

Seed source variation in pod, seed and seedling
characteristics of *Bauhinia variegata* Linn. from
Garhwal Himalaya, Uttarakhand

Thesis

Submitted to the



COLLEGE OF FORESTRY
V. C. S. G. UTTARAKHAND UNIVERSITY OF HORTICULTURE
AND FORESTRY, RANICHAURI CAMPUS
UTTARAKHAND, INDIA

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

Master of Science in Forestry

(Silviculture)

June, 2016



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CERTIFICATE

This is to certify that the thesis entitled “Seed source variation in pod, seed and seedling characteristics of *Bauhinia variegata* Linn. from Garhwal Himalaya, Uttarakhand” submitted in partial fulfilment of the requirements for the degree of **Master of Science in Forestry** with major in **Silviculture** of the College of Post-Graduate Studies, VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, is a record of *bonafide* research carried out by **Mr. Ambalal Nagar, Id. No. UUHF/14222** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

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

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ACKNOWLEDGEMENT

“Distance doesn’t matter only first step is difficult”

At last the moment has come to look in to deeper layers of heart, which is filled with the feeling of togetherness, loveliness, consolidation, satisfaction, a sign of relief and fulfillment. Some are momentary and some are permanent, but both involve a member of near and dear persons to whom I acknowledge my warm regards and take this opportunity to express my feeling in black and white.

*With over whelming sense of legitimate pride and genuine obligation, I express my deep sentiments and gratitude to the Chairman of my Advisory Committee **Dr. V.P. Khanduri**, Associate professor, Department of Forestry, My Co-Advisor **Dr. B.S. Butola**, Department of Forestry for their inspiring guidance, constant encouragement constructive criticism, immaculate suggestions and keen interest during the entire course of investigation and preparation of this manuscript. With great respect, immense pleasure and esteemed reverence, I express my sincere gratitude and humble thanks to member of my advisory committee **Dr. C.S. Dhanai**, Department of Forestry, **Dr. A.C. Mishra** Department of Vegetable Science for their inspiring guidance, congenial discussion and encouragement during the preparation of this manuscript.*

*I am highly indebted to **Prof. (Dr.) C. M. Sharma**, Dean, College of Forestry, Ranichauri Campus for his close supervision and providing essential facilities to conduct the proposed investigations. I am very much thankful to **Dr. A.C. Mishra**, Director Research of the University for his Vision to priorities thesis research and integrate it with research projects.*

*The “technical learning in homely environment” was unique experience of my study in this University. This was because of affectionate behavior of Hon’ble Vice-Chancellor of the University, **Prof. (Dr.) Matthew Prasad**, Who remained easily and frequently available among the students. His regular appraisal of the quality of education being given to students is deeply acknowledged.*

*I wish to thank the following and continuous support and encouragement given to me during my research work in this University by my different teachers: **Dr. J.S. Butola, Dr. Poonam, Dr. R.S. Bali, Dr. Reena Joshi, Dr. Y.S. Gusain, Dr. Ravi Bhardwaj, Dr. Manoj Riyal, Dr. Suresh N.V., Dr. M.S. Sankanur, Dr. Arun Bhatt, Dr. Laxmi Rawat, Dr. Rajesh Bijlwan and Miss. Anupma Thpaliyal.***

*On a personal note, I record my respectful indebtedness and gratitude to my beloved Parents **Sri. Gheesalal Nagar** and **Smt. Mahohar Devi** who love and affection have no equivalence and has*

been everlasting source of inspiration to me. There is no match to the affection and cooperation given to me by Brother **Pradhan Kumar Nagar** and special for **Aman Nagar**.

“Friends are one who loves you more than you”. I fail in my duty if I do not express my thanks to my innumerable friends. Their companionship and spontaneous help enabled me to complete this mammoth task. To name few **Sarath, Dhanush, Aman, Youvraj, Luvraj, Sandeep, Kattapa, Ankit, Deepika, Kanchan, Kiran, Divya**.

My thanks to cooperative seniors **Shailendra Tiwari, Vinay Chamoli, Anjay Bist, Naveen Bahuguna, Abhishek Panwar, Akhilesh Raturi, Ramgopal kumawat, Dhaval Prajapati, Digvijay Rathor, Pankaj Lal, Gaurav Ramola, Surjeet Rawat, Uday Rana, Akshit Kukreti, Sunita, Neha, Madhuri, Priyanka, Neelam**.

My thanks to sweet juniors **Charan, Prashanth, Ranjeet, Saurav, Amrit, Ruata, Anju, Rituraj, Sandeep (B.P.), Navneet, Rajeev, Ritesh, Kamal, Naveen, Siddharth, Jagmohan, Rajat, Pradeep, Manendra, Vijayprakash**, and so specially thanks **Saurav, Charan, Prashanth** for their love and help during the course of my study.

My Sincere word to thanks goes to **Shri Prashant Bhandari, Ashish Bhai Jayparkash Amola, Semwal Ji, Miss Rajni Ramola, Miss Sarita Pundir, Bahuguna Ji, Kuldeep Bhai, Vinod Sundriyal Ji and Negi Ji** and all field workers who provided me all the require timely help.

I extent my sincere and warmest thanks to all teaching and non- teaching staff members of Department of Forestry for their cooperation and help during the course of investigation.

I extend my gratitude to the **V.C.S.G. UTTARAKHAND UNIVERSITY OF HORTICULTURE AND FORESTRY, Bharsar** for providing financial support in the form of stipend during course of study.

Above all, I am extremely thankful and grateful to my **Almighty God** for showering his fervent wishes and giving me the opportunity, strength, zeal and good health in achieving my academic endeavor.

Ranichauri Campus
June, 2016

(Ambalal Nagar)
Author

DEDICATED
To
MY BELOVED
PARENTS

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ABBREVIATIONS USED

SL. No.	Particulars	Full name
1	masl	Mean above sea level
2	<i>i.e.</i>	That is
3	Viz.	<i>Videlicet</i> ; namely
4	<i>etc.</i>	<i>Etcetera</i> ; and others
5	<i>et al.,</i>	<i>et alia</i> ; and others
6	N.	North
7	E.	East
8	°C	Degree centigrade
9	Maxi.	Maximum
10	Mini.	Minimum
11	FYM	Farm yard manure
12	Hrs.	Hours
13	MGT	Mean germination time
14	GI	Germination index
15	SVI	Seedling vigour index
16	No.	Number
17	m	Meter
18	cm	Centimeter
19	mm	Millimeter
20	g	Gram
21	Aug.	August
22	Oct.	October
23	Nov.	November
24	Jan.	January
25	Feb.	February

INTRODUCTION

Forests are essential for economic development and ecological balance of a nation. The natural forest stands are culmination of various interacting plant genetics, soil and environmental factors. The quantum of biomass produce in them over the period of time depends largely on the nature and mixture of species and the soil nutrient supply to them. In developing countries, only the conventional tools are being used by foresters even today, for maintaining higher productivity and sustainability of forests.

Studies on forest tree population structure over wide range of environmental conditions show that physiological and genetic variations are associated with location or source of seeds. The relative importance of physiologic-genetic and ecological components in the growth and development of forest trees are important from silvicultural point of view (FAO, 1985).

Seed source, denote the original geographic area from where the seeds or other propagules were obtained (Zobel and Talbert, 1984). The concept of seed source testing has been well established and demonstrated through nationally and internationally conducted co-ordinated “seed source” trials (Subramaniam *et al.*, 1992). The dictionary meaning of “seed source” is ‘place of origin’, but in forestry it can have a variety of meanings, from population to country, and even a place where the species concern is not native, but has been introduced. It is frequently used to refer to a particular seed lot in a particular organization. Burley and Wood (1976) defined seed source as any stand of tree indigenous or not. They used the term ‘origin’ to refer to a place where a species is native. Turnbull and Griffin (1985) have discussed the seed source concept and believed that, it has implication for genetic differentiation, which might arise by natural selection or through human interference. Thus seed source is a vague term but also a useful one because, it can mean a seed source locality and need not imply assumption about gene flow (Matheson and Raymond, 1986). Seed source trials are the first step towards tree improvement program especially to save the endangered species from extinction. For this propose, collection, maintenance and evaluations of germplasm are the main prerequisites (Kedarnath, 1982).

Seed source is one of the major aspect for variation studies and the essence of natural variation involves all of the differences that can be observed or measured between living things. For effective utilization of natural variation the genetic and environmental components are first and foremost to be observed. The seed source or seed source variations in nursery as well as in the field is essentially genetic in origin. The genetic variability depends upon the edaphic and climatic factors operating in the species distributional range. Widely distributed forest tree species shows genetic variation between seed sources and also between individuals of the same seed source (Swain *et al.*, 1996).

A tree species extend over the large geographical area and can grow in wide range of environments with varying climate and topography shows that, its adaptation over large geographical area. After knowing the range of adaptation of a species, its populations may become more important in forest restoration, as global warming and other environmental changes disrupt natural forests. Geographic variation exists in forest trees due to the genetic differentiation and environmental divergence in which, they have developed through ages. The knowledge of genetic variation within a species is a prerequisite for developing effective tree improvement programme, which begins with the scanning of available variations in the entire range of species distribution and delimitation of seed source capable of providing best adapted trees (Suri, 1984). Seed source studies are also desirable to screen the natural available genetic variation to utilize the best material for maximum productivity and for further breeding work (Kumar and Banerjee, 1986).

A critical decision in forest management is the choice of seed sources for reforestation to ensure a successful crop. Seed source and seed transfer guidelines are essential tools in assisting this decision and to quantify the distance of seed transfer and determine the size of seed source to minimize the risk of planting of poorly adapted trees. Plant species possess substantial genetic variation in several growth and adaptive traits and the use of selective genotypes can enhance site productivity and reduce the risk of maladaptation (Hamann *et al.*, 2000).

The consideration of tree improvement is related to afforestation/reforestation programmes (Keiding, 1974). However, trials are needed wherever adequate information is lacking either on the requirements of the site or both (FAO, 1985). Therefore, a basic knowledge

about the nature and extent of seed source variation in seed parameters such as germination, seed vigour, seedling characteristics, frequency of abnormal seedlings, resistance to frost, drought and disease etc., will be very essential for genetic improvement of the species especially for early selection (Thapliyal and Gupta, 1980 and Singh, 2006).

In seed source trials, seed sources from varying climatic conditions are compared to assess the seed quality. As an early step towards tree improvement, seed source trials provide prerequisite knowledge of both genetic and environmental variations, which allow direct genetic comparisons among seed sources growing in different geographical location are ideally suited to quantify the impacts of changing climate on various characters viz., seed length, seed breadth, collar diameter, seedling height and biomass etc. Seed source variation study on *Dalbergia sissoo* in Central Himalayan region shows various morphological characters like pod size, seed size, seedling length and biomass etc. were better at seed source of 100-400 masl comparing to other seed sources of higher altitude 600-1130 masl (Singh and Bhatt, 2008).

Bauhinia variegata Linn. is a deciduous tree belonging to the family Fabaceae; sub-family Caesalpiniaceae. It is commonly known as Guriyal in local, Kachnar in Hindi, mountain-ebony in English and Kanchnar in Sanskrit. The word Kanchnar means “a glowing beautiful lady” and also camel's foot tree (Anonymous, 1988; Gaur, 1999; Mali and Dhake, 2009). *B. variegata* is a medium sized, fast-growing, moderate light demanding deciduous trees, which reaches a height (10-15 m) and a diameter (50 cm), which is liable to browsing damages. It is grow well in plain when mean annual temperature ranges from (0°-47° C) with mean annual rainfall (500-2500 mm). Tree grows well in areas with full sun or partial shade and fairly resistant to drought, but susceptible to fire. Though frost kills leaves of seedlings and saplings, they recover during summers. The tree grows in all types of soil, preferring a fertile, moisture-retentive, but well-drained soil. *B. variegata* is mostly grown in tropical and sub-tropical climate, well adopted with hot and dry summers and mild winters (Gautam, 2012). *B. variegata* is restore fertility to acid and degraded soils because of its ability to fix nitrogen (Acharya and Kafle, 2009). It is most suitable tree species for plantations and afforestation in Garhwal Himalayas (Mishra *et al.*, 2009).

B. variegata is native to Southeastern Asia and widely distributed in India, Nepal, Burma, China and Pakistan. The genus has 300 species spread all over the world with 30 species

in India. It also commonly grows in the Sub-Himalayan tract and outer Himalayas of the moist and dry deciduous forest of Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Himachal Pradesh and Tamilnadu (Troup, 1921). The species commands a good reputation for coppicing and wide adaptability; resistance to strong winds, frost, drought and high aesthetic value for its ornamental flowers. It constitutes the forest types viz., moist Shiwalik Sal forest, moist peninsular high level Sal forest, West Gangetic moist deciduous forest in association with *Shorea robusta*, *Terminalia alata*, *Syzygium cuminii*, *Emblia officinalis*, *Albizia procera*, *Adina cordifolia*, *Anogeissus latifolia*, *Pinus roxburghii*, *Acacia species* and *Boswellia serrata* etc. (Champion and Seth, 1968).

The phenophase; senescence commence on November-December and the tree remain leafless upto March; the leaf initiation starts in April and extends to May. The large pink to purple or white flowers appear from February to April, chiefly on the upper leafless branches and the lower branches often being still in leaf. The pods from rapidly ripening in May and June (Northern India); they are 6-12 inch by 0.7-1 inch, hard and flat, with 10 to 15 seeds and dehiscence occurs in the month of May. The seeds are 0.5-0.75 inch, nearly circular, flat and brown (Troup, 1921).

B. variegata is one of them on which farmer's bank up in during the long winter lean period when the grasses are dry, less digestible and unpalatable. This species can be grown either in combination with agricultural crops or on marginal, wasteland offer opportunity of producing green nutritious fodder for the livestock particularly during water scarcity period. Leaves make good fodder and greedily eaten by sheep, goats and cattle (Gautam, 2012). *B. variegata* is also widely used as a medicinal plant viz., its various part i.e., flowers, flower buds, stem, roots, stem bark, seeds and leaves have been used since ancient times for the treatment of a large range of diseases. It contained many secondary metabolites which are suitable to be used as medicines, pharmaceuticals, agrochemicals, flavours, fragrances, bio-pesticides and food additives (Al-Snafi, 2013). It is used for the treatment of bleeding haemorrhoids, cough, diarrhoea, dysentery, heartburn, indigestion, malaria, skin diseases, sore throat, dyspepsia, bronchitis, leprosy, ulcer, obesity and worms. *B. variegata* is also used as an astringent, tonic and anthelmintic. The root is used as an antidote to snake poison. A decoction of the root is

used to treat dyspepsia. The dried buds are used in the treatment of piles, dysentery, diarrhoea and worms (Gautam, 2012).

