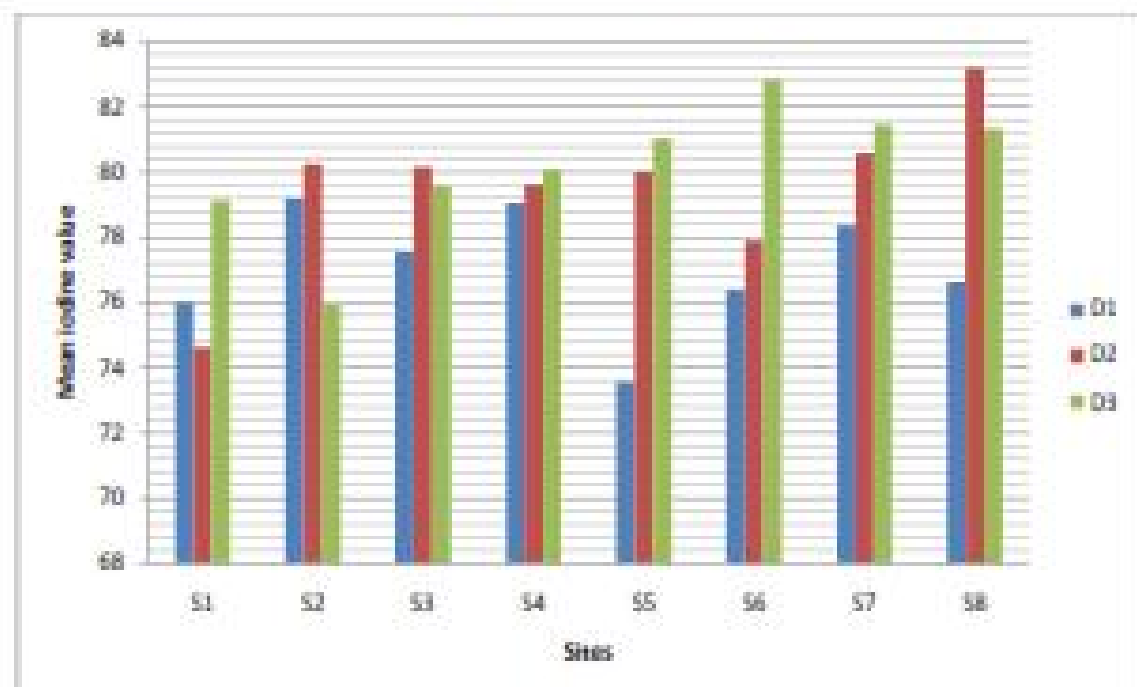


Table 35. Variation in the iodine value of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	76.45	79.67	71.90	76.01	76.19	77.87	69.78	74.61	76.67	79.23	81.50	79.13	76.58
S2 (Chail)	79.63	78.45	79.50	79.19	79.12	81.26	80.41	80.26	81.50	72.09	74.20	75.93	78.46
S3 (Taklech)	74.90	79.56	78.23	77.56	79.45	80.45	80.60	80.17	79.32	81.50	77.90	79.57	79.10
S4 (Summer-Hill)	78.65	80.63	77.90	79.06	76.43	81.24	81.20	79.62	85.34	79.45	75.45	80.08	79.59
S5 (Garsa)	79.50	71.63	69.56	73.56	82.13	82.98	74.90	80.00	81.02	80.13	81.90	81.02	78.19
S6 (Manikaran)	72.63	74.63	81.90	76.39	80.00	76.54	77.12	77.89	79.03	83.92	85.60	82.85	79.04
S7 (Sahu)	78.23	80.40	76.45	78.36	79.56	81.65	80.50	80.57	81.09	81.50	81.78	81.46	80.13
S8 (Salooni)	71.56	81.45	76.87	76.63	83.40	80.76	85.40	83.19	81.00	82.54	80.48	81.34	80.38
Mean	76.44	78.30	76.54	77.10	79.54	80.34	78.74	79.54	80.62	80.05	79.85	80.17	
CD(0.05)													
Diameter	1.81												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

4.3.7 Saponification Value

Data pertaining to the saponification values of fatty oil is presented in Table 36 (fig 12). None of the considered factors showed any significant variation. The value ranges between 171.17-188.70 for three diameter classes, eight sites and their interaction.

4.3.8 Unsaponification Matter

The perusal of data presented in Table 37 (fig 13) revealed that maximum mean value for unsaponification matter was showed by T8 (0.811) and minimum by T1 (0.625). The variation among the sites showed non significant variation with maximum mean value by site S5 (0.779) and minimum value for the same by S2 (0.688). Interaction among the diameter classes revealed maximum value for D3 (0.753) and D1 (0.678) had the minimum mean value. D2 (0.727) were found significantly at par with D3. Interaction studies between three diameter classes and eight sites showed the maximum mean value for S5D3 (0.853) and minimum for S1D1 (0.640). Non significant interaction was found between diameter classes and different sites.

4.3.9 Protein Content of deoiled cake

Data in Table 38 (fig 14) depicts that maximum mean value for protein content was showed by T9 (6.12) and minimum by T1 (4.45). The variation among the sites showed significant variation with maximum mean value (5.70) by site S7 and minimum mean value (4.70) by site S1. S4 (5.43), S5 (5.47), S6 (5.51) and S8 (5.63) were found statistically at par with S7. Interaction among the diameter classes revealed maximum value for D3 (6.07) and D1 (4.49) had minimum mean value. D2 (5.44) were found significantly at par with D1. Interaction between three diameter classes and eight sites showed maximum mean value of protein content for S8D3 (6.21) and minimum for S3D1 (3.86). However, non significant interaction was found between diameter classes and different sites.

4.3.10 Starch Content of deoiled cake

Data appended in Table 39 (fig 15) recorded that maximum mean value for starch content was showed by T7 (62.35) and minimum value by T4 (55.96). Variation among the sites showed non significant variation with maximum value was showed by site S8 (61.99) and minimum value for the same by S2 (55.67). Interaction among the diameter classes revealed maximum value for D3 (61.66) and minimum for while D1 (58.39). D2 (56.82) and

Table 36. Variation in the saponification value of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	197.00	188.15	182.04	189.06	181.50	191.70	175.63	182.94	174.23	174.59	174.54	174.45	182.15
S2 (Chail)	188.26	170.59	177.63	178.83	165.98	185.98	175.66	175.87	198.70	198.87	182.04	193.20	182.63
S3 (Taklech)	170.96	191.86	178.98	180.60	173.02	188.26	166.89	176.06	187.80	198.78	198.70	195.09	183.92
S4 (Summer-Hill)	191.70	191.00	178.03	186.91	179.89	197.00	176.09	184.33	177.63	198.70	191.70	189.34	186.86
S5 (Garsa)	190.35	170.59	174.59	178.51	174.54	196.97	178.98	183.50	198.70	173.02	185.98	185.90	182.64
S6 (Manikaran)	187.56	187.56	164.40	179.84	182.04	188.15	177.45	182.55	178.03	179.89	189.80	182.57	181.65
S7 (Sahu)	187.35	191.29	155.06	177.90	177.76	170.70	165.05	171.17	174.59	174.54	195.30	181.48	176.84
S8 (Salooni)	190.11	179.65	166.09	178.62	174.54	190.87	195.71	187.04	185.99	188.63	185.90	186.84	184.16
Mean	187.91	183.84	172.10	181.28	176.16	188.70	176.43	180.43	184.46	185.88	188.00	186.11	
CD(0.05)													
Diameter	NS												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 37. Variation in the unsaponifiable matter of *Quercus leucotrichophora* from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	0.650	0.620	0.650	0.640	0.760	0.780	0.690	0.743	0.650	0.790	0.790	0.743	0.709
S2 (Chail)	0.610	0.760	0.670	0.680	0.650	0.620	0.710	0.660	0.710	0.710	0.750	0.723	0.688
S3 (Taklech)	0.700	0.640	0.710	0.683	0.780	0.760	0.730	0.757	0.590	0.760	0.780	0.710	0.717
S4 (Summer-Hill)	0.550	0.730	0.730	0.670	0.770	0.780	0.740	0.763	0.780	0.770	0.780	0.777	0.737
S5 (Garsa)	0.560	0.740	0.810	0.703	0.680	0.890	0.770	0.780	0.750	1.020	0.790	0.853	0.779
S6 (Manikaran)	0.670	0.770	0.560	0.667	0.590	0.760	0.710	0.687	0.750	0.980	0.760	0.830	0.728
S7 (Sahu)	0.610	0.760	0.780	0.717	0.820	0.680	0.750	0.750	0.650	0.650	0.620	0.640	0.702
S8 (Salooni)	0.650	0.630	0.710	0.663	0.620	0.650	0.760	0.677	0.750	0.810	0.670	0.743	0.694
Mean	0.625	0.706	0.703	0.678	0.709	0.740	0.733	0.727	0.704	0.811	0.743	0.753	
CD(0.05)													
Diameter	0.047												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 38. Variation in the protein content of deoiled cake of *Quercus leucotrichophora* seeds from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	4.32	3.78	3.61	3.90	4.93	4.12	4.32	4.46	5.91	5.66	5.65	5.74	4.70
S2 (Chail)	4.99	4.71	3.98	4.56	4.02	5.98	4.92	4.97	6.16	5.88	6.05	6.03	5.19
S3 (Taklech)	3.28	3.99	4.32	3.86	4.32	5.03	5.98	5.11	5.92	6.10	6.34	6.12	5.03
S4 (Summer-Hill)	4.97	4.62	3.33	4.31	5.91	5.82	5.98	5.90	6.01	6.13	6.14	6.09	5.43
S5 (Garsa)	4.61	4.61	4.96	4.73	5.01	6.01	5.69	5.57	6.03	6.01	6.31	6.12	5.47
S6 (Manikaran)	4.54	4.65	4.98	4.72	4.99	6.12	6.12	5.74	6.01	6.05	6.13	6.06	5.51
S7 (Sahu)	3.99	4.99	5.82	4.93	6.13	6.01	5.91	6.02	6.23	6.10	6.13	6.15	5.70
S8 (Salooni)	4.87	4.89	5.01	4.92	5.92	5.32	6.01	5.75	6.14	6.30	6.18	6.21	5.63
Mean	4.45	4.53	4.50	4.49	5.15	5.55	5.62	5.44	6.05	6.03	6.12	6.07	
CD(0.05)													
Diameter	0.27												
Site	0.44												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Table 39. Variation in the starch content of deoiled cake of *Quercus leucotrichophora* seeds from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	58.90	51.64	59.87	56.80	59.87	54.28	55.38	56.51	63.98	56.92	58.01	59.64	57.65
S2 (Chail)	51.98	52.98	48.28	51.08	51.89	53.09	56.93	53.97	55.92	64.09	65.89	61.97	55.67
S3 (Taklech)	47.91	65.45	64.98	59.45	60.81	64.98	57.30	61.03	60.14	58.29	60.18	59.54	60.00
S4 (Summer-Hill)	65.56	53.67	52.59	57.27	51.89	54.02	55.83	53.91	66.57	66.87	61.09	64.84	58.68
S5 (Garsa)	46.89	53.26	69.87	56.67	54.29	55.63	59.01	56.31	66.75	59.71	61.67	62.71	58.56
S6 (Manikaran)	67.90	54.78	54.28	58.99	54.89	51.03	59.02	54.98	63.87	60.45	61.60	61.97	58.65
S7 (Sahu)	61.98	54.38	69.87	62.08	52.03	65.87	56.72	58.21	60.13	60.87	62.01	61.00	60.43
S8 (Salooni)	61.90	62.45	69.87	64.74	61.98	54.90	61.93	59.60	61.45	61.98	61.50	61.64	61.99
Mean	57.88	56.08	61.20	58.39	55.96	56.73	57.77	56.82	62.35	61.15	61.49	61.66	
CD(0.05)													
Diameter	3.03												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Figure 12 Variation in the saponification value of *Quercus leucotrichophora* from three diameter classes (D) among different sites (S)

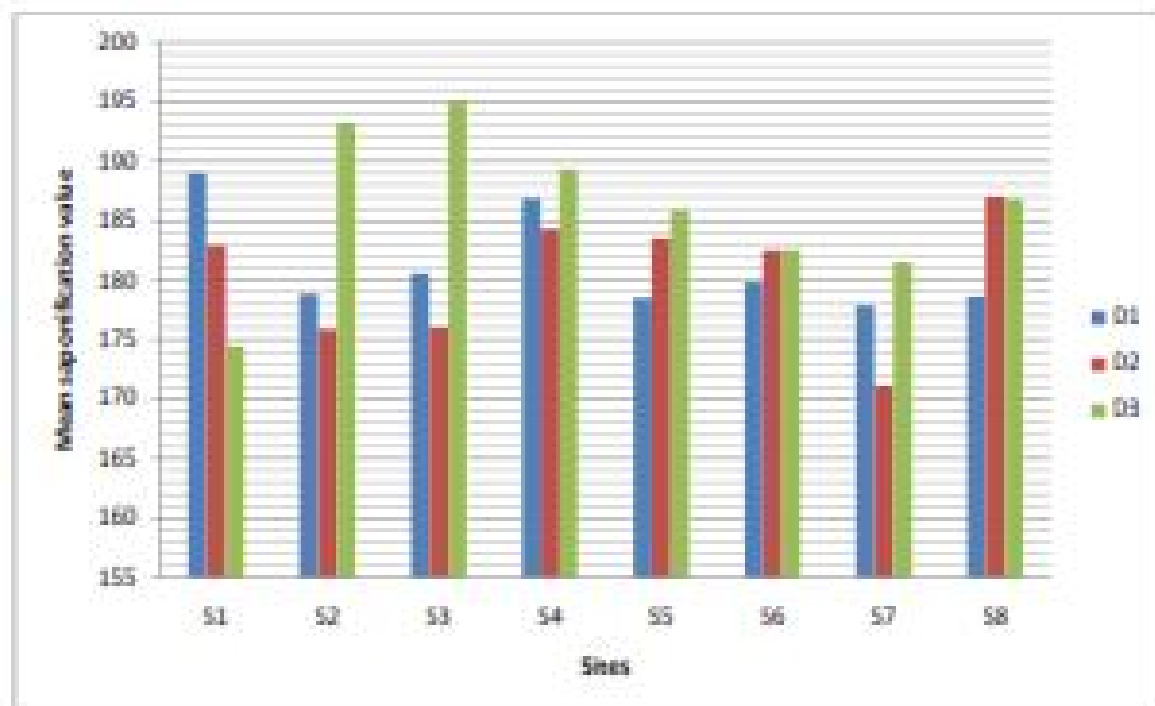


Figure 13 Variation in the unsaponifiable matter of *Quercus leucotrichophora* from three diameter classes (D) among different sites (S)

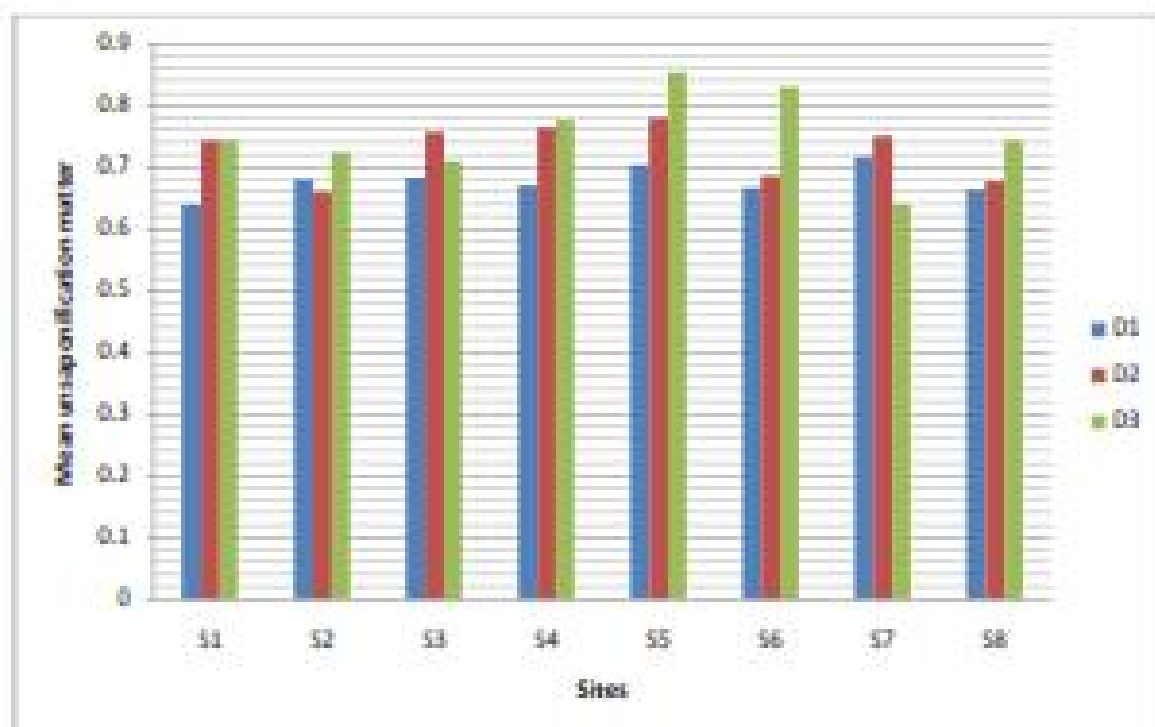


Figure 14 Variation in the protein content of deoiled cake of *Quercus leucotrichophora* seeds from three diameter classes (D) among different sites (S)