Being distributed in wide geographical area, *B. variegata* exhibits large scale variation in the biomass productivity of its leaves. Therefore, the artificial regeneration/plantation of this species requires a quality genetic material, which can give better quality and quantity of leaf fodder. The use of quantitative characters has been and remains the essential basis for phenotypic selection in any breeding programme (Gupta *et al.*, 2012). The expression of a character is sum total of the contribution of so many other characters and therefore, screening/selection should be done on the basis of components contributing towards that character. So, the knowledge of association for different characters among themselves is of utmost importance for any improvement programme. Hence, keeping in view that about mention fact, the present study was undertaken to analyse the seed source variation in pod, seed and seedling characteristics of *B. variegata*. On basis of these three broad objectives:

- 1. Variation in pod and seed morphological characteristics of *B. variegata*.**
- 2. To study the variation in seed germination of *B. variegata* at nursery condition.**
- 3. Variation in growth performance and biomass yield of seedlings, raised from different sources.**

REVIEW OF LITERATURE

Seed source testing is a useful approach for genetic improvement of many forest tree species. The purpose of the seed source test was to measure the pattern of genetic variation and to aid in selection of well adapted and highly productive seed sources for silviculture practices. Seed source research also aimed at defining the genetic and environmental components of phenotypic variability between trees from different geographic origin. Seed source or seed source variation is the occurrence of differences among individual due to difference in their genetic composition. This study aims at analysing the natural patterns of variation, comparison of superior and inferior characters which have great importance in breeding and/or tree improvement programme and preserving these variation intact for future use. A brief resume of the work already carried out with respect to seed source variability into the seed germination and seed and seedling characteristic have been reviewed under following parameters:

1. Seed morphological characteristics

Seed size and weight are the important characters for improving seedling production and reducing nursery cost through selection of quality seed, apart from selecting and delineating seed sources. Analysis of seed collected from wide populations frequently reveal statically significant variation in seed weight among and within parent plants. Several reports exist on seed size variation in plants. (Schmit *et al.*, 1992; Ramachandra, 1996; Chauhan, 1998).

Dhanai *et al.* (2003) conducted study on effect of source (altitude as well as geographic) variation in seed morphological characteristics, germination percentage and various seedling traits among and within 13 seed sources of *Albizia chinensis* were examined. The middle elevation sources showed consistent variation in different seed traits. Manan and Palampur populations had biggest and heaviest seeds among all the sources. Various seedling traits differed significantly among the sources.

Todaria *et al.* (2003) were observed that, variations with respect to different morpho-physiological characters of acorn/seed of *Quercus leucotrichophora* collected from Garhwal Himalaya, India. The computed values of phenotypic variance and phenotypic coefficient

variance were higher as compared to genotypic and environmental variance and coefficient. Geographic variables were not significantly correlated with acorn traits.

Singh *et al.* (2006) were conducted studied on seed source variation of *Celtis australis*, which were collected from 13 different sources, ranging from 550 to 1980 masl, in central Himalaya, India. Significant ($p < 0.05$) variation were observed for seed traits among seed source. However, among variation characters, seed weight exhibited maximum variation between seed population compare to other morphological characters.

Singh and Bhatt (2008) were conducted studied on *Dalbergia sissoo*, which were collected from 19 different altitudinal sources ranging from 120 to 1130 m in central Himalaya, India. They were evaluated for pod/seed morphology, seed weight, seed germination and seedling growth in nursery and also in field trial. The variation were observed for morphological and physiological variations between seed source for all the pod and seed traits including germination, plant height and collar diameter were found among the altitude. Among various parameters, seed weight and plant height were most heritable traits, followed by genetic advance and genetic gain.

Singh *et al.* (2008) were observed that, variation in different morpho-physiological characters of pod and seed *Albizia procera* collected from different seed source foot hills of Garhwal Himalaya, India. Significant ($p < 0.05$) variation in pod and seed characters were found in between seed source of *Albizia procera*. The germination percent in general decrease with increasing altitude of seed source, the effect of different temperature on seed germination was not much pronounced, however, 25°C constant temperature was found optimum for germination in all the seed sources.

Singh *et al.* (2010) were observed that, seed source variation in seed and seedling attributes of *Quercus glauca* in Garhwal, Himalaya, India. Significant differences were obtained in morphological and seedling attributes with populations. Altitude of seed source showed significant inverse correlation with seed length, seed weight and seedling weight. But altitude showed significant positive correlation with percentage germination and root collar diameter of seedlings. Significant positive correlation between seed weight and seedling weight were also observed.

Ahirwar (2012) was conducted, studied on *Alangium lamarckii* in Tikamgarh, Madhya Pradesh, India. To examine the morphological large size seeds gave maximum germination followed by medium size and small size seeds characterized by low germination percentage. It is evident that the germination percentage significantly declined with reduction in size and weight of the seeds.

Arthanari *et al.* (2013) were conducted a seed source variation study on species *Caesalpinia sappan* in two states (Kerala and Tamilnadu) at 15 seed sources. Then they observed that physical characters of pod and seed expressed wider variability among the seed sources. Nagercoil (seed source) recorded the highest values on pod length.

Kumar (2014) was recorded variation of pod, seed and seedling traits among seed sources on *Pongamia pinnata*, which was collected from India. Significant variability was observed among seed sources for pod, seed and seedling traits.

Amri (2014) was reported on *Dalbergia melanoxylon*, which was collected from 3 different altitudinal sources ranging from 104 to 475m (masl) in Salaam and Morogoro region of the Eastern part of Tanzania. Seed source variation in seed morphological traits of seed length, width, number of seeds/pod and 100 seed weight were also examined. Seed source variation in seed morphological traits also revealed that Mkundi seed source had significant high pod length, pod width and seed weight. Correlation analysis revealed highly significant positive correlation between pod width with seed viability and seed weight with seed germination.

Fredrick *et al.* (2015) were observed, seed source variation on *Faidherbia albida*, which were collected from 6 seed source in Eastern Africa. The study revealed highly significant differences among seed sources in all studied parameters except for seedling height at 2 to 5 month. Highest variation among seed sources in seed traits was observed in seed weight while seed thickness had the lowest variation. Significant correlation was found between seed length and collar diameter and between temperature and collar diameter.

Meena *et al.* (2015) were conducted studied on *Tecomella undulata*, which were collected from 20 seed sources from six districts of Rajasthan, India. Nature of variations in seed and pod characteristics, thirty seven phenotypically superior genotypes were identified

from 20 seed sources. Variations were observed in all the pod and seed characteristics viz., 100-seed weight, seed length, seed width, number of seeds/pods, pod length and pod width. Among all the genetic parameters studied, the phenotypic and genotypic coefficients of variations were found close to each other with 100-seed weight and pod length exhibiting the higher values. Estimates of broad sense heritability ranged seed length to pod length, genetic advance as per cent of the seed width giving the lowest value and 100-seed weight giving the highest value.

2. Variation in seed germination characteristics

Germination of seed is the initial and under some circumstances critical step in afforestation by natural and artificial means. Seeds of different species and of the same species from different seed sources behave differently in their germination behavior and knowledge of the same was very essential for understanding various plantation programmes. Tree seed quality is usually assessed by means of standard germination test. Dormancy and the genotypic effects are the main reasons of variation in seed germination (Doran and Gunn, 1986). The percent germination varies not only among the species but also within the species, depending upon the time of collection, sowing, climatic conditions, soil factors, seed quality and other physical conditions of the region (site). Studies on forest tree species also exhibit that germination rate and germination period may change from seed source, and even from family to family within a seed source (Wilcox, 1968; Webb and Farmer, 1968).

Kumar and Toky (1996) were assessed 12 seed sources of *Albizia lebbek* in arid India and reported significant variation in seed germination among the seed sources.

Gera *et al.* (1999) were conducted study of ten seed sources of *Dalbergia sissoo*, which were collected from Solan and Lucknow, India. Significant variations among the seed sources were observed in parameters, viz., germination percent and survival percent. Variations for most of the traits studied were non-clinal type, except seed germination percent, which showed significant negative correlation with altitude. Low germination among the seeds of higher elevation populations was found to be due to higher dormancy existing in these seed lots. The inverse relationship observed in seed germination percent among seed source.

Oyebade *et al.* (2012) were conducted study an effects of seed sources on early growth of *Chrysophyllum albidum*, were collected from six seed sources in Rivers State of Nigeria.

There were significant variations ($p < 0.05$) in all the evaluated growth variables across the locations with increases in time of sowing. Seed source from Bori had the highest germination percentage and less mortality rate.

Malhotra *et al.* (2013) were conducted study on seed germination traits i.e., germination percent, germination value and germination energy in laboratory and nursery conditions were evaluated for 97 accessions of *Jatropha curcas* belonging to 10 stands in Uttarakhand. On the basis of all seed germination traits tree T₁ of stand S₆ and tree T₁ of stand S₈ were best. Stand S₃, which was not the best stand for germination percentage on the basis of stand level analysis, had three trees showing 86 percent laboratory germination on par with the trees having the highest germination percent (87.5%) in the study at tree level.

Jagadish *et al.* (2014) seed samples of *Vateria indica* were collected from three contrasting locations represented by three random trees for each location in Karnataka were studied to know the pattern and extent of variation in seed germination parameters. Significant variation were observed among seed sources for germination parameters like, germination percent, time taken to initiate germination and germination value. But the results did not show any significant difference for speed of germination and time taken to complete germination.

3. Variation in growth performance and biomass yield

Krishan and Toky (1996) were collected twenty one seed source of *Acacia nilotica* sp. *indica* from 19 m to 650 m altitude in India and grown at Hisar, India. There were significant variations ($P < 0.05$) in stem height, branch, leaf and spine growth characters among the seed sources at 6 and 23 months stage after transplantation. The ranking of superiority changed for most of the characters with advancement in age. In general, seed sources from North-Western and Central India were found to be superior to those from South India. Variation in growth characters were random as they did not show any significant relation with latitude of origin seed source.

Kundu and Tigerstedt (1997) were conducted study of geographical variation in seedling traits of *Azadirachta indica*, which were collected from 10 seed sources from Myanmar and Bangladesh. The seed sources having lower shoot: root ratio and lesser number of leaves were separated with their corresponding mean annual rainfall. Seed weight, seedling height,

number of leaves and shoot: root ratio provided good discriminating characters for comparing seed sources.

Dhanai *et al.* (2003) were conducted study on effect of source (altitude as well as geographic) variation in seed morphological characteristics, germination percentage and various seedling traits among and within 13 seed sources of *Albizia chinensis* were examined. Various seedling traits differed significantly among the sources. Higher shoot length was recorded in Augastyamuni and Tuneta (lower altitudinal populations) sources. Significant differences were also found between and among various sources for all the root-shoot attributes. Root length were observed greater in lower and middle altitude sources (Moolgarh and Tallimari) but root biomass were found higher in high altitude sources (Kundhla and Palampur). Significant positive correlations were found between some of the seed traits among the sources, which could be an important criterion for early source selection. The sources from lower (centrally situated) elevational range appeared to be the most variable populations.

Singh *et al.* (2006) were conducted studied a seedling variation of species *Celtis australis*, which were collected from 13 seed sources, from 550 to 1980 masl, in central Himalaya, India. Significant ($p < 0.01$) positive correlation between growth performance of seed source was recorded. Across the seed source, shoot had the higher proportion of total biomass, followed by leaves and roots. Among various seed source, Badiyargaon, Agroda, Guptkashi, Jakholi, Gajeli, Srinagar and Palampur population produce heavier seedling grew faster compare to seedling of other sources.

Singh *et al.* (2006) study that the one year old seedlings, of *Celtis australis*, average shoot and root growth were 61.1 ± 13.3 cm and 30.5 ± 5.4 cm, respectively, irrespective of seed source variation. Inter-comparing biomass yield of the seedlings with altitude, average biomass production was 8.4 ± 2.5 , 9.4 ± 3.3 and 12.7 ± 1.7 g/plant, respectively, for low (550–1000 masl), middle (1050–1250 masl) and high (1350–1980 masl) altitudinal populations. Significant ($p < 0.01$) positive correlation between growth performance of seedlings and altitude of the seed source was recorded. Across the seed sources, shoots had the highest proportion of total biomass (42.3%), followed by leaves (32.6%) and roots (24.6%). Among various seed sources, Badiyargaon, Agroda, Guptakashi, Jakholi, Gajeli, Srinagar and Palampur populations produced heavier seedlings and grew faster compared to seedlings of other sources.

Ghildiyal *et al.* (2009) were conducted study on *Pinus roxburghii* from fourteen seed sources of Garhwal Himalaya. The differences were evaluated on the basis of variable and heritable characters in seedling growth and biomass production. The maximum environmental coefficient of variance was observed for root length and minimum for collar diameter. Among different seed sources, the root length oscillated between a minimum of 47.60 cm (in Badiyargarh seed source) to a maximum of 73.73 cm (in Kalimath seed source) after eighteen months of seedling growth. Heritability in broad sense for seedling height was coupled with genetic advance and subsequent gain. The phenotypic and genotypic coefficients of variance were observed for root length, root biomass, root /shoot ratio, seedling height and shoot biomass respectively. The maximum seedling biomass (11.372 g/seedling) was recorded for Thalishain seed source, while minimum (5.962 g/seedling) for Badiyargarh seed source, after eighteen months of growth.

Thakur *et al.* (2009) study that seeds were collected from phenotypically superior trees of *Bauhinia variegata* at 35 geographical locations from the natural distribution area in Himachal Pradesh. After fifteen month's growth, data were recorded on plant height, collar diameter, number of leaves, fresh and dry shoot weight, fresh and dry root weight. Significant and positive correlation between different characteristics indicated the possibility of indirect selection in the species.

Hembrom *et al.* (2011) studies for seed morphology, seedling growth and biomass attributes were made in 11 seed sources of *Terminalia arjuna* and 14 seed source of *T. tomentosa*. A wide variation were recorded for 13 seed and seedling traits in both the species. Single seed weight ranged between (1.15 to 4.52 g) in *T. arjuna* and (0.87 to 2.76 g) in *T. tomentosa*. Germination per cent was maximum (83.33) in *T. arjuna* seeds from Chakradharpur seed source (Jharkhand). Production of fresh biomass was maximum (2.03 g) in *T. tomentosa* seedlings from Kharsawan (Jharkhand). Root-shoot ratio an important parameter in initial establishment of seedling were also highest (3.08:1) in *T. tomentosa* from Ranka (Jharkhand). Vigour index ranged between 669.80% (*T. arjuna*) to 580.80 % in *T. tomentosa*. A positive and significant correlation was found in root length and vigour index.

Anand and Dwivedi (2014) were conducted of association studies for morphological and biomass traits on *Bauhinia variegata*, which was 48 plus trees selected from Himachal

Pradesh. Genotypic and phenotypic correlation was observed between biomass traits and morphological traits especially collar diameter, plant height and leaf area. Present study indicates that collar diameter, plant height and leaf area are the common causal factor that influences biomass productivity of *Bauhinia variegata* genotypes.

Salami and Akinyele (2015) were conducted seed source variation in seed and seedling attributes of *Jatropha curcas*, was investigate within south-western Nigeria with different climatic conditions. The growth parameters measured included lateral branch length, number of leaves, and biomass. Significant differences were observed on all the parameters measured among the seed sources ($p < 0.05$). Analysis of variance showed that there was no significant ($p > 0.05$) difference among the germination of seeds collected from all the seed source. Ondo seed source had the highest germination percentage followed by Ekiti seed source while the least seed source was Oyo.

Thakur and Dhuppe (2015) were investigated on *Albizia lebbek* (Benth) was carried out to study fifteen seed sources from Himachal Pradesh. Analysis of variance revealed significant differences for all the characters viz., fresh shoot weight, dry shoot weight, fresh root weight, dry root weight, shoot root ratio (fresh) and shoot root ratio (dry).

4. Phenotypic and genotypic coefficient of variation (PCV and GCV)

Uniyal (1998) was conducted study on *Grewia optiwa* and variability estimates computed for different characters indicated that values had a wide range depicting the presence of a good amount of variation. Among the seed traits, seed weight showed higher genotypic variation and genotypic coefficient of variation accompanied by high heritability and a good amount of genetic gain.

Thakur *et al.* (2002) were recorded significant variations in pod length, breadth, thickness and seed weight. High heritability coupled with high genetic advance was observed for pod breadth, pod thickness, pod weight and seed weight/ pod. High positive values of genotypic correlation coefficient between pod and seed character reveal that the traits are genetically controlled and selection can be very effective in tree improvement programme.

Roy *et al.* (2004) were conducted study of seed source variation on *Pinus roxburghii*. The wide range of climatic condition in the natural distribution of chir pine is expected to result

in high genetic variation within different populations of the species. In present study on the seed source variation of chir pine aims to determine the nature and extent of variation in wide range of populations with respect to 23 morphological traits of cone, seed and seedling, (at nursery stage) of 63 seed sources of *Pinus roxburghii*. Seed sources exhibited a wide range of variability in terms of mean values for various traits, standard deviation, variance, coefficient of variability, broad sense heritability, genetic advance and genetic gain and offer ample scope for undertaking screening for the desired traits. Genotypic variance (V_g) and genotypic coefficient of variability (GCV) for most of the parameters were found to be higher than corresponding environmental variance (V_e) and environmental coefficient of variability (ECV), except cone fresh weight, survival%, days taken for bud break and collar diameter where (V_e) and (ECV) dominated the (V_g) and GCV, thus indicating influence of environment on the expression of these traits.

Loha *et al.* (2006) Patterns of genetic variation in *Cordia africana*, a tropical timber species, were evaluated at the population level. Analysis of variance revealed significant differences among seed sources in all studied attributes except root collar diameter after 4 months of growth. The seed source effect, as determined by broad sense heritability, was 71–98 % for seed morphometric traits, 57–58 % for seedling height and 3–13 % for root collar diameter. Seed weight showed a significant positive correlation with altitude and negative correlation with mean annual temperature of seed origin. Seedling parameters and geo-climatic variables of seed origin were fairly correlated. A significant inter-character correlation was found between seed length and seed weight, between root collar diameter at the age of 4 months and seed length and weight, as well as between seedling height after 4 and 8 months of growth. It can be concluded that the observed patterns of variation will have implications for genetic resources conservation and tree improvement.

Selvan and Guleria (2012) had estimated the seed source variation on seed traits of *Acacia catechu* were carried out by collecting seeds from plus trees selected at 32 seed sources from Himachal Pradesh. Significant differences were observed for all seed traits. Very low to heavy infestation of pods were observed among the seed sources. The pod colour varied between greyed orange to brown. Seed length showed maximum variance, coefficient of variability both at phenotypic and genotypic levels with Heritability (95.30 %), Genetic

advance (2.71 %) and Genetic gain (49.63 %). At genotypic level seed length showed positive and significant correlation with seed width ($r < 0.99$), seed thickness ($r < 0.88$), 100 seed weight ($r < 0.91$) and pod length ($r < 0.82$); seed width with seed thickness ($r < 0.78$), 100 seed weight ($r < 0.86$), and pod width ($r < 0.88$), whereas being negatively related with seed length and number of seeds per pod ($r < -0.77$) and pod length ($r < -0.82$); and seed width with number of seeds per pod ($r < -0.80$) and pod length ($r < -0.81$).

Malhotra *et al.* (2013) study conducted on germination, high heritability (77 %) and moderate genetic gain (21%) were recorded at stand level for germination percent at 5% selection intensity. The expression of germination traits was usually higher under laboratory than under nursery conditions. It was suggested that the collection of seeds for germination purpose should be done by taking individual tree as a unit rather than taking stand as unit of collection.

Wani and Wani (2014) were conducted study of thirty two different seed sources on *Bauhinia variegata* from Himachal Pradesh, Uttarakhand, Haryana, Jammu and Kashmir were studied for morphological and biomass traits of one year old seedling on the mid hills of Himalayas (at an altitude of 1,350 m). The study showed that the phenotypic coefficient of variation (PCV) was higher than the corresponding genotypic coefficient of variation (GCV) for all the morphological and biomass traits which revealed that the traits are sensitive to environmental fluctuations.

Thakur and Dhuppe (2015) were investigated on *Albizia lebbek* Benth was carried out to study fifteen seed sources from Himachal Pradesh. High phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was observed for root fresh weight i.e. 22.10 % and 20.70 %, respectively. High heritability (98.00 %) was estimated for both shoot dry weight and root dry weight. As far as genetic gain is concerned it was found high for root fresh weight (40.07 %).

MATERIAL AND METHODS

The present study is entitled as “Seed source variation in pod, seed and seedling characteristics of *Bauhinia variegata* Linn. from Garhwal Himalaya, Uttarakhand” was undertaken in the Department of Forestry, College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand (V.C.S.G. Uttarakhand University of Horticulture and Forestry) during May 2015 to June 2016. The experimental details relating to site description, seed source, materials used and procedures followed during the course of study were described here under following heads:

3.1 Description of experiment site

3.1.1 Location of experimental site

The experiment site College of Forestry, V.C.S.G. Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal, is located at 10 Km away from Chamba (Rishikesh-Gangotri Road) at an altitude of about 2100 masl, lying between 30° 15' N latitude and 78° 30' E longitudes under mid hills of Uttarakhand, India. The field parameter was carried out in the experimental block of nursery at College of Forestry, Ranichauri.

3.1.2 Climate of Ranichauri campus

Ranichauri campus experiences moist temperate type of climate with chilled winters. The mean monthly maximum and minimum temperature during the study period (June to May, 2015-16) varies between 25.9°C to 2.0°C, respectively. The average annual rainfall of 1.2 to 276.4 mm (2015-16). Major portion of annual rainfall occurs during August. Winter rains and snowfall occurs during December-February (Table 1).

3.2 Description of seed source

Seed source is the place from, where the seeds or other propagules materials are collected for the present study purpose. The selection of seed source play an important role

because, it determines the physiological potential and the genetic quality of the seeds/other propagules (Zobel and Talbert, 1984).

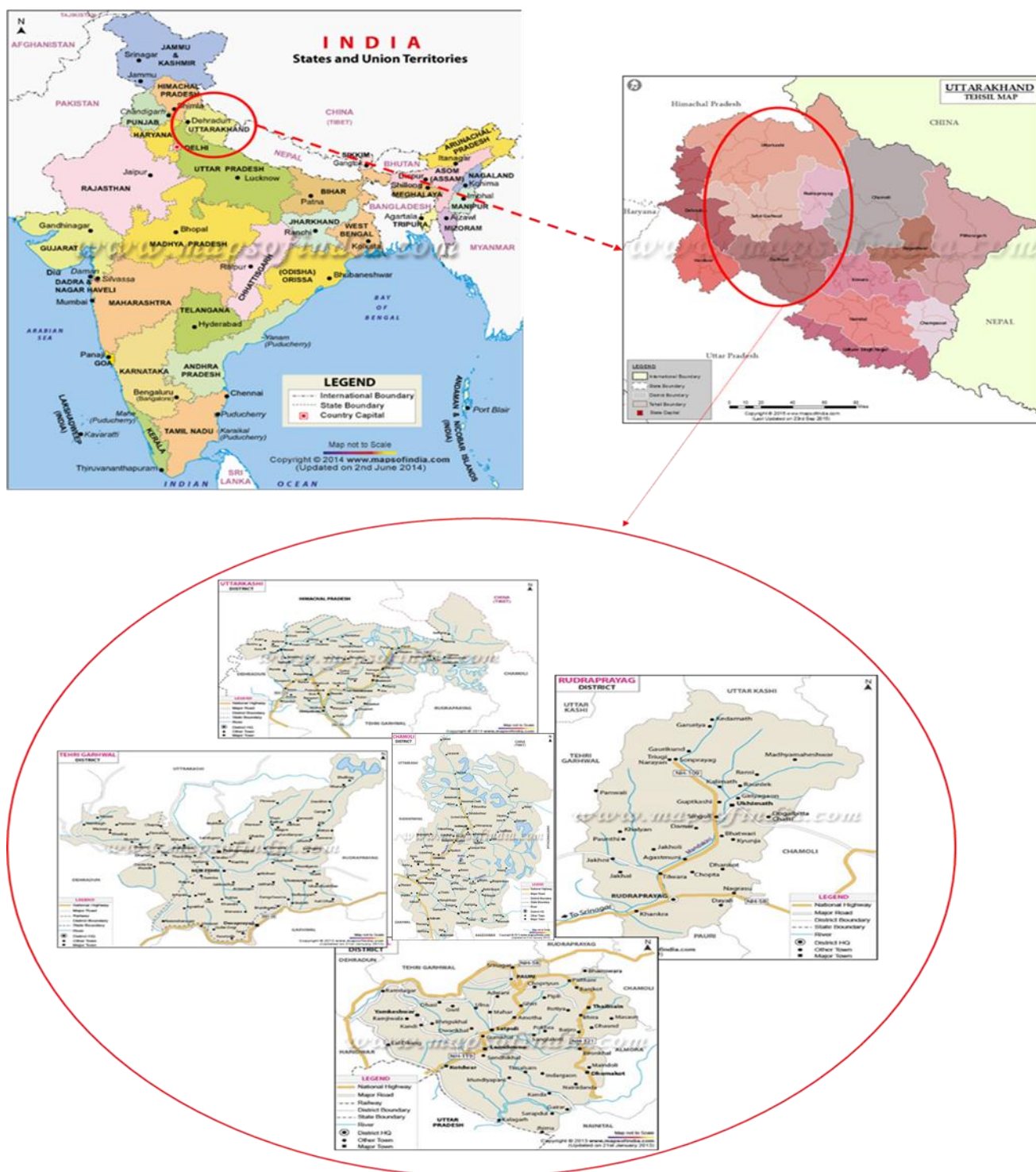


Figure 1 Geographic locations of the different seed sources of *B. variegata* represented in this study.

3.2.1 Selection of seed source

Ten seed sources representing the Garhwal region, natural range of distribution of *B. variegata* in Garhwal Himalaya, possessing a considerable variation in latitude, longitude, altitude, climatic and edaphic factor etc., were identified, pods and seeds were harvested from each source to record the further observation.

3.2.2 Location of seed source

During the course of present investigation, 10 seed source of *B. variegata* were selected from Pauri Garhwal, Tehri Garhwal, Rudraprayag, Chamoli and Uttarkashi region parts of Uttarakhand, India. Seed sources ranged from 29° 48' 14'' N to 30° 61' 51'' N latitude and 78° 22' 01'' E to 79° 25' 82'' E longitude and altitude varied from 668 to 1875 masl (Figure 1, Table 2).

3.2.3 Climate of seed source

The seed source localities (i.e., Dugadda, Langasu, Khadi, Gajeli, Harmani, Tela, Khandikhal, Chinyalisaur, Pabo and Maun), generally fall under sub-tropical to sub-temperate climate with May-June as the hottest and December-January coldest months, with maximum rainfall during June-September. Higher elevation ranges also experience snowfall during December-January.

3.2.4 Selection of trees from seed source

The success of seed source research depends on the extent to which selected seed sources represent genetic diversity within natural populations. Therefore, pods were collected from 10 sites. For each site, pods were collected from 5 trees or availability of resources, which were 100 to 300 m apart to avoid narrowing down the variation in samples due to relatedness or inbreeding (Schmidt, 2000). The bulk sample from a population formed the pod/seed lot for particular site, which were properly marked before bringing to laboratory.

3.2.5 Time and season for pods collection

The time and season is an integral part of any seed source trial, so for the present study ensure that, pods are collected in May-June (summer season).