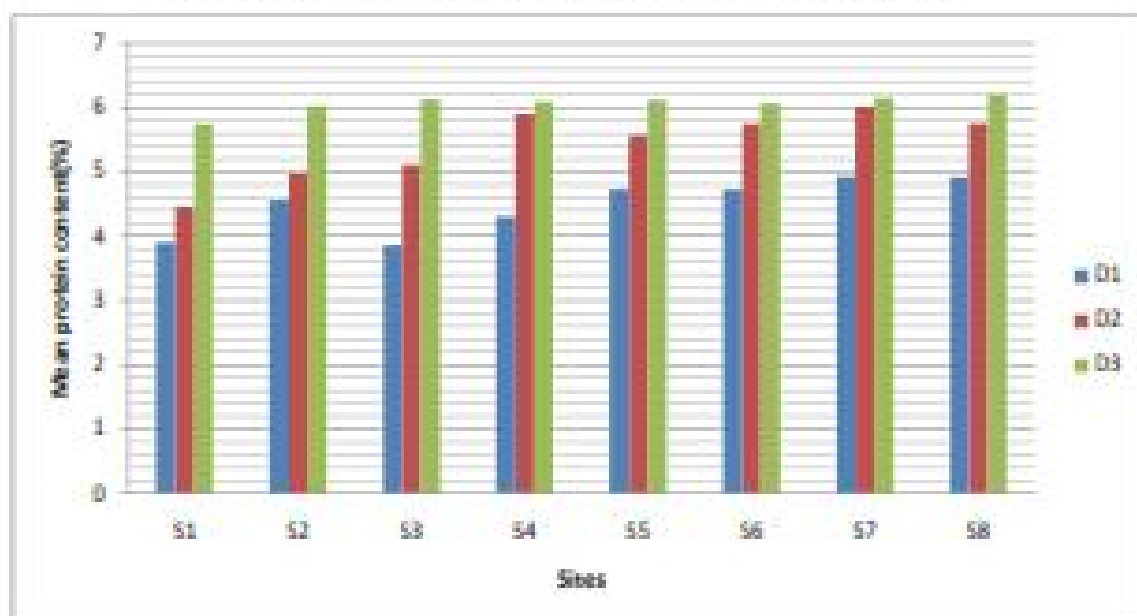
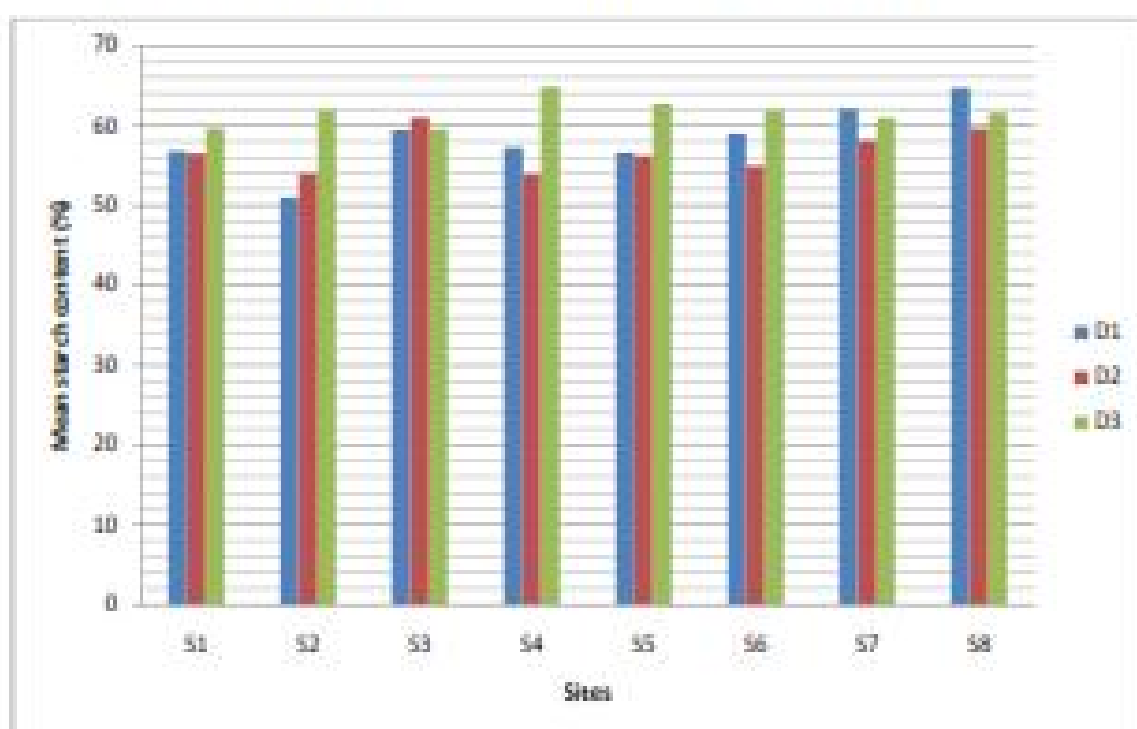


Figure 15 Variation in the starch content of deoiled cake of *Quercus leucotrichophora* seeds from three diameter classes (D) among different sites (S)



were found significantly at par with D1. For diameter and site interaction the maximum mean value was showed by S4D3 (64.84) and minimum by S2D1 (51.08). Non significant interaction was found between diameter classes and different sites.

4.2.11 Total Sugar Content of deoiled cake

The perusal of data presented in Table 40 (fig 16) revealed that maximum mean value for sugar content was showed by T9 (1.78) and minimum by T1(1.54). Variation among the sites showed non significant variation with maximum mean value for site S8 (1.71) and minimum value for the same by S1 (1.59). Interaction among the diameter classes revealed maximum value for D3 (1.75) and minimum value for D1 (1.58). D2 (1.67) and were found significantly at par with D1. Interaction studies between three diameter classes and eight sites showed maximum mean value for S8D3 (1.79) and minimum for S1D1 (1.50). However, non significant interaction was found between three diameter classes and eight sites.

Significant variation among the diameter classes were recorded for the characters namely percentage seeds to acorns, oil content, acid value, iodine value, protein content, starch content, total sugar and unsaponification value. All these parameter showed excellence in larger diameter classes, i.e., > 60 cm. On seed basis, maximum oil content was recorded in Site S5 (Garsa-Kullu) (12.56%) and minimum oil content was recorded for S1 (Shilli-Solan) of 11.54%. Site S8 (Salooni- Chamba) excelled in total sugar content, starch content, iodine value whereas Site S7 (Sahu-Chamba) excelled in protein content and percentage seeds to acorns. The present study revealed that there was no significant variation among different sites and between D.B.H classes in oil physico-chemical traits such as saponification value, specific gravity and refractive index.

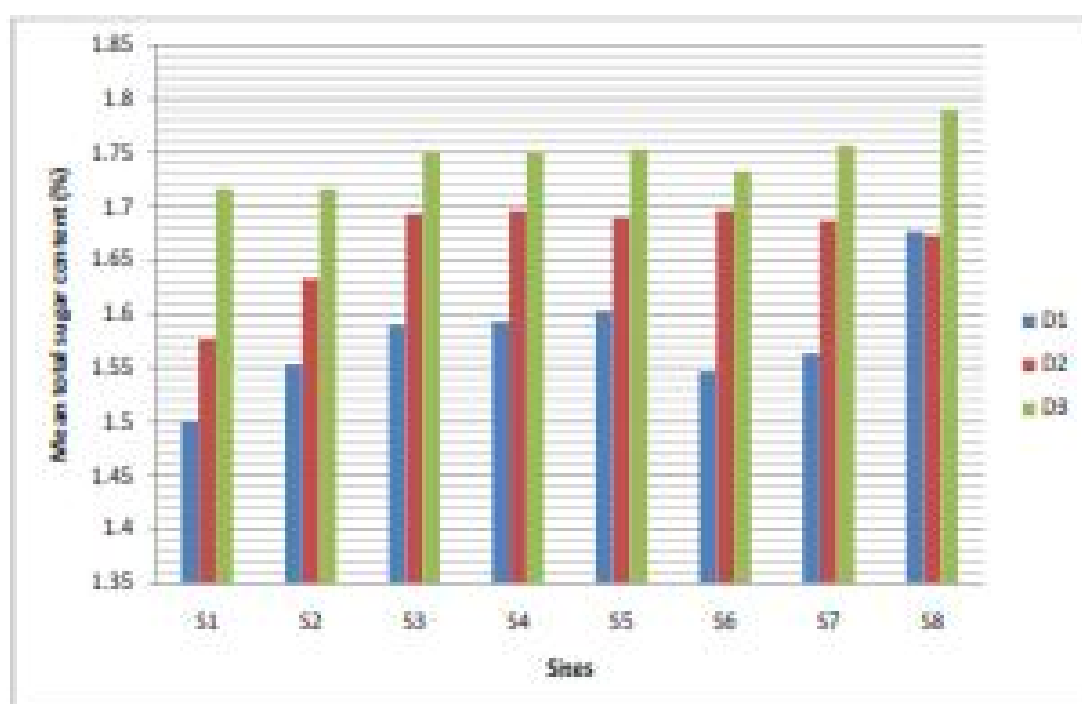
The present finding also get support from the results obtained by Gupta (2006) while studying on seed sources variation in *Prunus armeniaca* and also reported in oil physico-chemical traits such as saponification value, specific gravity and refractive index from seed samples of different sources does not vary significantly. Sankhyan (1992) studied some of the *Quercus* spp of Himachal Pradesh for their chemical traits and nutritional traits and recorded that within localities non significant interaction was found for per cent oil content. Sophia (2004) studied seed sources variation in *Juglans regia* for oil quality parameters and reported non-significant variation in specific gravity and saponification value of oil sample recovered from walnut sample from different seed sources. Mir (2011) studied seed sources variation in

Table 40. Variation in the total sugar content of deoiled cake of *Quercus leucotrichophora* seeds from three diameter classes among different sites

Diameter classes													
Sites/Trees	D1 (<30 cm)				D2 (30-60 cm)				D3 (>60 cm)				Overall Mean
	T1	T2	T3	Mean (D1)	T4	T5	T6	Mean (D2)	T7	T8	T9	Mean (D3)	
S1 (Shilli)	1.55	1.47	1.48	1.50	1.53	1.49	1.71	1.58	1.69	1.70	1.76	1.72	1.59
S2 (Chail)	1.56	1.56	1.54	1.55	1.63	1.56	1.71	1.63	1.72	1.72	1.71	1.72	1.63
S3 (Taklech)	1.63	1.67	1.47	1.59	1.71	1.74	1.63	1.69	1.74	1.75	1.76	1.75	1.67
S4 (Summer-Hill)	1.68	1.54	1.56	1.59	1.71	1.75	1.63	1.70	1.71	1.78	1.76	1.75	1.68
S5 (Garsa)	1.45	1.65	1.71	1.60	1.69	1.69	1.69	1.69	1.69	1.78	1.79	1.75	1.68
S6 (Manikaran)	1.55	1.50	1.59	1.55	1.71	1.71	1.67	1.70	1.70	1.69	1.81	1.73	1.65
S7 (Sahu)	1.45	1.61	1.63	1.56	1.69	1.65	1.72	1.69	1.70	1.68	1.89	1.76	1.67
S8 (Salooni)	1.47	1.69	1.87	1.68	1.76	1.54	1.72	1.67	1.71	1.87	1.79	1.79	1.71
Mean	1.54	1.59	1.61	1.58	1.68	1.64	1.69	1.67	1.71	1.75	1.78	1.75	
CD(0.05)													
Diameter	0.48												
Site	NS												
Diameter× Site	NS												

Where T1 to T9 = Tree Number

Figure 16 Variation in the total sugar content of deoiled cake of *Quercus leucotrichophora* seeds from three diameter classes (D) among different sites (S)



Sapindus mukorossi and reported no significant variation in saponification value, specific gravity and refractive index among different seed sources.