Table 1 Monthly meteorological data during the period of investigation (June to May, 2015-2016)

Months	Temperature ° C		Relative humidity (%)		Rainfall (mm)	Sunshine (hrs.)
	Maxi.	Mini.	Maxi.	Mini.		
June	25.1	15.4	72	59	130.3	7.0
July	22.6	16.3	95	84	276.4	4.3
August	22.8	16.2	96	84	197	4.9
September	22.8	13.9	88	83	20.3	7.5
October	21.0	10.4	78	59	7.5	7.6
November	18.1	6.8	79	52	5.3	7.7
December	13.5	2.6	79	55	14.6	6.3
January	12.4	2.0	79	53	1.2	6.6
February	15.2	5.4	77	52	68.3	7.3
March	18.5	8.7	71	51	44.2	6.7
April	24.5	13.2	48	31	15.3	8.8
May	25.9	15.1	66	54	78.0	8.2

Source: Department of Agrometeorology, College of Forestry, Ranichauri Campus, Tehri Garhwal Uttarakhand.

Table 2 Geographic locations (latitude, longitude and mean altitude) of the different seed sources of *B. variegata* represented in this study

Seed sources	District	Altitude (masl)	Latitude (N)	Longitude (E)
Dugadda	Pauri	668	29° 48' 14''	78° 36' 08''
Langasu	Chamoli	815	30° 22' 23''	79° 19' 73''
Khadi	Tehri Garhwal	898	30° 16' 15''	78° 22' 01''
Gajeli	Pauri	960	30° 14' 08''	78° 34' 40''
Chinyalisaur	Uttarkashi	1033	30° 61' 51''	78° 32' 10''
Harmani	Chamoli	1151	30° 06' 45''	79° 25' 82''
Tela	Rudraprayag	1254	30° 22' 59''	78° 53' 12''
Khandikhal	Tehri Garhwal	1556	30° 20' 40''	78° 38' 05''
Pabo	Pauri	1620	30° 15' 38''	79° 01' 25''
Maun	Tehri Garhwal	1875	30° 18' 55''	78° 24' 67''

3.3 Collection of pods and extraction of seeds

Pod/ seeds collection is an integral part of any seed source trial, so for the present study ensured the collection of ripened pods from different seed sources by direct climbing method was adopted. The mature dry pods were kept loosely packed in cotton bags and kept in open place to allow for adequate air circulation. The pods have been dried in sunlight for dehiscence. Seeds were winnowed to separate the husk. Seeds were stored in the gunny bags for further study.

3.4 Studies on morphological characters of pod and seed

To determine the variability in pod, seed morphological characters i.e., length, width, thickness and weight were measured for each seed source. Seed length was measured over the seed coat along the longest axis of the seed; seed width measurement was taken on one of the widest faces at the middle of the seed while seed coat thickness was measured on one of the smallest faces at the middle of the seed.

3.4.1 Pods size measurement (cm)

Five replicates with 20 pods from each seed source were selected randomly from pods collection and their length, breadth and thickness were measured with the help of digital calliper (Mitutoyo Absolute).

3.4.2 Number of seeds per pod

The sample of fresh pod of five replicate with 20 pods was drawn at random taken from the each seed source, counted number of seed per pods and weighted on an electronic balance.

3.4.3 Seed size measurement (cm)

Five replicates with 20 seeds from each seed source were selected randomly taken from seed collection and their length, breadth and thickness were measured with the help of digital calliper (Mitutoyo Absolute).

3.4.4 Seed length/ breadth ratio

The seed length was divided by the seed breadth of the same seeds to determine the length/ breadth ratio. 20 randomly selected seedlings of each five replication for each seed source.

3.4.5 Seed weight (g)

The sample of seed weight of eight replicates with 100 seeds was drawn at random taken from the each seed source, counted and weighted on an electronic balance as per ISTA (1999) rules.

3.4.6 Moisture contents (%)

The moisture content was determined as per ISTA rule, 1999. The metal container along with lids were weighted up to four decimal places. Five randomly drawn samples of seed in each seed sources were measured for fresh weight by placing each sample in the metal dish. Then the metal dish along with the lid were weighted again up to four decimal place. The lid were opened and kept below the metal dish and both placed in hot air oven at 103°C for 24 hrs. Then the moisture content was calculated as per the following formula:

$$\text{Moisture content (\%)} = \frac{\text{Fresh seed weight} - \text{Dry seed weight}}{\text{Fresh seed weight}} \times 100$$

3.5 Potting mixture

Before sowing of seeds in nursery, polybags were filled with mixture made by sand, soil and FYM in the ratio of 1:2:1 ratio. 100 Seed of each seed source were sown in the polybags. Seed germination was recorded daily to a minimum of 28 days or until there was no further germination for a few days. The weeding and watering of polybags were done manually when needed till the completion of the experiment, i.e., one year. Seed and seedling parameters for 5 replications (10 each) were taken from each seed source.

3.6 Study on seed germination at nursery level

3.6.1 Seed germination percent

The physiological processes in the first stages of growth of seed. In seed germination, resumption of active growth in the embryo of a seed is demonstrated by the protrusion of the radicle. In seed testing (ISTA definition) resumption of active growth in an embryo, which results in its emergence from the seed and development of those structures essential to normal plant development.

It was the percent of the sown seeds germinated at the completion of test period, i.e., 30 days after sowing (ISTA, 1999). Total germination was calculated by the following formula:

$$\text{Germination (\%)} = \frac{\text{Total number of germinated seeds}}{\text{Total number of sown seeds}} \times 100$$

3.6.2 Mean germination time (MGT)

Mean germination time was calculated based on the following equation of Ellis and Roberts (1981).

$$\text{Mean Germination Time} = \frac{\sum n}{\sum Dn}$$

Where, n = number of seed, which were germinated on day D, and D is number of days counted from the beginning of germination.

3.6.3 Germination index (GI)

Germination index (GI) was calculated as described by given formula Kendrick and Frankland (1969).

$$GI = \frac{\text{Total germination percent}}{\text{Time (hours) taken for 50\% germination}}$$

3.6.4 Survival of seedling (%)

Survival seedling in each seed source at the time of recording seedling height, collar diameter etc., in the nursery after 3, 6, 9, 12 months of growth and the survival percent was worked out as follows:

$$\text{Survival (\%)} = \frac{\text{Total percent germination}}{\text{Number of seeds germinated in the that seed source}} \times 100$$

3.6.5 Seedling vigour index (SVI)

The seedlings vigour index was calculated by given formula (Abdul-Baki and Anderson, 1973). Seedling vigour index was used for determining the germination percentage and seedling length of the same seed lot.

$$\text{SVI} = \text{Seedling length (cm)} \times \text{germination percent}$$

3.7 Study on seedling growth characteristics at nursery

To assess the periodic growth, ten seedlings of each seed source in each of the five replicates were randomly tagged and data on morphological traits viz., shoot length, collar diameter, number of leaves/seedling and root length was recorded quarterly till twelve months. At the end of one year's growth, tagged seedlings were uprooted and seedling growth with regard to the following morphological parameters was recorded.

3.7.1 Shoot length (cm)

Length of the shoot was measured from the cut base to the shoot tip. The shoot length was calculated with the help of a measuring scale for 10 randomly selected seedlings on periodic months 3, 6, 9, 12 each replication for each seed sources.

3.7.2 Collar diameter (mm)

This was taken as the thickness of the stem from the ground level to the collar of the plant. The collar diameter was calculated with the help of a using digital calliper (Mitutoyo Absolute). 10 randomly selected seedlings on periodic months 3, 6, 9 and 12 for each replications for each seed sources.

3.7.3 Number of leaf per plant

The total number of leaf recorded from each seedling, which was counted by randomly selected 10 seedling on periodic months 3, 6, 9 and 12 for each replication at seedling stage for each seed sources.

3.7.4 Root length (cm)

The root length was measured with the help of a using digital calliper (Mitutoyo Absolute) from the cut base to the tip of the taproot. 10 randomly selected seedlings on final count after one year in each replications for each seed sources.

3.7.5 Root/ shoot length ratio

The root length was divided by the shoot length of the same seedling to determine the root/ shoot length ratio. 10 randomly selected seedlings of each five replication for each seed source.

3.7.6 Total seedling length (cm)

The total length of seedlings was measured by adding root and shoot length for each five replication for each seed source. 10 randomly selected seedlings of each five replication for each seed source.

3.8 Determination of dry weight of seedling (biomass)

The biomass content was determined on dry weight basis as per ISTA rule, 1999. 10 randomly seedlings was selected for each five replications of each seed sources. In the uprooted seedlings, shoot; root and leaves was detached and 10gm of the materials put into samples viz., shoot; root and leaves.

3.8.1 Leaves dry weight (g)

The leaves dry weight was obtained by drying it at 103⁰C for 24 hrs. in oven. After drying leaves was weighed using electronic balance (Contech).

3.8.2 Shoot dry weight (g)

The shoot dry weight was obtained by drying it at 103⁰C for 24 hrs. in oven. After drying shoot was weighed using electronic balance (Contech).

3.8.3 Root dry weight (g)

The root dry weight was obtained by drying it at 103⁰C for 24 hrs. in oven. After drying root was weighed using electronic balance (Contech).

3.8.4 Root/ shoot dry weight ratio

The root /shoot dry weights ratio were work out by dividing the dry weight of root by the shoot dry weight for each replication separately.

3.9 Study on phenotypic and genotypic coefficient of variation (GCV and PCV)

3.9.1 Computation of variability parameters

Genotypic, phenotypic and environmental variances were calculated using the following equations:

$$\text{Genotypic variance (Vg)} = \frac{Mt - Me}{R}$$

$$\text{Phenotypic variance (Vp)} = Vg + Ve$$

$$\text{Environmental variance (Ve)} = Me$$

Where, Mt = Mean sum of square due to treatment, Me = Mean sum of square due to error, and
R = Number of replications.

3.9.2 Phenotypic coefficient of variation (PCV)

It is the measure of total variation existing in a particular character, which was calculated as suggested by Burton and Devane (1953):

$$\text{PCV (\%)} = \frac{\sqrt{Vp}}{\bar{X}} \times 100$$

Where, $\bar{X}$ = Mean of the character and Vp = Phenotypic variance.

3.9.3 Genotypic coefficient of variance (GCV)

GCV represents the manner of total genetic variability existing in a particular character and it was calculated by using the formula as suggested by Burton and Devane (1953):

$$\text{PCV (\%)} = \frac{\sqrt{Vg}}{\bar{X}} \times 100$$

Where, $\bar{X}$ = Mean of the character and Vg = Genotypic variance.

3.9.4 Environmental coefficient of variance (ECV)

It was the measure of environmental variation existing in a particular character and was calculated as suggested by Burton and Devane (1953):

$$PCV (\%) = \frac{\sqrt{V_e}}{\bar{X}} \times 100$$

Where, $\bar{X}$ = Mean of the character and V_e = Environmental variance.

3.9.5 Heritability in broad sense (h^2)

Heritability is the ratio of genetic variance to the total phenotypic variance was estimated as suggested (Burton and Devane, 1953; Johnson *et al.*, 1955):

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

Where, h^2 = Broad sense heritability in per cent, V_g = Genetic variance, and V_p = Phenotypic variance.

3.9.6 Genetic advance

Genetic advance is the expected increase in the magnitude of a particular character when a selection pressure of chosen intensity is applied. This was calculated as per Johnson *et al.* (1955):

$$\text{Genetic advance (GA)} = K \cdot \sqrt{VP} \cdot h^2$$

Where, K = Selection intensity at 5 percent, which is equal to 2.06 (Allard, 1960),

VP = Phenotypic variance and h^2 = Broad sense heritability (%)

3.9.7 Genetic gain

Genetic gain expressed percentage of mean was calculated using the formula given (Johnson *et al.*, 1955).

$$GA = \frac{GA}{\bar{X}} \times 100$$

Where, GA = Genetic advance and $\bar{X}$ = Mean of the character.

3.10 Data analysis

The field experiment data analysed according to the procedure of analysis of variance for two factor Randomized Block Design with five replications for each seed source of *B. variegata*. Data will be collected on pod, seed, germination, growth and biomass characteristics of seedling parameters will be subjected to analysis using the statistical software (WASP version 1.0, ICARGOA, India) online software package. The critical difference (5 % level of significance) will be calculated to compare the mean and standard deviation. The analysis of variance (ANOVA) procedures will be used to test for significant effect of treatments. Correlation coefficients (Karl Pearson's) will be also determined in order to know the strength of linear relationship among the parameters as dependent variables.

RESULT AND DISCUSSIONS

4.1 Seed source variation on pod morphological characteristics of *B. variegata*

4.1.1 Pods size (cm)

The data on pods morphological characteristics of 10 seed sources for *B. variegata* had been illustrated in table 3. Significant ($p < 0.05$) variation have been recorded for pods characteristics between pod length, pod breadth and pod thickness. On average, pod length extended from $(16.72 \pm 0.72$ to 22.38 ± 1.01 cm) among seed sources with average value $(19.26 \pm 1.97$ cm). The pod length was found highest at Khadi (22.38 ± 1.01 cm) followed by Pabo (21.76 ± 0.77 cm) seed source, whereas lowest was recorded at Harmani (16.72 ± 0.72 cm) respectively. Similarly, pod breadth value ranged from $(1.63 \pm 0.04$ to 2.41 ± 0.03 cm) among the seed sources with average value $(1.95 \pm 0.27$ cm). The pod breadth was noticed highest at Khadi (2.41 ± 0.03 cm) followed by Pabo (2.36 ± 0.05 cm) seed source, whereas lowest at Harmani (1.63 ± 0.04 cm) seed source. Pod thickness value varied from $(0.31 \pm 0.05$ to 0.63 ± 0.03 cm) among the seed sources with average value $(0.48 \pm 0.11$ cm). The pod thickness was recorded highest value at Khadi (0.63 ± 0.03 cm) followed by Pabo (0.60 ± 0.04 cm), whereas lowest value at Harmani (0.31 ± 0.05 cm) seed source of *B. variegata*. Coefficient of variation (CV %), which helps in comparing the variability for different characters exhibited that there was (47.98 %) difference between lowest and highest values for pod size characteristics. Whereas, there were non-significant ($p < 0.05$) inverse correlation between altitudes of seed source.