Ruan and Huang (2006) reported non-significant variation in saponification value among different seed sources while working on seed sources variation in *Sapindus mukorossi* and found range between 173-196 mg KOH/g. Sayeed *et al.* (2004) studied the physio chemical characteristics of seed oils of *Mesua ferrea* such as specific gravity, refractive index and saponification value and found non significant differences among different seed sources. Nyakudya *et al.* (2015) studied *Grewia bicolour* seeds and recorded high acid value, iodine value and saponification value. They concluded that thought seeds had less oil per cent but it can be utilized as an industrial ingredient in the manufacturing of soaps, pharmaceutical products and cosmetics. Gul and Khan (1979) reported that acorn of *Quercus dilatata* have shown them to be a suitable feedstuff for livestock and poultry.

Sehgal *et al.* (1989) studied the seeds of *Pinus roxburghii* and reported variation in seed oil content and oil quality parameters. Anonymous (1969) reported iodine value for *Quercus dilatata* (90.3), *Quercus ilex* (86-89) and *Quercus leucotrichophora* (81.5) which is in close proximity with the present investigation. Singh (1981) noticed significant variation in protein contents of *Quercus leucotrichophora* seeds collected from different sites. Kaushal *et al.* (1971) reported 4.72 per cent crude protein in *Quercus leucotrichophora*, which is in close proximity with the present investigation and also investigated variation in per cent nitrogen free extract of different *Quercus* spp.

4.4 ESTIMATION OF KARL PEARSON'S CORRELATION COEFFICIENT BETWEEN MORPHOMETRIC TRAITS, PROGENY PERFORMANCE TRAITS AND PHYSIO-CHEMICAL PROPERTIES OF FATTY OIL AND NUTRITIONAL VALUE OF DEOILED CAKE.

4.4.1 Estimation of Karl Pearson's Correlation Coefficient between Different Morphometric Traits

Data presented in Table 41 revealed that out of 36 correlation coefficients calculated among different morphological traits, only five were found positively and significantly correlated with each other at different level of significance. Positive and significant correlation was found between tree height and clean bole height (0.572), tree height and crown length (0.957), tree height and crown width (0.603), crown length and crown width (0.642) (at 0.01% level of significance). At 0.05% level of significance, positive and

significant correlation was found between clean bole height and leaf length (0.509). All other characters were found non significant with each other.

Table 41. Karl Pearson's Correlation Coefficient between Morphometric Traits

Parameters/Traits	Tree height	Clean bole height	Crown length	Crown width	Primary braches	Leaf area	Leaf length	Leaf width
Tree height	1.000	0.572**	0.957**	0.603**	-0.151	0.291	0.297	0.350
Clean bole height		1.000	0.394	0.198	0.280	0.096	0.509*	0.235
Crown length			1.000	0.642**	-0.245	0.206	0.234	0.321
Crown width				1.000	-0.030	0.312	0.277	0.120
Primary braches					1.000	0.152	0.403	0.285
Leaf area						1.000	0.071	0.377
Leaf length							1.000	0.139
Leaf width								1.000

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

4.4.2 Estimation of Karl Pearson's Correlation Coefficient between Progeny Performance Traits

Perusal of data in Table 42 exhibited that out of 120 correlation coefficients 19 were found positively significantly correlated with each other while two were found negatively significantly correlated at different level of significance.

Seedling length showed significant and positive correlation with inter-nodal length (0.521), number of leaves per seedling (0.720), shoot length (0.827) at 0.01 level of significance. At 0.05% level of significance it showed negative significant correlation with root : shoot length ratio (-0.463). Collar diameter showed positive and significant correlation with inter-nodal length (0.586) at 0.01% level of significance. At 0.05 level of significance it showed positive and significant correlation with shoot dry weight (0.407). Inter nodal length showed positive and significant correlation with leaves per seedling (0.544) at 0.01 level of significance. Leaves per seedling showed positive and significant correlation with shoot length (0.544) at 0.01% level of significance.

Fresh leaf biomass showed positive and significant correlation with shoot fresh weight (0.868) and shoot dry weight (0.742) at 0.01% level of significance. Root length showed positive and significant correlation with root : shoot length ratio (0.637) at 0.01%

Table 42 Karl Pearson's Correlation Coefficient between Progeny Performance Traits

Parameters/Traits	Seedling length	Collar diameter	Inter-nodal length	Number of Leaves per seedling	Leaf area of seedling	Fresh leaf biomass	Root length	Shoot length	Root:Shoot length ratio	Root fresh weight	Shoot fresh weight	Root:Shoot fresh weight ratio	Root dry weight	Shoot dry weight	Root:Shoot dry weight
Seedling length	1	0.371	0.521**	0.720**	0.013	0.235	0.381	0.827**	-0.463*	0.245	-0.068	0.231	0.046	0.004	-0.009
Collar diameter		1	0.586**	0.316	0.319	0.307	0.101	0.332	-0.204	0.223	0.288	0.063	0.128	0.407*	-0.05
Inter-nodal length			1	0.535**	0.098	-0.053	0.289	0.375	-0.153	0.073	-0.172	0.076	-0.164	-0.075	-0.12
Number of Leaves per seedling				1	-0.024	0.143	0.358	0.544**	-0.271	0.197	0.054	0.225	-0.023	0.004	0.035
Leaf area of seedling					1	0.209	-0.099	0.075	-0.088	-0.01	0.144	-0.062	-0.016	0.187	-0.092
Fresh leaf biomass						1	0.134	0.167	-0.084	0.231	0.868**	-0.056	0.167	0.742**	-0.188
Root length							1	-0.205	0.637**	0.436*	-0.167	0.423*	0.206	-0.101	0.173
Shoot length								1	-0.877**	-0.005	0.029	-0.013	-0.076	0.065	-0.115
Root:Shoot length ratio									1	0.216	-0.133	0.222	0.164	-0.116	0.181
Root fresh weight										1	0.066	0.937**	0.843**	0.096	0.741**
Shoot fresh weight											1	-0.227	0.098	0.782**	-0.222
Root:Shoot fresh weight ratio												1	0.768**	-0.157	0.815**
Root dry weight													1	0.213	0.803**
Shoot dry weight														1	-0.31
Root:Shoot dry weight															1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

level of significance. At 0.05 % level of significance it showed positive and significant correlation with root fresh weight (0.436) and root : shoot fresh weight ratio (0.423).

Shoot length showed negative significant correlation with root : shoot length ratio (-0.877) at 0.01% level of significance. Root fresh weight showed positive and significant correlation with root : shoot fresh weight ratio (0.937), root dry weight (0.843), root : shoot dry weight ratio(0.741) at 0.01 %level of significance. Shoot fresh weight showed positive and significant correlation with shoot dry weight (0.782) at 0.01 level of significance. Root : Shoot fresh weight ratio showed positive and significant correlation with root dry weight (0.768) and root : shoot dry weight ratio (0.815) at 0.01% level of significance. Root dry weight showed positive and significant correlation with root : shoot dry weight ratio(0.803) at 0.01% level of significance.

4.4.3 Estimation of Karl Pearson's Correlation Coefficient between Physical and Chemical Properties of Fatty Oil and Nutritional Value of De oiled Cake

A critical analysis of Table 43 exhibited that correlation coefficients worked out for eleven characters exhibited that out of 66 correlation only 21 were found positively significantly correlated with each other at different level of significance while other are non significantly correlated.

Percentage of seeds to acorn was found positively significantly correlated with oil content (0.434), protein content (0.448) at 0.05 level of significance. At 0.01% level it was found positive significant correlation with acid value (0.524) and starch content (0.552). Oil content was found positively significantly correlated with acid value (0.601), unsaponification matter (0.592), protein content (0.758), starch content (0.594) and total sugar content (0.790) at 0.01% level of significance. Refractive index was found positively significantly correlated with saponification value (0.416) at 0.05 % level of significance. Acid value was found positively significantly correlated with iodine value (0.485), unsaponification matter (0.448) and starch content (0.492) at 0.05 level of significance. At 0.01% level of significance it was found significant with protein content (0.713) and total sugar content (0.640).

Iodine value was found positively significantly correlated only with protein content (0.600) and total sugar content (0.586) at 0.01% level of significance. Unsaponification matter was found positively significantly correlated with protein content (0.526) and total

Table 43 Karl Pearson's Correlation Coefficient between Physio-chemical traits of Fatty oil and Nutritional Value of Deoiled Cake

Parameters/Traits	Percentage of seeds to acorn	Oil content	Specific gravity	Refractive index	Acid value	Iodine value	Saponification value	Unsaponification matter	Protein content	Starch content	Total sugar content
Percentage of seeds to acorns	1	0.434*	-0.129	0.136	0.524**	0.395	0.053	0.252	0.448*	0.552**	0.404
Oil content		1	0.247	0.202	0.601**	0.401	0.375	0.592**	0.758**	0.594**	0.790**
Specific gravity			1	-0.188	0.143	0.363	-0.154	0.257	0.293	0.058	0.292
Refractive index				1	0.297	0.151	0.416*	0.097	0.156	0.062	0.202
Acid value					1	0.485*	0.145	0.448*	0.713**	0.492*	0.640**
Iodine value						1	0.014	0.343	0.600**	0.180	0.586**
Saponification value							1	0.058	0.223	0.198	0.235
Unsaponification matter								1	0.526**	0.298	0.519**
Protein content									1	0.365	0.907**
Starch content										1	0.477*
Total sugar content											1

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

sugar content (0.519) at 0.01% level of significance and protein content was found positively significantly correlated with total sugar content (0.907) at the same level of significance. Starch content was found positively significantly correlated only with total sugar content (0.477) at 0.05% level of significance.

Correlation is one of the important biometrical tools which measure the degree and magnitude of association between various traits. In tree improvement program, a clear understanding of association among different traits is of great importance as it illustrates wheather the choice of one character confirms to the appearance or disappearance of the other.

The above results are in agreement with the findings of Srivastava *et al.* (1995) in *Bauhinia variegata* who reported that seedling length, shoot fresh weight, root fresh weight and root dry weight exhibited highly significant positive correlation coefficient with shoot dry weight. Tyagi *et al.* (1999) in *Grewia optiva* recorded highly significant correlation between different pairs of characters. Thakur and Thakur (2015) in *Melia azedarach* recorded significant positive correlation between number of branches and collar diameter and number of branches and number of leaves. Thakur *et al.* (2000) reported a positive and significant correlation for number of leaves per seedling, leaf length and breadth in *Alnus nitida* while Anand (2003) reported positive and significant correlation coefficient for dry shoot weight with seedling length, collar diameter, number of nodes, number of leaves, leaf area and fresh shoot weight for forty eight plus tree progenies of *Bauhinia variegata*.

Lune *et al.* (2008) evaluated 49 exotic and indigenous clones of poplar for eight morphological traits and reported that plant height showed positive and significant correlation with diameter. Kumaran *et al.* (2010) carried out correlation between 15 seed sources of *Simarouba glauca* and recorded highly significant positive correlation for height and diameter. Srivastava *et al.* (1993) studied correlation on six attributes of *Terminalia arjuna* using data from an eight years old plantation. The study revealed that plant height and number of leaves per branch gave a direct effect on leaf yield. Tikader and Roy (1999) studied *Morus* spp. and reported highly significant positive association of number of shoots with length of longest shoot, total shoot length and leaf yield, length of the longest shoot with total shoot length, inter-nodal distances and leaf yield. Devagiri *et al.* (2007) in *Dalbergia sissoo* Roxb. recorded significant positive correlations between different growth characters (seedling length, collar diameter and root length).

4.5 VARIABILITY ESTIMATES AND GENETIC PARAMETERS

Variability and genetic parameters were worked out with regards to estimate of variance (phenotypic, genotypic and environmental), coefficient of variability (phenotypic and genotypic), heritability (broad sense), genetic advance and genetic gain (genetic advance as percent of mean). The results obtained for variability and genetic parameters are presented in the ensuing Tables and described below:

4.5.1 Germination Parameters

Partition of variance into different components as depicted in Table 44 showed that highest variance (phenotypic, genotypic and environment) was observed in seedling survival percentage (69.07), (58.46) and (10.62) and was followed by germination (%) (55.26), (38.97) and (16.29) respectively. For the phenotypic coefficient of variability (PCV) the maximum value was recorded for germination value (28.73), which was followed by number of days for complete germination (14.12). In case of genotypic coefficient of variability (GCV) the maximum value was recorded for germination value (15.06) and was followed by number of days for complete germination (12.26). Maximum heritability was depicted by seedling survival percentage (0.85) which was followed by number of days for complete germination (0.75). Genetic advance was found maximum for seedling survival percentage (14.49) and was followed by number of days for complete germination (10.12). Genetic gain was found maximum for number of days to complete germination (21.92) which was followed by seedling survival percentage (19.93).

4.5.2 Progeny Performance Traits

Analysis of Table 45 showed that maximum value for phenotypic, genotypic and environmental variance was recorded for seedling length (5.57), (1.65) and (3.92) which was followed by shoot length (4.9), (1.51) and (3.39), respectively. For the phenotypic coefficient of variability (PCV) the maximum value was recorded for root : shoot dry weight ratio (34.866) and was followed by collar diameter (31.903). In case of genotypic coefficient of variability (GCV) the maximum value was recorded for root fresh weight (16.435) and was followed by root : shoot fresh weight ratio (15.723). Maximum heritability was depicted by

Table 44 Variability and Genetic Parameters for Germination Traits

Parameters/Traits	Variance			Coefficient of variability (%)		Heritability (broad sense)	Genetic advance	Genetic gain (%)
	Phenotypic	Genotypic	Environmental	Phenotypic	Genotypic			
Number of days for initiation of germination	7.98	4.29	3.69	13.26	9.72	0.54	3.13	14.69
Number of days for complete germination	42.52	10.47	32.05	14.12	12.26	0.75	10.12	21.92
Germination (%)	55.26	38.97	16.29	11.52	9.67	0.71	10.80	16.74
Germination value	3.50	0.96	2.54	28.73	15.06	0.27	1.06	16.27
Seedling survival percentage	69.07	58.46	10.62	11.43	10.52	0.85	14.49	19.93

Table 45 Variability and Genetic Parameters for Progeny Performance Traits

Parameters/Traits	Variance			Coefficient of variability (%)		Heritability (broad sense)	Genetic advance	Genetic gain (%)
	Phenotypic	Genotypic	Environmental	Phenotypic	Genotypic			
Seedling length	5.565	1.649	3.916	9.738	5.301	0.296	1.440	5.944
Collar diameter	0.008	0.002	0.006	31.903	14.980	0.220	0.041	14.489
Inter-nodal length	0.564	0.141	0.423	28.896	14.425	0.249	0.386	14.835
Number of Leaves per seedling	3.264	0.648	2.617	18.767	8.359	0.198	0.738	7.669
Leaf area of seedling	1.429	0.522	0.907	11.242	6.792	0.365	0.899	8.455
Root length of seedling	2.241	0.344	1.897	12.980	5.082	0.153	0.153	4.099
Shoot length of seedling	4.900	1.504	3.395	17.440	9.664	0.307	1.400	11.030
Root:Shoot length ratio	0.047	0.008	0.038	22.958	9.792	0.182	0.081	8.603
Root fresh weight	0.418	0.145	0.273	27.933	16.435	0.346	0.461	19.921
Shoot fresh weight	0.084	0.014	0.069	12.437	5.168	0.173	0.103	4.424
Root:Shoot fresh weight ratio	0.110	0.027	0.083	31.966	15.723	0.242	0.165	15.931
Root dry weight	0.089	0.017	0.071	29.433	13.022	0.196	0.120	11.868
Shoot dry weight	0.029	0.006	0.023	16.626	7.529	0.205	0.072	7.023
Root:Shoot dry weight ratio	0.133	0.026	0.026	34.866	15.559	0.199	0.149	14.303

leaf area (0.365) followed by root fresh weight (0.346). Genetic advance was found maximum for seedling length (1.44) which was followed by shoot length (1.40). Genetic gain was found maximum for root fresh weight (19.921) and was followed by root : shoot fresh weight ratio (15.931).

4.5.3 Physio-Chemical Properties of Fatty Oil and Nutritional Value of Deoiled Cake

Perusal of data in Table 46 showed that maximum value for phenotypic variance was recorded for starch content (30.36) and was followed by percentage seeds to acorns (14.08), for the genotypic variance the maximum value was depicted for percentage seeds to acorns (9.31) which was followed by starch content (3.19), in environmental variance the maximum value was recorded for starch content (27.18), which was followed by iodine value (9.67). The phenotypic coefficient of variability (PCV) value proved that the maximum value was recorded for protein content (16.03) which was followed by percent oil content (10.60). For genotypic coefficient of variability (GCV) the maximum value was recorded for protein content (13.45), which was followed by percent oil content (5.57). Maximum heritability was depicted by protein content (0.70) which was followed by percentage seeds to acorns (0.66). Genetic advance was found maximum for percentage seeds to acorns (5.11) and was followed by iodine value (1.66). Genetic gain was found maximum for protein content (23.25) which was followed by percentage seeds to acorns (6.54).

Success of any breeding programme depends on the variability present in the plant material. Sufficient variability in the material provides liberty to the breeder for the selection as per his objectives because of selection to be a mechanism of change. There must exist certain amount of observed genetic differences in a population amongst the individuals to be selected. A tree breeder doesn't create variations but uses the already existing variation as a tool for improvement through selection. Therefore, to start the improvement work the assessment of genetic variation in the material under study becomes imperative. There may be various parameters used for assessing the inherent genetic variability. Hence information on variation among the desirable parameters and their correlation is important for selection and breeding programme (Johnson *et al.* 1955). The observed variation in a character is partly composed of genetic (heritable) variation and partly of non-heritable. The portion of total variation, which is heritable, is termed as heritability in broad sense (Lush, 1937). Heritability and genetic advance provide the information of total variation present in the population and simultaneously gives an indication of the influence of environment on the character under study.