A basic knowledge about the nature and extent of pod variation in relation to pod parameters will be very useful for the production of quality seedlings. Various workers have reported that, pods of a single species, when collected from different sources or from different altitudes differ in viability, germination, growth performance and biomass. These variations may be due to the fact that, this species grows over a wide range of climatic conditions as well as soil types and altitudes. In an early studies had been findings Sniezko and Stewart (1989) in *Acacia albida*; Arya *et al.* (1992) in *Prosopis cineraria*; Reddy *et al.* (2007) in *Pongamia pinnata*; Singh and Bhatt (2008) in *Dalbergia sissoo*. Latest studies had been finding Palanikumar (2015) in *Calophyllum inophyllum*.

Table 3 Seed source variation with respect to pod characteristics (Mean $\pm$ S.D) of *B. variegata*

Seed sources	Altitude (masl)	Pod length (cm)	Pod breadth (cm)	Pod thickness (cm)	Pod length/breadth ratio	No. of seed/Pod
Dugadda	668	19.42 $\pm$ 0.75 ^c	1.92 $\pm$ 0.06 ^{bc}	0.51 $\pm$ 0.04 ^b	10.12 $\pm$ 0.50 ^{NS}	10.76 $\pm$ 0.76 ^{abc}
Langasu	815	18.07 $\pm$ 0.26 ^d	1.86 $\pm$ 0.14 ^{cd}	0.41 $\pm$ 0.05 ^c	9.77 $\pm$ 0.69 ^{NS}	10.32 $\pm$ 0.94 ^{abcd}
Khadi	898	22.38 $\pm$ 1.01 ^a	2.41 $\pm$ 0.03 ^a	0.63 $\pm$ 0.03 ^a	9.29 $\pm$ 0.38 ^{NS}	11.16 $\pm$ 0.05 ^a
Gajeli	960	20.43 $\pm$ 0.54 ^b	2.07 $\pm$ 0.15 ^b	0.54 $\pm$ 0.02 ^b	9.91 $\pm$ 0.54 ^{NS}	10.98 $\pm$ 0.79 ^{ab}
Chinyalisaur	1033	17.32 $\pm$ 0.95 ^{de}	1.73 $\pm$ 0.07 ^{de}	0.38 $\pm$ 0.02 ^c	10.00 $\pm$ 0.37 ^{NS}	10.52 $\pm$ 0.63 ^{abc}
Harmani	1151	16.72 $\pm$ 0.72 ^e	1.63 $\pm$ 0.04 ^e	0.31 $\pm$ 0.05 ^d	10.23 $\pm$ 0.18 ^{NS}	9.48 $\pm$ 0.74 ^d
Tela	1254	19.57 $\pm$ 0.62 ^{bc}	1.94 $\pm$ 0.09 ^{bc}	0.54 $\pm$ 0.05 ^b	10.10 $\pm$ 0.38 ^{NS}	10.16 $\pm$ 0.71 ^{bcd}
Khandikhal	1556	20.03 $\pm$ 0.54 ^{bc}	1.87 $\pm$ 0.29 ^{cd}	0.52 $\pm$ 0.01 ^b	11.00 $\pm$ 2.16 ^{NS}	10.84 $\pm$ 0.27 ^{ab}
Pabo	1620	21.76 $\pm$ 0.77 ^a	2.36 $\pm$ 0.05 ^a	0.60 $\pm$ 0.04 ^a	9.21 $\pm$ 0.42 ^{NS}	10.42 $\pm$ 0.73 ^{abc}
Maun	1875	16.92 $\pm$ 0.77 ^e	1.68 $\pm$ 0.06 ^e	0.36 $\pm$ 0.02 ^{cd}	10.10 $\pm$ 0.57 ^{NS}	9.96 $\pm$ 0.40 ^{cd}
Mean		19.26	1.95	0.48	9.97	10.46
C.V.		3.81	6.29	7.94	8.26	6.43
‘r’		-0.10 ^{NS}	-0.11 ^{NS}	-0.10 ^{NS}	0.19 ^{NS}	-0.36 ^{**}

r' represent correlation coefficient computed between altitude of seed source and pod characteristics

* Significant at P < 0.05; ** Significant at P < 0.01; NS = Non-significant.

4.1.2 Pod length/ breadth ratio and Number of seeds per pod

Table 3 represents the data on pod length/ breadth ratio of different seed source of *B. variegata*. Significant ($p < 0.05$) variation have been recorded for pods characteristics between pod length/ breadth ratio and number of seeds per pod. On average, pod length/ breadth ratio varied from (9.21 ± 0.42 to 11.00 ± 2.16 cm) among seed sources with average value of (9.97 ± 0.50 cm.), Pod length/ breadth ratio was recorded highest value at Khandikhal (11.00 ± 2.16 cm) followed by Harmani (10.23 ± 0.18 cm), whereas lowest value were observed at Pabo (9.21 ± 0.42 cm) seed source respectively.

Similarly, on average, number of seeds per pod extended from (9.48 ± 0.74 to 11.16 ± 0.50) among seed sources with average value recorded (10.46 ± 0.51). The number of seeds per pod was observed highest value at Khadi (11.16 ± 0.50) followed by Gajeli (10.98 ± 0.79), whereas lowest value found at Harmani (9.48 ± 0.74) seed source respectively.

Coefficient of variation (CV %), which helps in comparing the variability for pod length/ breadth ratio and number of seeds per pod exhibited that there was (95.31 %) difference between lowest and highest values for pod length/ breadth ratio. Whereas, there were significant ($p < 0.05$) positive correlation between altitudes of seed source of pod length/ breadth ratio and number of seeds per pod (0.19 and -0.36).

In an similar work were observed Singh and Bhatt (2008) in *Dalberiga sissoo* in central Himalayas and latest study Selvan and Guleria (2012) in *Acacia catechu* were observed that the number of seeds per pod ranged (2.98) for Nalagarh to (6.11) for Aulinda seed source. The average pod length amongst the different seed sources was found to be (5.64 cm) with a coefficient of variability (3.36 %). Maximum pod length (7.35 cm) was observed from (Aulinda) and Ghrindan had minimum pod length (4.29 cm). Maximum pod width (1.78 cm) was noticed for (Nalagarh), whereas (Baljol) exhibited minimum pod width (1.05 cm) also supports the current study.

4.2 Seed source variation on seed morphological characteristics of *B. variegata*

4.2.1 Seed size (cm)

The data indicated that on seed size morphological characteristics of *B. variegata* (Table 4). Significant ($p < 0.05$) variation have been recorded for seed size characteristics between seed length, seed breadth and seed thickness. On average, seed length ranged from (1.40 ± 0.06 to 1.77 ± 0.07 cm) among seed sources with average value observed (1.58 ± 0.13 cm). The seed length was recorded highest at Khandikhal (1.77 ± 0.07 cm) followed by Dugadda and Khadi (1.71 ± 0.05 and 1.71 ± 0.40 cm) seed sources, whereas lowest was found at Harmani (1.40 ± 0.06 cm) seed source respectively. Similarly, seed breadth value ranged from (1.27 ± 0.03 to 1.48 ± 0.05 cm) among the seed sources with average value found (1.35 ± 0.07 cm). The seed breadth was recorded highest at Khandikhal (1.48 ± 0.05 cm) followed by Khadi (1.45 ± 0.06 cm), whereas lowest at Chinyalisaur (1.27 ± 0.03 cm) respectively. Seed thickness value varied from (0.23 ± 0.01 to 0.29 ± 0.02 cm) among the seed sources with average value recorded (0.26 ± 0.02 cm). The seed thickness was reported that highest value at Pabo (0.29 ± 0.02 cm) followed by Gajeli and Khandikhal (0.28 ± 0.03 , 0.28 ± 0.02 cm), whereas lowest value was found at Harmani (0.23 ± 0.01 cm) seed source respectively. Coefficient of variation (CV %), which helps in comparing the variability for different characters exhibited that there were (36.87 %) difference between lowest and highest values for seed size viz., seed length and seed thickness respectively. Whereas, there were significant ($p < 0.05$) positive correlation between altitudes of seed source and seed thickness.

Seeds, which was principal means of propagation, contain a lot of variation depending upon the source of origin with regard to morphological and physiological characters (Mathur *et al.*, 1984). A basic knowledge about the nature and extent of seed variation in relation to seed parameters will be very useful for the production of quality seedlings. These variation in seed morphological characteristics of *B. variegata* may probably be due to resources availability, which varies over seasons and therefore, may influence the seed size (Murali and Sukumar, 1994). It is possible that the variation in morphological characters between seed source is due to resource availability at the time of fruiting and so to different environments at the geographical origins of each seed and seasonal variability (Murali, 1997). Variation in seed weight, length, width and thickness between or within plant species was due to evolutionary responses of plant to maximize the potential fitness by producing a larger number of seeds and increase the chance of establishment of resulting seedlings through great allocation of maternal resources to individual seeds (Zhang, 1998).

The variation observed for seed traits did not follow any particular trend with regard to different populations. This could be probably because of environmental factors which might have played a significant role in changing the component of seed as also reported in *Acacia* (Bagchi *et al.*, 1990). Similar observation have been also recorded seed length, breadth and thickness different significantly ($p < 0.05$) between seed sources Singh *et al.* (2006) in *Celtis australis* and Singh and Bhatt (2008) in *Dalbergia sissoo*. Recent study Abdelbasit *et al.* (2014) in *Acacia raddiana* were recorded significant differences between seed length, thickness and breadth ($p < 0.01$) and significant difference in seed width ($p < 0.05$) between the seed source.

4.2.2 Seed length/ breadth ratio

Table 4 depicts the data on seed length/ breadth ratio of *B. variegata* from different seed sources. Significant ($p < 0.05$) variation have been recorded for seed length/ breadth ratio. On average, seed length/ breadth ratio ranged from (1.07 ± 0.03 to 1.24 ± 0.04) among seed sources with average value (1.17 ± 0.06). The seed length/ breadth ratio was recorded highest value at Gajeli (1.24 ± 0.04) followed by Pabo (1.24 ± 0.04), whereas lowest value observed at Harmani (1.07 ± 0.03) seed source respectively.

4.2.3 Seed weight (g/100 seeds)

The data on seed weight of *B. variegata* was indicated (Table 4). Significant ($p < 0.05$) variation have been recorded for seed weight among different seed sources. On average, seed weight ranged from (33.72 ± 1.05 to 50.70 ± 1.47 g/100 seeds) among seed sources with average value of (44.21 ± 6.18 g/100 seeds). The seed weight was recorded highest value at Khadi (50.70 ± 1.47 g/100 seeds) followed by Khandikhal (49.66 ± 1.48 g/100 seeds), whereas lowest value observed at Harmani (33.72 ± 1.05 g/100 seeds) seed source respectively. The data on 100 seed weight revealed that the higher seed weight was recorded for the seed having higher moisture content; this may influence the germination percentage. The seeds were collected from different location, from trees approximately of the same age, therefore, differences observed in seed characters may be result of adaption to diverse environmental conditions prevailing in their distribution range (Mathur *et al.*, 1984).

Table 4 Seed source variation with respect to seed characteristics (Mean $\pm$ S.D) of *B. variegata*

Seed sources	Altitude (masl)	Seed length (cm)	Seed breadth (cm)	Seed thickness (cm)	Seed length/breadth ratio	Seed weight (g/100 seeds)	Seed moisture content (%)
Dugadda	668	1.71 $\pm$ 0.05 ^{ab}	1.41 $\pm$ 0.02 ^{bc}	0.24 $\pm$ 0.01 ^{de}	1.21 $\pm$ 0.04 ^{ab}	47.45 $\pm$ 1.11 ^c	35.94 $\pm$ 1.03 ^{cd}
Langasu	815	1.48 $\pm$ 0.04 ^d	1.29 $\pm$ 0.05 ^{ef}	0.25 $\pm$ 0.03 ^{cde}	1.15 $\pm$ 0.04 ^{cd}	44.52 $\pm$ 0.93 ^d	33.76 $\pm$ 2.76 ^{def}
Khadi	898	1.71 $\pm$ 1.40 ^{ab}	1.45 $\pm$ 0.06 ^{ab}	0.26 $\pm$ 0.02 ^{bcd}	1.18 $\pm$ 0.02 ^{cd}	50.70 $\pm$ 1.47 ^a	37.43 $\pm$ 2.21 ^{bc}
Gajeli	960	1.62 $\pm$ 0.07 ^c	1.31 $\pm$ 0.03 ^{ef}	0.28 $\pm$ 0.03 ^{ab}	1.24 $\pm$ 0.04 ^a	48.98 $\pm$ 0.79 ^b	39.69 $\pm$ 2.54 ^{ab}
Chinyalisaur	1033	1.51 $\pm$ 0.06 ^d	1.27 $\pm$ 0.03 ^f	0.25 $\pm$ 0.03 ^{cde}	1.18 $\pm$ 0.03 ^{bc}	37.94 $\pm$ 1.47 ^e	31.62 $\pm$ 1.46 ^{ef}
Harmani	1151	1.40 $\pm$ 0.06 ^e	1.29 $\pm$ 0.03 ^{ef}	0.23 $\pm$ 0.01 ^e	1.07 $\pm$ 0.03 ^e	33.72 $\pm$ 1.05 ^g	31.01 $\pm$ 3.68 ^f
Tela	1254	1.50 $\pm$ 0.03 ^d	1.31 $\pm$ 0.04 ^{ef}	0.27 $\pm$ 0.01 ^{abc}	1.15 $\pm$ 0.02 ^{cd}	46.85 $\pm$ 0.63 ^c	40.47 $\pm$ 1.87 ^{ab}
Khandikhal	1556	1.77 $\pm$ 0.07 ^a	1.48 $\pm$ 0.05 ^a	0.28 $\pm$ 0.02 ^{ab}	1.20 $\pm$ 0.06 ^{bc}	49.66 $\pm$ 1.48 ^{ab}	39.68 $\pm$ 3.13 ^{ab}
Pabo	1620	1.68 $\pm$ 0.06 ^{bc}	1.37 $\pm$ 0.04 ^{cd}	0.29 $\pm$ 0.02 ^a	1.22 $\pm$ 0.05 ^{ab}	46.78 $\pm$ 1.09 ^c	41.68 $\pm$ 3.15 ^a
Maun	1875	1.45 $\pm$ 0.03 ^{de}	1.34 $\pm$ 0.02 ^{de}	0.27 $\pm$ 0.03 ^{abcd}	1.08 $\pm$ 0.03 ^e	35.54 $\pm$ 1.12 ^f	34.49 $\pm$ 4.31 ^{cde}
Mean		1.58	1.35	0.26	1.17	44.21	36.58
CV		3.09	2.86	8.38	2.73	2.59	6.66
‘r’		-0.09 ^{NS}	0.12 ^{NS}	0.59 ^{**}	-0.30 [*]	-0.28 [*]	0.27 [*]

‘r’ represent correlation coefficient computed between altitude of seed source and seed characteristics including seed weight and seed moisture content.