Table 46. Variability and Genetic Parameters for Physio-chemical Properties of Fatty oil and Nutritional Value of Deoiled Cake

Parameters/Traits	Variance			Coefficient of variability(%)		Heritability (broad sense)	Genetic advance	Genetic gain (%)
	Phenotypic	Genotypic	Environmental	Phenotypic	Genotypic			
Percentage of seeds to acorns	14.08	9.31	4.77	4.80	3.90	0.66	5.11	6.54
Percent oil content	1.65	0.46	1.20	10.60	5.57	0.28	0.73	6.03
Acid value	1.14	0.11	1.03	8.44	2.59	0.09	0.21	1.63
Iodine value	12.52	2.84	9.67	4.48	2.14	0.23	1.66	2.10
Protein content	0.73	0.51	0.22	16.03	13.45	0.70	1.24	23.25
Starch content	30.36	3.19	27.18	9.35	3.03	0.10	1.19	2.02
Total sugar content	0.01	0.00	0.01	6.28	3.89	0.38	0.08	4.96

The traits with higher heritability and higher genetic gain can be undertaken for further improvement programs, since they indicate the heritable additive component of variance. High heritability indicates the effectiveness of selection based on good phenotypic performance but does not necessarily mean a high genetic gain for a particular trait. Heritability estimates in broad sense will be reliable if accompanied by high genetic gain (Burton and De Vane, 1953). Johnson *et al.* (1955) reported that heritability estimates along with expected gain is more useful and realistic than the heritability alone predicting the resultant effect for selecting the best genotype.

The above findings are in conformity with all those reported by Subramanian *et al* (1995) in *Eucalyptus grandis* and the result revealed the presence of high magnitude variation for height, girth and basal area. There were fair differences between phenotypic and genotypic co-efficient of variability also. Both heritability and genetic advance values were low for all characters. Surendran and Chandrasekharan (1984) studied seedlings of 35 selected *Eucalyptus teriticornis* plus trees and reported that heritability and genetic advance were found highest for number of branches and recommended that this could be useful in selection programme for higher biomass production.

Chauhan and Verma (1993) in *Acacia catechu* recorded that high heritability coupled high genetic advance for seedling length, collar diameter, number of leaves and branches per plant thereby, indicating the importance of additive gene effects. Hosalli (1997) observed moderate to high heritability and genetic gain for seedling length, collar diameter, internodal length, shoot and root fresh and dry weight among 49 species/varieties of *Leucaena leucocephala* at nursery stage. Manga *et al.* (1998) in *Prosopis cineraria* reported that the phenotypic and genotypic coefficients of variation were high for number of branches, shoot dry weight, total dry weight, number of lateral roots and dry root weight. Heritability in broad sense was observed higher for seedling length and root length, moderate for number of branches, collar diameter, total dry weight and dry root weight. Thakur *et al.* (2000) in the seedlings of *Alnus nitida* recorded high heritability associated with high genetic advance for collar diameter, shoot height, number of branches per plant and number of leaves per seedling which indicated the presence of additive genetic effect. Luna and Singh (2009) in *Eucalyptus* hybrid reported high heritability values for height (0.67-0.71), diameter (0.50-0.59) with high genetic gain upto three years of observations.

Rana *et al.* (2009) evaluated progenies of 25 seed sources (plus trees) of *Toona ciliata* under nursery and field conditions. Seedling length and collar diameter exhibited high heritability (broad sense) coupled with high genetic advance after 120 days of sowing. Uppal and Singh (2010) in *Albizia chinensis* recorded significant variance for seedlings height, collar diameter and number of leaves under nursery conditions. Mohapatra (1996) reported that genotypic correlation coefficient were found higher than phenotypic ones for almost all the morphological traits in *Acacia catechu*, thereby indicating strong inherent genetic control on morphological traits. Uniyal *et al.* (2003) in *Grewia optiva* reported considerable morphological and physiological variation between provenances for seed weight germination rate, germination per cent, average plant height and other seedling attributes and the characters showed varied heritability.

In the end we can conclude that the overall variation were found in different morphometric traits and in tree height maximum mean value was recorded for S6D3; in DBH maximum mean value was for S5D3; in clean bole height maximum mean value was for S7D2; crown length recorded maximum mean value in S6D3; whereas crown width depicted maximum mean value for S8D3; in primary branches maximum mean value was recorded for S6D1; in case of leaf area maximum mean value was recorded for S7D2, while leaf length was maximum in S3D2 and maximum mean value for leaf width was recorded for S8D3.

In case of germination parameters it was observed that number of days of initiation germination had maximum mean value in S4D1; while, in case of complete germination the maximum mean value was recorded in S3D1; germination (%) was maximum in S5D2; germination value had maximum mean value in S2D3 and seedling survival percentage had maximum mean value for S7D2.

Under variation studies in progeny performance traits it was observed that seedling length was maximum in S2D3; in case of collar diameter maximum mean value was observed in S7D3; inter-nodal length was maximum in S6D3; leaves per seedling was maximum for S4D2; leaf area had maximum mean value for S1D1; fresh leaf biomass had maximum mean value for S3D3; in root length maximum mean value was recorded for S6D2; maximum mean value for shoot length was recorded for S4D3; in case of root : shoot length ratio S1D1 had the maximum mean ratio; root fresh weight was maximum in S1D3; whereas, maximum mean value for shoot fresh weight was recorded for S3D3; root : shoot fresh weight ratio had

maximum mean value for S5D3; root dry weight was maximum in S3D3; shoot dry weight was maximum in S3D3 and root : shoot dry weight ratio was maximum in S1D2.

Variations studies in case of oil content, physio-chemical properties of fatty oil and nutritional value of de oiled cake it was observed that percentage to seeds acorns had maximum mean value in S6D3; oil content was maximum in S5D3; acid value had maximum mean value for S4D3; whereas, iodine value was maximum in S8D2; unsaponification matter, protein content, starch content and total sugar content had recorded maximum mean value in S5D3, S8D3, S4D3 and S8D3 respectively. Specific gravity, refractive index and saponification value did not show any variations in different diameter classes and different sites.

Similar findings have also been observed by different workers in different species. Mohapatra (1996) in *Acacia catechu*, Salazar (1989) in *Acacia mangium*, Srivastava *et al.* (1993) in *Terminalia arjuna*, Ginwal *et al.* (1995) in *Acacia nilotica*, Manga *et al.* (1998) in *Prosopis cineraria*, Nautiyal *et al.* (2000) in *Quercus leucotrichophora*, Dhillon *et al.* (2009) in *Melia azedarach*, Rana *et al.* (2009) in *Toona ciliata*, Singh and Saxena (2009) in *Jatropha curcas*, Uppal and Singh (2010) in *Albizia chinensis*, Bagchi and Sharma (1989) in *Santalum album* and Veerendra (1995) in *Azadirachta indica*.

Chapter-5

SUMMARY AND CONCLUSION

The present investigation entitled “**Variability Studies on *Quercus leucotrichophora* A. Camus Populations in Himachal Pradesh**” was conducted in the Natural forests, experimental farm (Shilli-Solan) and laboratory of the Department of Tree Improvement and Genetic Resources, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during the years 2014-2016. To evaluate various morphometric traits, progeny performance traits, oil content, physico-chemical traits of fatty oil and nutritional value of de oiled cake. Eight geographically isolated sites were selected in four districts of Himachal Pradesh which include Solan, Shimla, Chamba and Kullu, where this species occurs in abundance. From each site, three diameter classes, i.e., <30 cm (D_1), 30-60 cm (D_2) and >60 cm (D_3) were selected. Three trees were selected from each diameter class. In total 72 trees were selected from eight sites. Seeds were collected during the month of December, 2014 and were sown at experimental farm (Shilli-Solan) of the Department of Tree Improvement and Genetic Resources in the month of January 2015 and remaining of the seeds were evaluated in the laboratory for oil content, physico-chemical traits and nutritional value of de oiled cake. The observations recorded for various characters were used to calculate variability estimates, genetic parameters and correlation studies.

The study was comprised of four separate experiments as mentioned below:

1. Variation studies in morphometric traits.
2. Variation studies in germinations traits.
3. Variation studies in progeny performance traits.
4. Variation studies in oil content, oil physico-chemical traits and nutritional value of deoiled cake.

In the first experiment, i.e., morphometric traits variation studies, physical characteristics of trees were recorded in the natural forest. Data pertaining to tree height, DBH, clean bole height crown length, crown width, number of primary branches, leaf length, leaf width and leaf area were recorded. In the second experiment germination traits were

recorded, viz., number of days for initiation of germination, number of days for complete germination, germination (%), and germination value and seedling survival percentage. In the third experiment, progeny performance traits were recorded viz., seedling length, collar diameter, inter-nodal length, number of leaves per seedling, leaf area of seedling, fresh leaf biomass, root length, shoot length, root: shoot length ratio, root fresh weight, shoot fresh weight, root: shoot fresh weight, root dry weight, shoot dry weight and root: shoot dry weight ratio were recorded for respective sites and diameter classes in experimental field condition. In fourth experiment oil content, various oil physico-chemical traits like that of viscosity, saponification value, specific gravity and refractive index, acid value, iodine value, unsaponifiable matter, protein content, starch content and total sugar content for each site and diameter class were also recorded. The findings of the study have been summarized as under.

- ❖ Analysis of data obtained directly from the natural forest for the morphological traits revealed that significant variation was found among different sites for characters viz., tree height, clean bole height, crown width, leaf area, leaf length and leaf width. Site S8 (Salooni-Chamba) excelled in most of the traits followed by site S6 (Manikaran - Kullu). Diameter class D3 (>60 cm) excelled in maximum characters viz., Tree height, clean bole height, crown length, crown width, leaf area, and leaf width. With in diameter classes significant variation were recorded for tree height, DBH, clean bole height, crown length, crown width and leaf length.
- ❖ Sites differed significantly for germination traits, viz., number of days for complete germination and seedling survival percentage. Whereas, with in the diameter classes significant variation was recorded for characters viz., number of days for initiation of germination, number of days for complete germination, germination (%), germination value and seedling survival percentage. Site S6 (Manikaran-Kullu) excelled for maximum germination traits followed by Site S8 (Salooni-Chamba). Diameter class D2 (30-60 cm) excelled in germination (%) and seedling survival percentage.
- ❖ In case of progeny performance traits, leaf area of seedling, shoot length, root fresh weight, root:shoot fresh weight ratio, root dry weight, root:shoot dry weight ratio recorded significant variation among various sites. Site S4 (Summar Hill- Shimla) excelled in maximum traits followed by Site S6 (Manikaran – Kullu). With in diameter classes significant variation recorded for characters viz., seedling length,

collar diameter, inter-nodal length, number of leaves per plants and shoot length. Diameter class > 60 cm excelled for maximum characters.

- ❖ Significant variation among the diameter classes were recorded for the characters like percentage of seeds to acorns, oil content, acid value, iodine value, protein content, starch content, total sugar and unsaponification value. Whereas in case of sites significant variation was recorded for percentage seeds to acorns and protein content. All these parameters showed excellence in larger diameter class (>60 cm).
- ❖ In case of seed physiochemical characters maximum oil content was recorded in site S5(Garsa - Kullu) (12.56%), Site S8 (Salooni- Chamba) excelled in total sugar content (1.71), starch content (62.03), iodine value (80.30) whereas site S7 (Sahu-Chamba) excelled in protein content (5.66) and percentage of seeds to acorns (80.83). The present study revealed that there was non significant variation among different sites and between D.B.H classes in oil physico-chemical parameters such as saponification value, specific gravity and refractive index.
- ❖ Karl Pearson correlation studies for morphological traits revealed that out of 36 correlation coefficients calculated among morphological traits, only five were found positively and significantly correlated with each other at different levels of significance. In case of progeny performance traits, out of 120 correlation coefficients 19 were found positively significantly correlated with each other while two were found negatively significantly correlated at different levels of significance. In case of physio-chemical traits and nutritional value of de oiled cake correlation coefficients worked out for eleven characters exhibited that out of 66 correlation only 21 were found positively significantly correlated with each other at different levels of significance while other were non significantly correlated.
- ❖ Variability and genetic estimates among morphometric traits, progeny performance traits, germination traits and physio chemical traits of fatty oil showed that phenotypic coefficient of variability (PCV) was greater than the corresponding genotypic coefficient of variability (GCV). Morphological traits and progeny performance traits showed wider variation between PCV and GCV which indicate that they are sensitive to environmental changes.

CONCLUSIONS

On the basis of present findings the following conclusions can be drawn:

- ❖ Analysis of variation showed that site S8 (Salooni-Chamba) showed best results for most of the morphological parameters followed by site S6 (Manikaran-Kullu). This indicates that direct selection from the altitude ranging between 1700 to 1900 m amsl for the improvement of species can fetch better results.
- ❖ The sites S4 (Summer Hill – Shimla, 2120 m amsl) and S6 (Manikaran – Kullu 1760 m amsl) are found best among other sites for progeny performance traits. Selection from these sites will be better for future breeding purpose.
- ❖ Analysis of variance on the basis of diameter classes revealed clearly that contents related to oil per cent, physio chemical traits and nutritional value of de oiled cake, highest value was showed by trees in the larger diameter class, i.e., > 60 cm. This diameter class also proved best in morphological parameters except leaf length and number of primary branches. In case of germination traits medium diameter class (30 – 60 cm) showed best results.
- ❖ PCV is higher than GCV for all the morphological traits, progeny performance traits and physio chemical traits.
- Though the oil content in the seeds of *Quercus leucotrichophora* is less, but considering its wide distribution in Himachal Pradesh, this species can be tapped for oil and oil cake utilization.
- The moderate iodine value suggest that oil of the species can be suitable for soap preparations but not for paint and varnishes. Though, the non saponifiable matter is low, but, high acid value demands that that these oils should be refined sufficiently to reduce acid values to make them suitable for edible purposes.
- Though, protein content as well as soluble sugar contents are low, but high starch contents in the cake suggest them as good poultry feed.

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APPENDIX-I

1. ANOVA for Variations in Morphometric traits

Tree height

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	54.4568	27.2284	0.8072
Diameter (D)	2	1075.4539	537.7269	15.9418
Site (S)	7	589.7575	84.2511	2.4978
Interaction D*S	14	621.5119	44.3937	1.3161
Error	46	1551.6094	33.7306	
Total	71	3892.7895		

Diameter at Breast Height

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	159.3723	79.6861	4.0173
Diameter (D)	2	17616.1752	8808.0876	444.0490
Site (S)	7	31.5546	4.5078	0.2273
Interaction D*S	14	120.4950	8.6068	0.4339
Error	46	912.4489	19.8358	
Total	71	18840.0460		

Clean bole height

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	0.801944	0.400972	0.571787
Diameter (D)	2	9.341111	4.670556	6.660214
Site (S)	7	12.28986	1.755694	2.503621
Interaction D*S	14	9.305556	0.664683	0.947838
Error	46	32.25806	0.701262	
Total	71	63.99653		

Crown length

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	112.148	56.07401	1.632685
Diameter (D)	2	901.5535	450.7767	13.12509
Site (S)	7	382.2137	54.60196	1.589824
Interaction D*S	14	745.3613	53.24009	1.550171
Error	46	1579.855	34.34466	
Total	71	3721.131		

Crown width

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	53.70083	26.85042	50.22341
Diameter (D)	2	11.67437	5.837187	10.91839
Site (S)	7	15.74444	2.249206	4.207116
Interaction D*S	14	30.61785	2.186989	4.090739
Error	46	24.5925	0.53462	
Total	71	136.33		

Number of Primary Branches

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	9.083333	4.541667	1.101978
Diameter (D)	2	3	1.5	0.363956
Site (S)	7	25.55556	3.650794	0.885819
Interaction D*S	14	62.77778	4.484127	1.088017
Error	46	189.5833	4.121377	
Total	71	290		

Leaf length

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	13.10618	6.553089	1.774939
Diameter (D)	2	28.1053	14.05265	3.806236
Site (S)	7	108.9651	15.56644	4.216255
Interaction D*S	14	27.36892	1.954923	0.529501
Error	46	169.8324	3.692008	
Total	71	347.3779		

Leaf width

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	10.03822	5.01911	49.18061
Diameter (D)	2	0.612811	0.306406	3.002367
Site (S)	7	3.245676	0.463668	4.543331
Interaction D*S	14	4.119878	0.294277	2.883524
Error	46	4.694514	0.102055	
Total	71	22.7111		

Leaf Area

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	541.30043	270.65022	9.58258
Diameter (D)	2	34.46641	17.23320	0.61016
Site (S)	7	698.49539	99.78506	3.53297
Interaction D*S	14	768.92981	54.92356	1.94461
Error	46	1299.22290	28.24398	
Total	71	3342.41495		

2. ANOVA for Variations in germination traits and progeny performance traits

Number of days to initiation of germination

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	17.69554	8.847772	2.399828
Diameter (D)	2	306.712	153.356	41.59555
Site (S)	7	10.7652	1.537886	0.417129
Interaction D*S	14	63.48329	4.534521	1.229922
Error	46	169.5945	3.686836	
Total	71	568.2504		

Number of days to complete germination

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	452.6574	226.3287	21.61454
Diameter (D)	2	1870.933	935.4665	89.33765
Site (S)	7	289.8541	41.40772	3.954464
Interaction D*S	14	291.4642	20.81887	1.988216
Error	46	481.6721	10.47113	
Total	71	3386.581		

Germination (%)

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	119.79	59.89685	3.676067
Diameter (D)	2	2417.81	1208.903	74.19435
Site (S)	7	90.11	12.87288	0.790051
Interaction D*S	14	555.80	39.70001	2.436521
Error	46	749.51	16.29373	
Total	71	3933.02		

Germination value

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	2.784003	1.392001	0.54861
Diameter (D)	2	18.35827	9.179135	3.617641
Site (S)	7	25.82891	3.689844	1.454226
Interaction D*S	14	80.56053	5.754324	2.267869
Error	46	116.717	2.537326	
Total	71	244.2487		

Seedling survival percentage

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	39.88672	19.94336	1.878354
Diameter (D)	2	3417.754	1708.877	160.9496
Site (S)	7	298.3886	42.62695	4.014794
Interaction D*S	14	561.4561	40.10401	3.777172
Error	46	488.4035	10.61747	
Total	71	4805.889		

Seedling length

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	10.66656	5.333279	1.362065
Diameter (D)	2	70.07741	35.0387	8.94853
Site (S)	7	43.4403	6.205757	1.584887
Interaction D*S	14	90.32115	6.451511	1.64765
Error	46	180.1168	3.915582	
Total	71	394.6222		

Collar diameter

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	0.000169	8.47E-05	0.013367
Diameter (D)	2	0.172136	0.086068	13.57895
Site (S)	7	0.013532	0.001933	0.30499
Interaction D*S	14	0.083797	0.005986	0.944334
Error	46	0.291564	0.006338	
Total	71	0.561199		