* Significant at P < 0.05; ** Significant at P < 0.01; NS = Non-significant.

Similarly, difference in seed weight between populations could have been a result of differences in the environmental conditions e.g. nutrients, light or water to which the mother plants were subjected during growing season (Guttermann, 1992 and Wolfe, 1995). Uniyal *et al.* (2003); Dhanai *et al.* (2003) and Singh (2004) were recorded that seed weight positively correlated to seedling growth attributes (i.e., shoot length, root collar diameter, root length, dry weight and nursery germination) indicating that seed weight could be a valuable indicator of the survival and growth potential of the seedling. Saklani (2011) was observed increasing acorn weight of *Q. leucotricophora* with increasing elevational range of seed source.

4.2.4 Seed moisture content (%)

Seed moisture content of various seed sources of *B. variegata* was depicted in table 4. Significant ($p < 0.05$) variation have been recorded for seed moisture content among different seed sources. On average, seed moisture content extended from $(31.01 \pm 3.68$ to 41.68 ± 3.15 %) among seed sources with average value $(36.58 \pm 3.79$ %). Seed moisture content was founded highest percentage at Pabo (41.68 ± 3.15 %) followed by Tela (40.47 ± 1.87 %), whereas lowest observed at Harmani (31.01 ± 3.68 %) respectively.

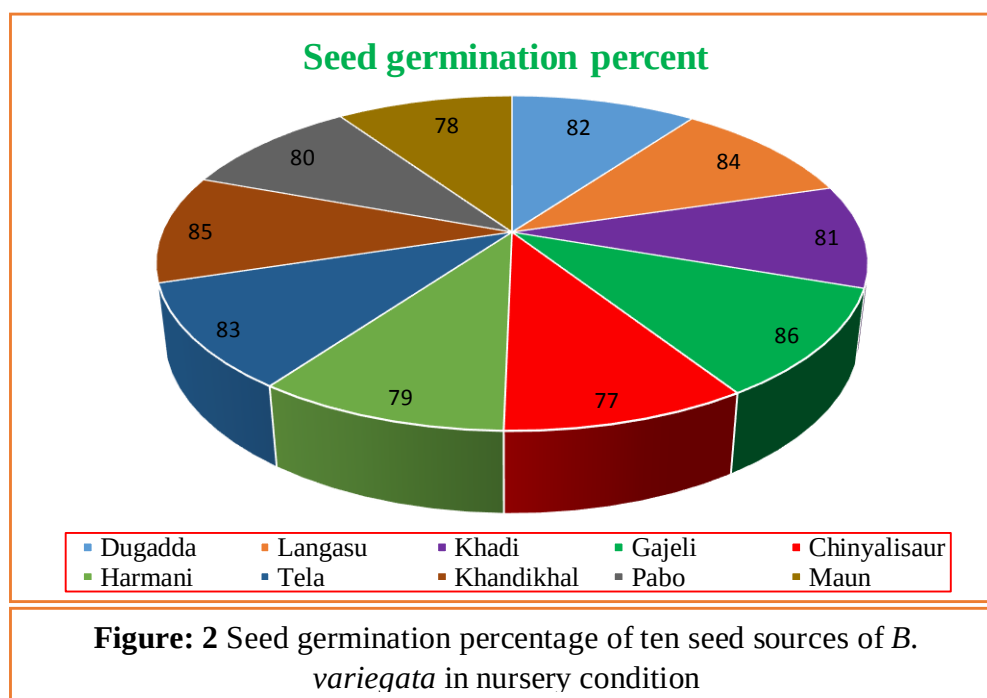
Coefficient of variation (CV %), which helps in comparing the variability for seed moisture content exhibited that there was (6.66 %) difference between lowest and highest values. Seed moisture content among seed sources was found significant correlations was reported that along with altitude (0.27). Seed moisture content indicating that seed moisture content was the most variable trait while seed viability, germination characters respectively.

4.3 Germination studies of different seed sources at nursery stage of *B. variegata*

4.3.1 Seed germination percent

The result of seed germination percent in *B. variegata* was represent (Table 5). Non-significant ($p < 0.05$) variation have been recorded for seed germination percent among different seed sources. On average, seed germination ranged from $(77 \pm 9.75$ to 86 ± 4.18 %) among seed sources with average value $(81.50 \pm 3.03$ %). The seed germination was highest value recorded at Gajeli (86 ± 4.18 %) followed by Khandikhal (85 ± 5.00 %), whereas lowest value at Chinyalisaur (77 ± 9.75 %) seed source respectively. Overall seed germination percent was recorded more than 75 percent. Maximum seed germination percent was found at Gajeli

(86.00 %), followed by Khandikhal (85.00 %) and Langasu (84.00 %) seed sources. Whereas, minimum seed germination percent was recorded at Chinyalisaur (77.00 %) seed sources. Thus seed germination percent of two seed source Gajeli and Khandikhal exhibited the seed germination (> 85 %) with highest (86 and 85 %); five seed sources Langasu, Tela, Dugadda, Khadi and Pabo had the seed germination of (> 80 %). Whereas, but the seed sources – Harmani, Maun, Tela and Chinyalisaur exhibited comparatively seed germination (< 80 %) respectively (Figure 2).



Coefficient of variation (CV %), which helps in comparing the variability for seed germination percent exhibited that there was (7.86 %) difference between lowest and highest values. Seed moisture content among seed sources was found significant and inverse correlations was reported that along with altitude (-0.28) respectively.

Seed germination rate, performance and seed dormancy was physiological phenomena in the seed that strongly related to prevailing environmental conditions (Mahgoub, 2002).

The ability of the species to remain dormant was particularly associated with seeds of species from unpredictable environments and climate with variable rainfall trends (Khurana and Singh, 2001). The size and shape of seeds was variable depending on the structure and form of the ovary and environmental conditions under which plant was growing. It is evident from

the result that seeds from Gajeli seed source was found to be superior with respect to seed germination percentage. There was in line with study made by Dwivedi (1993) in *Azadirachta indica* and Devagiri *et al.* (1998) in *Dalbergia sissoo*. They found that the variation observed in the seed germination may be attributed to adverse environment and differences in their distribution range this in turn affect the germination of seeds. Various researchers have reported that, seed germination of a single species, when collected from different sources or from different altitudes differ in viability, germination and seed dormancy. These variations may be due to the fact that, this species grows over a wide range of climatic conditions as well as soil types and altitudes.

So far effect of seed source (altitude) on seed germination was concerned, significant and inverse correlation between germination with altitude of seed source was recorded. It indicates that with increasing elevational range of seed source the germination percentage decreased. Some other workers have also recorded decreasing germination response with increase in altitude of seed origin (Chauhan *et al.*, 1996; Isik, 1986 and Saklani, 1999). Likewise, Gairola *et al.* (2011) were recorded seed germination (6.20 to 10.44 %) in all seed sources with significant differences.

4.3.2 Mean germination time (MGT)

These present study shows that, the mean germination time ranged from (11.41 to 12.30) days with average value (11.84±0.26) days. The maximum mean germination time of (12.30) days have been recorded at Harmani, followed by Pabo (12.07) days, whereas minimum mean germination time have been recorded at Dugadda (11.41) days seed sources respectively. Highest MGT days recorded in Harmani and Pabo sources indicated late and most slow germination. Lowest MGT days recorded in Dugadda source indicated an early and most rapid germination as compared to other seed sources respectively. Mean germination time indirectly expresses the rapidity of germination and lower the mean germination time was faster the germination, which was evidenced from the average value of MGT. Thus the seeds of Harmani took maximum (12.30) days to complete the germination whereas, Dugadda the process of germination was faster, uniform and took minimum (11.30) days to complete the germination. Differences were also found for MGT (1.00) days among the seed sources (Table 5; Figure 3).

4.3.3 Germination index (GI)

The data on germination index of *B. variegata* was showed (Table 5). These present study shows that, on average germination index values ranged from (0.27 ± 0.03) to (0.31 ± 0.03) with average value (0.30 ± 0.01) . The maximum average germination index value was recorded at Khadi (0.31 ± 0.03) followed by Gajeli (0.31 ± 0.03), whereas minimum germination index value was recorded at Harmani (0.27 ± 0.03) among seed sources respectively. The corresponding higher values for germination index represent comparatively higher germination percentage in the seed sources, e.g., seed source at Gajeli had 86.0 % germination and also had higher value (0.31) of germination index at Khadi (Figure 4).

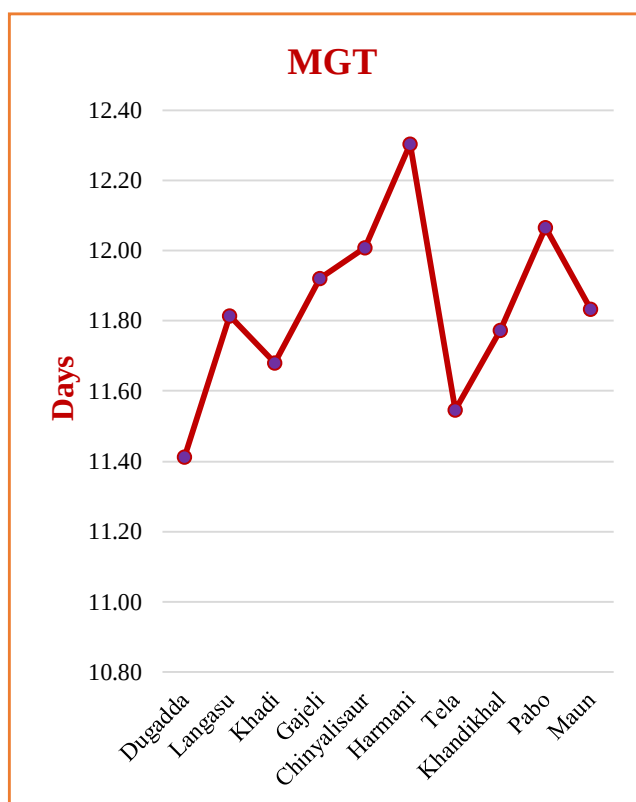


Figure: 3 Mean germination time of germinating seeds in nursery stage

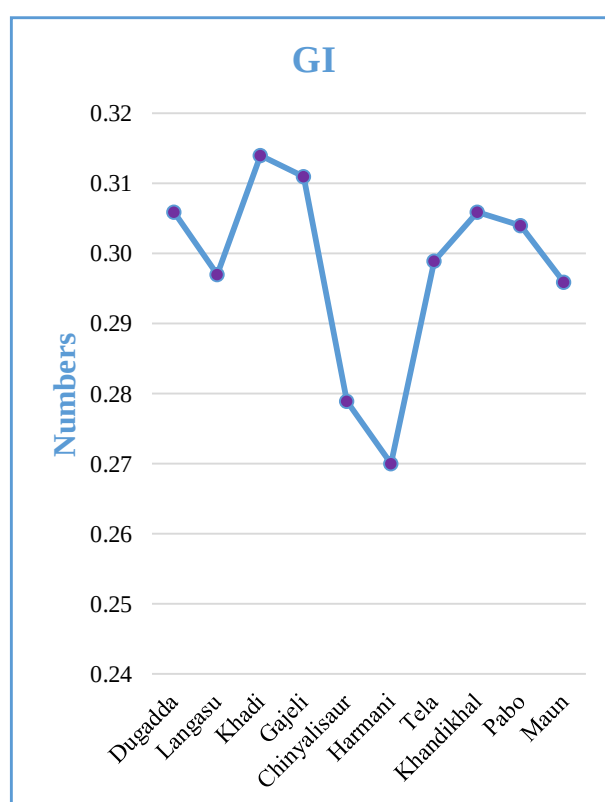


Figure: 4 Germination index of germinating seeds in nursery stage

Table 5 Seed source variation with respect to germination percent, germination index, and seedling vigour index (Mean $\pm$ S.D) of *B. variegata*

Seed sources	Altitude (masl)	Germination (%)	MGT	GI	SVI
Dugadda	668	82 $\pm$ 5.70	11.41 $\pm$ 0.38	0.31 $\pm$ 0.03	5783.35 $\pm$ 453.61
Langasu	815	84 $\pm$ 8.94	11.81 $\pm$ 0.28	0.30 $\pm$ 0.03	5041.01 $\pm$ 603.19
Khadi	898	81 $\pm$ 7.42	11.68 $\pm$ 0.45	0.31 $\pm$ 0.03	5970.67 $\pm$ 559.08
Gajeli	960	86 $\pm$ 4.18	11.92 $\pm$ 0.57	0.31 $\pm$ 0.03	6760.40 $\pm$ 264.91
Chinyalisaur	1033	77 $\pm$ 9.75	12.01 $\pm$ 0.48	0.30 $\pm$ 0.05	4382.93 $\pm$ 486.65
Harmani	1151	79 $\pm$ 7.42	12.30 $\pm$ 0.91	0.27 $\pm$ 0.03	4479.73 $\pm$ 411.33
Tela	1254	83 $\pm$ 2.74	11.55 $\pm$ 0.40	0.30 $\pm$ 0.02	5870.20 $\pm$ 251.72
Khandikhal	1556	85 $\pm$ 5.00	11.77 $\pm$ 0.37	0.31 $\pm$ 0.02	6286.10 $\pm$ 256.30
Pabo	1620	80 $\pm$ 3.54	12.07 $\pm$ 0.56	0.30 $\pm$ 0.02	5724.32 $\pm$ 225.91
Maun	1875	78 $\pm$ 2.74	11.83 $\pm$ 0.12	0.30 $\pm$ 0.02	4457.57 $\pm$ 249.86
Mean		81.5	11.83	0.30	5475.63
CV		7.86	13.28	9.97	26.37
‘r’		-0.28*	0.29*	-0.06 ^{NS}	-0.06 ^{NS}

‘r’ represent correlation coefficient computed between altitude of seed source and germination including MGT, GI and SVI.

*Significant at $P < 0.05$, ** Significant at $P < 0.01$, NS = Non-Significant.

The result revealed that, the sharp decrease in the values of germination index (GI) while, mean germination time increased with altitude to germinating seeds of *B. variegata*. Greater the values of germination index, the greater will be germination percentages of seed sources. Uniyal and Nautiyal (1998) also observed the decreasing germination index and increasing mean germination time to the seeds of *Ougeinia dalbergioides*. In an early study in were observed Saklani (1999) in *Q. leucotrichophora*; Dhanai (2002) in *A. chinensis*; Todaria *et al.* (2002) in *Albizia lebbek*.

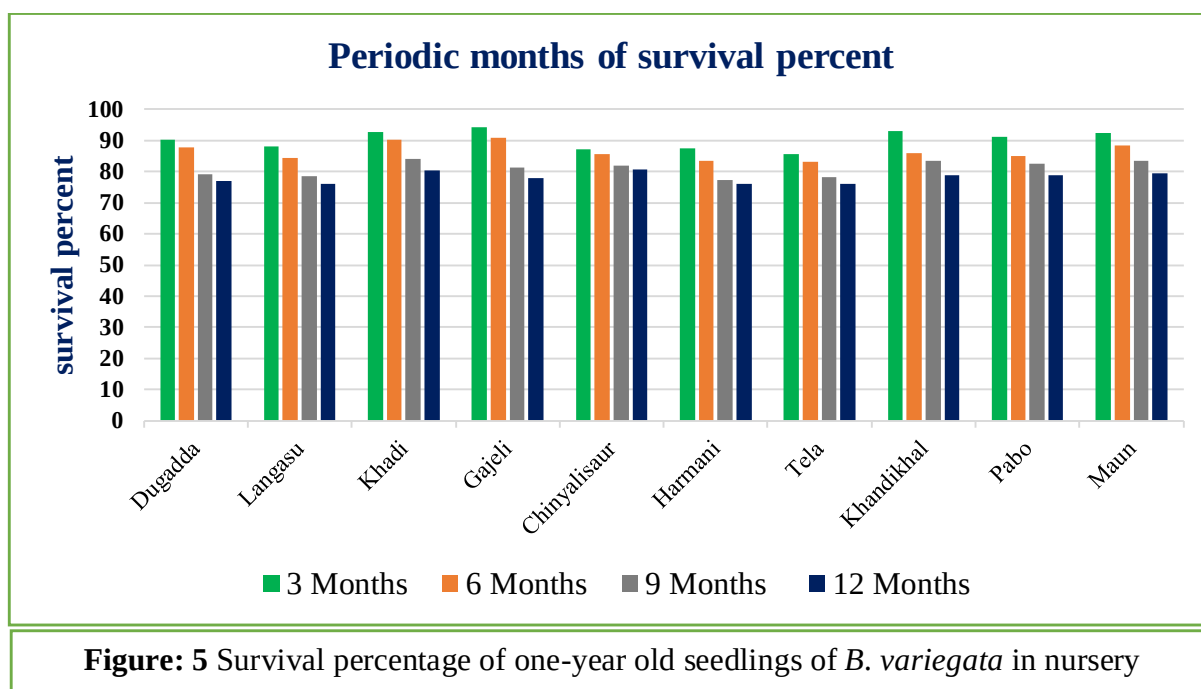
4.3.4 Seedling vigour index (SVI)

Table 5 depicted that on seedling vigour index of *B. variegata*. These present study shows that, the average seedling vigour index values ranged from (4382.93±486.65 to 6760.40±264.91) with average value (5475.63±835.06). The maximum average seedling vigour index value was recorded at Gajeli (6760.40±264.91) followed by Khandikhal (6286.10±256.30), whereas minimum seedling vigour index value was recorded at Chinyalisaur (4382.93±486.65) among seed sources respectively. Coefficient of variation (CV %), which helps in comparing the variability for germination index exhibited that there was (26.80 %) difference between lowest and highest values for seed germination and seedling vigour index. Seedling vigour index among seed sources was found significant and inverse correlations was reported that along with altitude (-0.06).

Similar type of study in seedling vigour index of seed source variation had been carried out by Saklani (1999) in *Q. leucotrichophora*; Todaria *et al.* (2002) in *Albizia lebbek* and Singh *et al.* (2010) in *Quercus glauca*.

4.4 Survival percent of seedling at nursery stage of *B. variegata*

The data on periodic survival percentage of seedlings was showed (Figure 5). Significant ($p < 0.05$) variation have been recorded for survival percent among different seed sources. On average, survival of seedling ranged from (83-94 %) among seed sources with average value of (82.23±2.96 %). The data on periodic survival percent of seedling shows that, on average survival percent of seedling, an initial 3 months of survival percentage was recorded (82.23±2.96 %) with highest percent recorded at Gajeli (94 %) and lowest at Tela (86 %).



In an initial 3 months of survival of seedling from Tela and Chinyalisaur had comparatively lower survival than the seedling survival percent of other seed sources. On average survival percent was recorded at $(79.17 \pm 2.66 \%)$ up to 6 months of growth, with highest survival percent recorded at Gajeli (91 %) and lowest survival observed at Tela (83 %) irrespective of seed sources. On average, survival percent up to 9 months of growth, with survival was recorded $(74.45 \pm 2.45 \%)$ with highest survival percentage found at Khandikhal (84 %) and lowest observed at Harmani (77 %) respectively of seed source. Survival of seedling of all the seed sources reached to maximum survival of seedling up to 12 months of growth with average value recorded $(72.06 \pm 1.77 \%)$ with highest survival percentage at Chinyalisaur (81 %) followed by Khadi (80 %), whereas lowest survival % founded at Tela (76 %) irrespective of seed sources. Thus after one year of seedling growth, survival percent of two seed source Chinyalisaur and Khadi exhibited the survival of seedling ($> 80.0 \%$) and eight seed sources (Maun, Khandikhal, Pabo, Gajeli, Dugadda, Langasu, Harmani and Tela) had the survival of seedling ($> 70.0 \%$) respectively of seed source .

Tree species in which seeds germinate and survive in dry periods was expected to show variation in morphological and physiological traits that may arise due to evolution of certain potentiality and adaptive genetic correlation between germination and post-germination traits (Evans and Cobin, 1995 and Raddad, 2007). Nursery survival after one year's growth was also

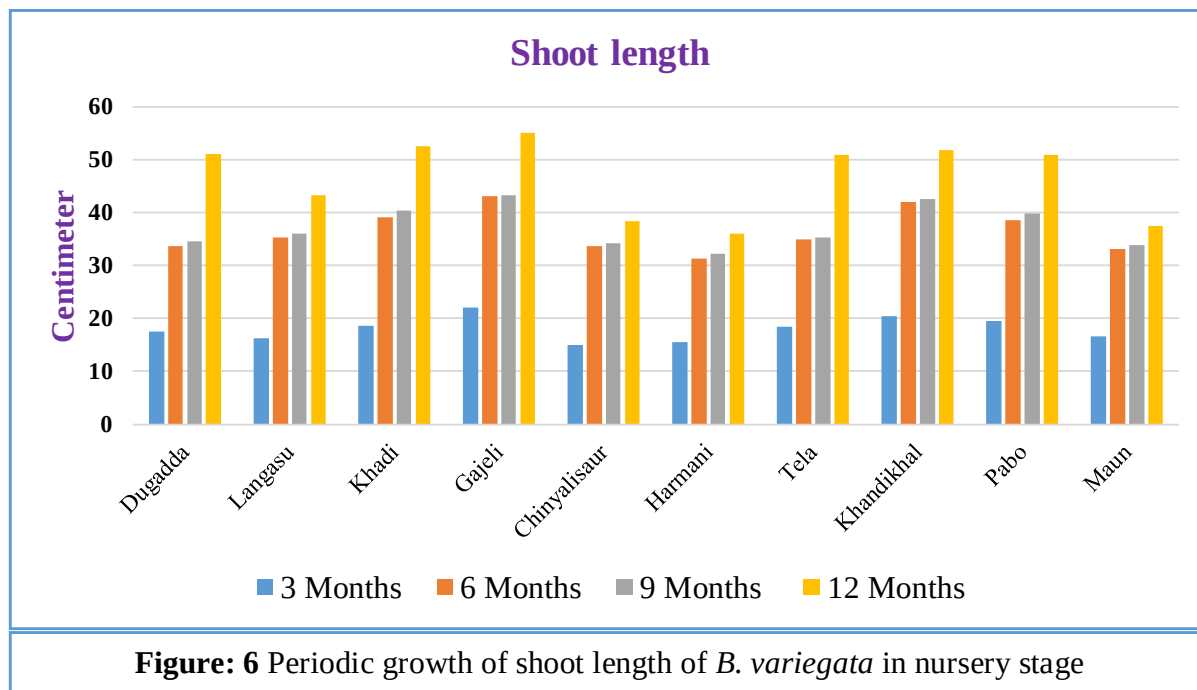
found maximum in middle altitudinal seed sources. It has been amply demonstrated that, seeds of a single species when collected from different sources or from different altitudes, differ in viability, germination, growth and biomass performance (Isik, 1986; Todaria and Negi, 1995; Chauhan *et al.*, 1996). Similar kind of study had been conducted Dhanai (2002) in *A. chinensis* and Singh *et al.* (2006) in *Celtis australis*.

4.5 Growth performance of seedling at nursery stage of *B. variegata*

4.5.1 Shoot length of seedling (cm)

The data on periodic shoot length of seedling was depicted (Table 6; Figure 6). Significant ($p < 0.05$) variation have been recorded for shoot length of seedling among different seed sources. On average growth of shoot length recorded after 3 months of growth were recorded (17.96 ± 2.24 cm), irrespective of seed sources with highest at Gajeli (21.98 ± 1.26 cm) followed by Khandikhal (20.34 ± 0.76 cm), whereas lowest found at Chinyalisaur (14.90 ± 0.63 cm) respectively. In the initial 3 months of growth, shoot length raised from Langasu, Harmani and Chinyalisaur had comparatively lower growth than the growth performance of other seed sources. On average shoot length were observed at (36.46 ± 3.96 cm) after 6 month of growth, irrespective of seed sources with highest founded at Gajeli (43.02 ± 0.70 cm) and lowest observed at Harmani (31.38 ± 0.79 cm), respectively. The growth of shoot length between 6 to 9 months were comparatively low, as average shoot length were recorded 37.19 ± 3.95 cm, with highest observed at Khandikhal (42.48 ± 1.04 cm) and lowest recorded Harmani (32.12 ± 1.24 cm) respectively. Shoot length of all the seed sources reached to maximum length measured between 9 to 12 months of growth with average value of (46.72 ± 7.19 cm), irrespective of seed sources with highest recorded at Gajeli (55.02 ± 0.50 cm) and lowest observed at Harmani (36.02 ± 1.44 cm), respectively. Thus after one year of growth, shoot length of one seed source Gajeli exhibited the shoot length measured (> 55.0 cm) with highest (55.02 ± 0.50 cm); five seed sources (Khadi, Khandikhal, Dugadda, Pabo and Tela) had the shoot length recorded (> 50.0 cm). Similarly, one seed source Langasu showed that the average shoot length (> 40.0 cm). But the seed sources – Chinyalisaur, Maun and Harmani exhibited comparatively poor growth with average shoot length growth of (38.30 ± 1.52 , 37.42 ± 1.22 and 36.02 ± 1.44 cm), respectively. Coefficient of variation (CV %), which helps in comparing the variability for different periodic

months of shoot growth length exhibited that there was (53.49 %) difference between lowest and highest values for periodic growth of shoot length.



These variations in growth characteristics of different seed sources may be attributed to adaptation, because the seedlings from all the sources were raised under similar conditions (Singh and Pokhriyal, 2000). Snieszko and Stewart (1989) suggested that seed source variation in growth characteristics is essentially genetic in nature. Comparable findings were reported by Dhanai (2002) in *A. chinensis*; Singh (2003) in *Celtis australis*. Likewise, Saklani *et al.* (2011) in *Q. leucotricophora* significantly ($p < 0.05$) variations have been recorded for growth of seedling among seed sources. The average shoot length was 34.96 cm for one year old seedlings, irrespective of seed source.

4.5.2 Root length (cm)

The data on root length of one year old seedling growth was represented (Table 6). On average, root length ranged from $(16.65 \pm 0.94$ to 23.62 ± 1.05 cm) growth after one year old seedling, irrespective of seed sources with highest observed at Gajeli (23.62 ± 1.05 cm) and lowest at Harmani (16.65 ± 0.94 cm) seed source respectively. Root length of all the sources were reached to maximum length measured between 9 to 12 months of growth irrespective of seed sources. Thus after one year of growth, root length of one seed source Gajeli exhibited the shoot length recorded (> 23.0 cm); four seed sources (Pabo; Harmani; Khadi and Khandikhal)

had the root length recorded (> 20.0 cm); But five seed sources (Langasu; Chinyalisaur; Dugadda; Maun and Tela) exhibited comparatively poor growth as compare to other seed source respectively.

Related type of study conducted by Dhanai (2002) in *A. chinensis*; Singh (2003) in *Celtis australis*; Saklani *et al.* (2011) in *Q. leucotricophora* significantly ($p < 0.05$) variations have been recorded for root of seedling among seed sources.

4.5.3 Total length (cm)

The data on total length of one year old seedling growth was represent (Table 6). Significant ($p < 0.05$) variation have been recorded for total length of seedling among different seed sources. On average, root length were ranged from 78.64 to 56.74 cm growth after one year old seedling, irrespective of seed sources with highest were observed at Gajeli (78.64 cm) and lowest at Harmani (56.74 cm) seed source respectively. Thus after one year of growth, total length of one year old seedling of Gajeli exhibited the shoot length measured (> 75.0 cm); five seed sources (Khandikhal; Khadi; Pabo; Tela and Dugadda) had the total length recorded (> 70.0 cm), but four seed sources (Langasu; Chinyalisaur; Maun and Harmani) exhibited comparatively poor growth as compare to other seed source respectively.