Inter-nodal length

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	0.877658	0.438829	1.036536
Diameter (D)	2	12.31623	6.158113	14.54577
Site (S)	7	3.735276	0.533611	1.260416
Interaction D*S	14	3.382419	0.241601	0.570675
Error	46	19.47461	0.423361	
Total	71	39.78619		

Number of leaves per seedling

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	0.310303	0.155151	0.059288
Diameter (D)	2	41.99069	20.99534	8.023003
Site (S)	7	22.5288	3.2184	1.229855
Interaction D*S	14	40.35251	2.882322	1.101429
Error	46	120.3771	2.616893	
Total	71	225.5594		

Leaf area per seedling

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	107.3068	53.65341	59.1362
Diameter (D)	2	2.058544	1.029272	1.134453
Site (S)	7	22.42962	3.204232	3.53167
Interaction D*S	14	32.37821	2.312729	2.549065
Error	46	41.73512	0.907285	
Total	71	205.9083		

Fresh leaf biomass

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	1.947158	0.973579	3.661436
Diameter (D)	2	0.381408	0.190704	0.7172
Site (S)	7	0.373928	0.053418	0.200895
Interaction D*S	14	3.169814	0.226415	0.851502
Error	46	12.23144	0.265901	
Total	71	18.10375		

Root length

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	16.75184	8.375918	4.414977
Diameter (D)	2	9.856044	4.928022	2.597578
Site (S)	7	10.87805	1.554008	0.819123
Interaction D*S	14	46.6036	3.328829	1.754638
Error	46	87.26936	1.89716	
Total	71	171.3589		

Shoot length

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	11.70575	5.852876	1.723758
Diameter (D)	2	45.49702	22.74851	6.699769
Site (S)	7	59.97591	8.567987	2.523398
Interaction D*S	14	76.42218	5.458727	1.607675
Error	46	156.1892	3.395417	
Total	71	349.79		

Root:Shoot length ratio

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	0.250694	0.125347	3.284914
Diameter (D)	2	0.213006	0.106503	2.791073
Site (S)	7	0.473944	0.067706	1.774349
Interaction D*S	14	0.776208	0.055443	1.45298
Error	46	1.755287	0.038158	
Total	71	3.469138		

Root fresh weight

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	0.140486	0.070243	0.257058
Diameter (D)	2	0.891786	0.445893	1.631768
Site (S)	7	7.112422	1.01606	3.718325
Interaction D*S	14	8.264436	0.590317	2.160295
Error	46	12.56985	0.273258	
Total	71	28.97898		

Shoot fresh weight

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	8.528619	4.26431	61.47529
Diameter (D)	2	0.131319	0.06566	0.946566
Site (S)	7	0.288821	0.04126	0.594816
Interaction D*S	14	2.174258	0.155304	2.238901
Error	46	3.190847	0.069366	
Total	71	14.31387		

Root:Shoot fresh weight ratio

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	2.291908	1.145954	13.75997
Diameter (D)	2	0.030735	0.015367	0.184523
Site (S)	7	1.979522	0.282789	3.395568
Interaction D*S	14	1.739118	0.124223	1.491596
Error	46	3.830961	0.083282	
Total	71	9.872244		

Root dry weight

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	0.091136	0.045568	0.639195
Diameter (D)	2	0.040936	0.020468	0.287111
Site (S)	7	1.64051	0.234359	3.287406
Interaction D*S	14	1.155419	0.08253	1.157669
Error	46	3.279331	0.07129	
Total	71	6.207332		

Shoot dry weight

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	2.080553	1.040276	45.14774
Diameter (D)	2	0.058678	0.029339	1.273301
Site (S)	7	0.203132	0.029019	1.259411
Interaction D*S	14	0.678256	0.048447	2.10258
Error	46	1.059914	0.023042	
Total	71	4.080532		

Root:Shoot dry weight ratio

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Replication	2	3.264819	1.63241	15.34851
Diameter (D)	2	0.024892	0.012446	0.117023
Site (S)	7	2.329348	0.332764	3.128767
Interaction D*S	14	1.916678	0.136906	1.287236
Error	46	4.892387	0.106356	
Total	71	12.42812		

3. ANOVA for Variations in physical and chemical characteristics of fatty oil and nutritional value of de oiled cake**Percentage of seeds to acorns**

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	165.79817	82.89908	17.36758
Site (S)	7	279.75685	39.96526	8.372828
Interaction D*S	14	306.48374	21.8917	4.586368
Error	48	229.11407	4.77321	
Total	71	981.15283		

Per cent oil content

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	11441.3	5720.648	2015.226
Site (S)	7	9021.731	1288.819	454.0152
Interaction D*S	14	17171.05	1226.504	432.0634
Error	48	136.2582	2.838712	
Total	71	37770.34		

Specific gravity

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	0	0	1.166667
Site (S)	7	0	0	2.071429
Interaction D*S	14	0	0	0.785714
Error	48	0	0	
Total	71	0		

Refractive index

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	0	0	2.818182
Site (S)	7	0	0	0.61039
Interaction D*S	14	0	0	0.220779
Error	48	0	0	
Total	71	0		

Acid value

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	16.9429	8.47145	8.220618
Site (S)	7	6.647372	0.949625	0.921507
Interaction D*S	14	7.475478	0.533963	0.518153
Error	48	49.4646	1.030512	
Total	71	80.53035		

Iodine value

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	126.7685	63.38427	6.552174
Site (S)	7	92.59453	13.22779	1.367386
Interaction D*S	14	199.318	14.237	1.47171
Error	48	464.3413	9.673778	
Total	71	883.0224		

Saponification value

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	450.1783	225.0891	2.17987
Site (S)	7	508.52	72.64571	0.703535
Interaction D*S	14	1422.357	101.597	0.983913
Error	48	4956.388	103.2581	
Total	71	7337.443		

Unsaponification matter

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	0.069008	0.034504	5.444444
Site (S)	7	0.053483	0.00764	1.205598
Interaction D*S	14	0.098658	0.007047	1.111956
Error	48	0.3042	0.006337	
Total	71	0.52535		

Protein content

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	30.1059	15.05295	69.59472
Site (S)	7	7.1582	1.0226	4.727814
Interaction D*S	14	3.213408	0.229529	1.061188
Error	48	10.38213	0.216294	
Total	71	50.85964		

Starch content

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	293.8152	146.9076	5.4054
Site (S)	7	227.9105	32.5586	1.1980
Interaction D*S	14	323.1976	23.0855	0.8494
Error	48	1304.5517	27.1782	
Total	71	2149.4750		

Total sugar content

Source of variation	Degree of Freedom	Sum of Squares	Mean sum of Square	F calculated values
Diameter (D)	2	0.3373	0.16865	25.07807
Site (S)	7	0.076683	0.010955	1.628961
Interaction D*S	14	0.029367	0.002098	0.311914
Error	48	0.3228	0.006725	
Total	71	0.76615		

**Dr. Y.S. Parmar University of Horticulture and Forestry
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Department of Tree Improvement and Genetic Resources

Title of Thesis : **“Variability Studies on *Quercus leucotrichophora* A. Camus Populations in Himachal Pradesh”**
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Admission Number : **F-2014-24-M**
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Minor Field(s) : **Forest Genetic Resources**
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Year of Award of Degree : **2016**
No. of Pages in Thesis : **114+x**
No. of words in Abstract : **357**

ABSTRACT

The present study entitled, “Variability Studies on *Quercus leucotrichophora* A. Camus Populations in Himachal Pradesh” was carried out in the Natural forests, experimental field and laboratory of the Tree Improvement and Genetic Resources, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during 2014-16. In order to select best sites for improved genetic gain and quality production of *Quercus leucotrichophora*, eight sites and three D.B.H. classes from Himachal Pradesh were evaluated on the basis of morphometric traits, progeny performance traits, oil content, physico-chemical characteristics of fatty oil and nutritional value of deoiled cake. The study revealed significant variation among different sites for traits viz., tree height, clean bole height, crown width, leaf area, leaf length, leaf width, shoot length, root fresh weight, root:shoot fresh weight ratio, root dry weight, root:shoot dry weight ratio, number of days to initiation of germination, number of days to complete germination, seedling survival percentage, percentage of seeds to acorns and protein content. Whereas, among the different diameter classes all the traits showed significant variation except number of primary branches, leaf area, leaf width, fresh leaf biomass, root length, root:shoot length ratio, root fresh weight, shoot fresh weight, root:shoot fresh weight ratio, root dry weight, shoot dry weight, specific gravity, refractive index and saponification value. Over all site S8 (Salooni-Chamba) was found to be superior followed by site S6 (Manikaran-Kullu) for all traits. Diameter class D3 (>60 cm) excelled in morphometric traits, oil content, physico-chemical characteristics of fatty oil and nutritional value of deoiled cake. Whereas, for germination traits diameter class D2 (30-60 cm) showed best results. Correlation studies showed many significant positive and negatives values between different traits. Phenotypic coefficient of variability is higher than genotypic coefficient of variability for all traits which means that the characters have interacted with the environment to some degree of extent. Though the oil content in the seeds of *Quercus leucotrichophora* is less, but considering its wide distribution in Himachal Pradesh, this species can be tapped for oil and oil cake utilization. Oil of the species is recommended for soap preparation but not for paint and varnishes. Deoiled cake is recommended as good poultry feed.

Signature of Major Advisor

Signature of Student

Countersigned

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Whether sponsored by some state : No

Scholarship/Stipend/ Fellowship, : M.Sc. (University Merit Scholarship)
any other financial assistance
received during the study period

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