Coefficient of variation (CV %), which helps in comparing the variability for different total length of seedling exhibited that there were (95.72 %) difference between lowest and highest values for total seedling length and shoot length. Total length of seedling among seed sources was found significant at 1% and 5% level and non-significant correlations along with altitude (-0.13 %) respectively, irrespective of seed sources.

In this study different seedling traits and other traits like shoot length, root length and total seedling length showed great variation among and within seed sources, however any single character could not perfectly differ within entire sources. Therefore, all these characters should be considered as important traits for the selection because seedlings of seed lots selected on the basis of one character alone may sometime not give the desired level of superiority. Seed source selection should be made on the basis of multi traits consideration as reported Ginwal *et al.* (1996) and Vakshasya *et al.* (1992).

Table 6 Periodic growth of shoot and root length (cm) (Mean $\pm$ S.D) of *B. variegata* at nursery stage

Seed source	Altitude (masl)	Shoot length after (cm)				Root length (cm)	Total length (cm)	Root/ shoot
		3 months (May-July)	6 months (Aug.-Oct.)	9 months (Nov.-Jan.)	12 months (Feb.-April)	after 12 months (May)	after 12 months	length ratio
Dugadda	668	17.60 $\pm$ 0.83 ^{de}	33.64 $\pm$ 1.60 ^{de}	34.56 $\pm$ 0.93 ^{cd}	51.14 $\pm$ 1.27 ^b	19.38 $\pm$ 1.84 ^{de}	70.52 ^c	0.38 $\pm$ 0.03 ^e
Langasu	815	16.18 $\pm$ 0.60 ^f	35.22 $\pm$ 1.40 ^c	35.92 $\pm$ 0.98 ^c	43.32 $\pm$ 2.64 ^c	16.65 $\pm$ 0.94 ^f	59.97 ^d	0.39 $\pm$ 0.04 ^e
Khadi	898	18.56 $\pm$ 1.76 ^{cd}	39.12 $\pm$ 0.40 ^b	40.28 $\pm$ 0.61 ^b	52.44 $\pm$ 1.03 ^b	21.26 $\pm$ 0.38 ^{bc}	73.70 ^b	0.41 $\pm$ 0.02 ^{de}
Gajeli	960	21.98 $\pm$ 1.26 ^a	43.02 $\pm$ 0.70 ^a	43.32 $\pm$ 0.78 ^a	55.02 $\pm$ 0.50 ^a	23.62 $\pm$ 1.05 ^a	78.64 ^a	0.43 $\pm$ 0.02 ^d
Chinyalisaur	1033	14.90 $\pm$ 0.63 ^g	33.70 $\pm$ 1.21 ^{de}	34.14 $\pm$ 1.07 ^d	38.30 $\pm$ 1.52 ^d	18.74 $\pm$ 1.65 ^e	57.04 ^e	0.49 $\pm$ 0.04 ^c
Harmani	1151	15.54 $\pm$ 0.53 ^{fg}	31.38 $\pm$ 0.79 ^f	32.12 $\pm$ 1.24 ^e	36.02 $\pm$ 1.44 ^e	20.72 $\pm$ 1.03 ^{bcd}	56.74 ^e	0.58 $\pm$ 0.03 ^a
Tela	1254	18.50 $\pm$ 1.08 ^{cd}	34.84 $\pm$ 1.75 ^{cd}	35.32 $\pm$ 1.74 ^{cd}	50.84 $\pm$ 1.53 ^b	19.90 $\pm$ 1.38 ^{cde}	70.74 ^c	0.39 $\pm$ 0.02 ^e
Khandikhal	1556	20.34 $\pm$ 0.76 ^b	41.98 $\pm$ 1.03 ^a	42.48 $\pm$ 1.04 ^a	51.82 $\pm$ 0.71 ^b	22.20 $\pm$ 0.83 ^{ab}	74.02 ^b	0.43 $\pm$ 0.01 ^d
Pabo	1620	19.42 $\pm$ 1.26 ^{bc}	38.52 $\pm$ 0.86 ^b	39.88 $\pm$ 1.95 ^b	50.92 $\pm$ 1.02 ^b	20.66 $\pm$ 1.02 ^{bcd}	71.58 ^{bc}	0.41 $\pm$ 0.02 ^{de}
Maun	1875	16.54 $\pm$ 1.13 ^{ef}	33.18 $\pm$ 1.40 ^e	33.84 $\pm$ 1.11 ^d	37.42 $\pm$ 1.22 ^e	19.72 $\pm$ 1.27 ^{cde}	57.14 ^e	0.53 $\pm$ 0.03 ^b
Mean		17.96	36.46	37.19	46.72	20.29	67.01	0.44
CV		5.44	3.21	3.22	2.91	5.93	3.04	6.18
‘r’		0.11 ^{NS}	0.06 ^{NS}	0.06 ^{NS}	-0.21 [*]	0.22 [*]	-0.13 ^{NS}	0.38 ^{**}

‘r’ represent correlation coefficient computed between altitude of seed source and seedling length including shoot length, root length and root/ shoot length ratio.

*Significant at P < 0.05, ** Significant at P < 0.01, NS = Non-Significant.

4.5.4 Root/ shoot length ratio

The data on root/shoot length ratio characteristics of 10 seed sources of *B. variegata* was showed (Table 6). Significant ($p < 0.05$) variation have been recorded for root/ shoot length ratio of seedling among different seed sources. On average, root/shoot length ratio ranged from (0.38 ± 0.03 to 0.58 ± 0.03 cm) among seed sources with average value of (0.44 ± 0.07 cm). The root/shoot dry weight ratio were highest value recorded at Harman (0.58 ± 0.03 cm), whereas lowest value recorded at Dugadda (0.38 ± 0.03 cm) seed source respectively. Coefficient of variation (CV %) which helps in comparing the variability for different characters exhibited that there were (95.95 %) difference between lowest and highest values for root/shoot length ratio and root length irrespective of seed sources. Root/ shoot length ratio of seedling among seed sources were found significant and positive correlations among altitude (0.38) respectively.

4.5.5 Collar diameter (mm)

Table 7 depicts the data on periodic growth of collar diameter. Significant ($p < 0.05$) variation have been recorded for collar diameter of seedling among different seed sources. Wide variation have been recorded among the populations for collar diameter at periodic intervals. The average collar diameter after 3 months growth were recorded (2.42 ± 0.15 mm) irrespective of seed sources with highest recorded at Gajeli (2.82 ± 0.08 mm) and lowest observed at Langasu (2.26 ± 0.11 mm), respectively. In initial 3 months growth, seedlings raised from Khadi, Dugadda and Langasu exhibited poor diameter growth, compared to other seed sources. On average, collar diameter were recorded (3.61 ± 0.19 mm) after 6 months, irrespective of seed source, with highest observed at Gajeli (3.90 ± 0.12 mm) and lowest founded at Harmani (3.24 ± 0.11 mm), respectively. The average collar diameter growth between six to nine months were recorded (3.73 ± 0.19 mm) with highest observed at Gajeli (4.08 ± 0.15 mm) and lowest (3.40 ± 0.07 mm) to Harmani, respectively. Seedlings from all the sources exhibited collar diameter growth between 9 to 12 months growths, with average value of (4.25 ± 0.34 mm), irrespective of seed source. Thus after one year of growth, seedlings of Gajeli source exhibited maximum (4.68 ± 0.23 mm) collar diameter growth, followed by Khandikhal (4.60 ± 0.23 mm). Seedlings raised from Harmani, however, showed lowest (3.72 ± 0.23 mm) collar diameter growth. Coefficient of variation (CV %), which helps in comparing the variability for different

periodic months of collar diameter exhibited that there were (56.94 %) difference between lowest and highest values for collar diameter of seedling (Figure 7).

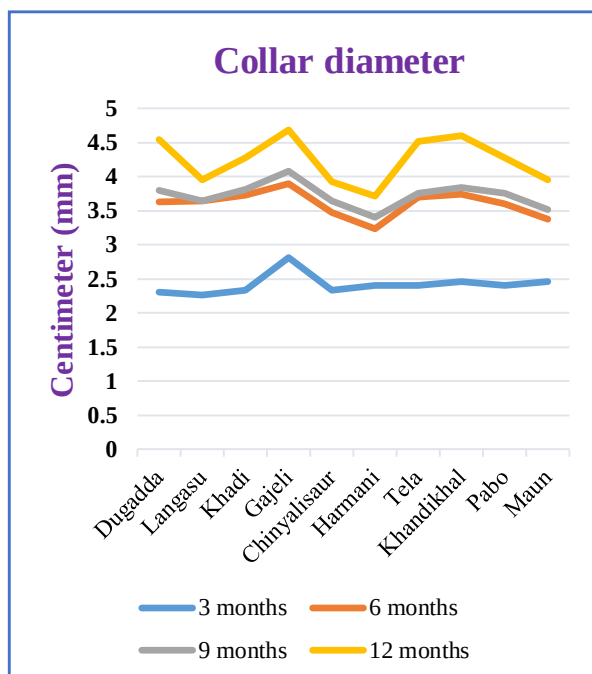


Figure: 7 Periodic growth of collar diameter (mm) of seedling

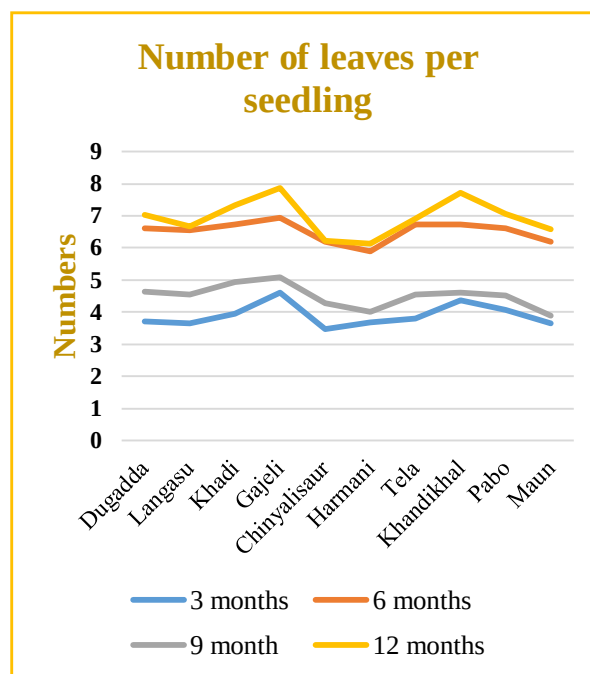


Figure: 8 Periodic number of leaves per seedling

4.5.6 Number of leaves per seedling

Table 8 represents the data on number of leaves per seedling at periodic intervals. Significant ($p < 0.05$) variation have been recorded for number of seedling per seedling among different seed sources. On average number of leaves per seedling after 3 month of growth were recorded 3.89 ± 0.36 , irrespective of seed sources with highest found at Gajeli (4.62 ± 0.13) and lowest were recorded at Chinyalisaur (3.46 ± 0.11), seed sources respectively. Seedlings raised from Maun, Langasu and Chinyalisaur had comparatively lesser number of leaves per seedling than those from other seed sources. On average number of leaves per seedling were (6.52 ± 0.33) after 6 months growth, irrespective of seed sources with highest recorded at Gajeli (6.94 ± 0.17) and lowest was found at Harmani (5.88 ± 0.22) seed sources respectively. The number of leaves per seedling during 6 to 9 months growth were comparatively decrease, as average leaves recorded (4.51 ± 0.37) with highest observed at Gajeli (5.08 ± 0.29) and lowest found at Maun (3.90 ± 0.45) seed sources respectively. The number of leaves per seedling were recorded after one year of growth in the seedlings of all the sources with average value (6.95 ± 0.58)

Table 7 Periodic growth of collar diameter (Mean $\pm$ S.D) of *B. variegata* at nursery stage

Seed source	Altitude (masl)	Collar diameter after (mm)			
		3 months (May-July)	6 months (Aug.-Oct.)	9 months (Nov.-Jan.)	12 months (Feb.-April)
Dugadda	668	2.31 $\pm$ 0.06 ^{bc}	3.63 $\pm$ 0.09 ^{bc}	3.80 $\pm$ 0.07 ^{bc}	4.54 $\pm$ 0.21 ^a
Langasu	815	2.26 $\pm$ 0.11 ^c	3.65 $\pm$ 0.03 ^{bc}	3.65 $\pm$ 0.03 ^{cd}	3.95 $\pm$ 0.02 ^c
Khadi	898	2.33 $\pm$ 0.10 ^{bc}	3.73 $\pm$ 0.05 ^{ab}	3.81 $\pm$ 0.07 ^{bc}	4.28 $\pm$ 0.29 ^b
Gajeli	960	2.82 $\pm$ 0.08 ^a	3.90 $\pm$ 0.12 ^a	4.08 $\pm$ 0.15 ^a	4.68 $\pm$ 0.23 ^a
Chinyalisaur	1033	2.34 $\pm$ 0.09 ^{bc}	3.48 $\pm$ 0.08 ^{cd}	3.65 $\pm$ 0.03 ^{cd}	3.92 $\pm$ 0.16 ^c
Harmani	1151	2.40 $\pm$ 0.10 ^{bc}	3.24 $\pm$ 0.11 ^e	3.40 $\pm$ 0.07 ^e	3.72 $\pm$ 0.23 ^c
Tela	1254	2.41 $\pm$ 0.07 ^{bc}	3.70 $\pm$ 0.12 ^b	3.76 $\pm$ 0.09 ^{bc}	4.52 $\pm$ 0.24 ^{ab}
Khandikhal	1556	2.46 $\pm$ 0.29 ^b	3.74 $\pm$ 0.23 ^{ab}	3.84 $\pm$ 0.17 ^b	4.60 $\pm$ 0.23 ^a
Pabo	1620	2.41 $\pm$ 0.14 ^{bc}	3.60 $\pm$ 0.20 ^{bc}	3.76 $\pm$ 0.11 ^{bc}	4.28 $\pm$ 0.29 ^b
Maun	1875	2.46 $\pm$ 0.18 ^b	3.38 $\pm$ 0.26 ^{de}	3.52 $\pm$ 0.22 ^{de}	3.96 $\pm$ 0.24 ^c
Mean		2.42	3.61	3.73	4.25
CV		5.66	4.28	3.27	4.49
‘r’		0.19 ^{NS}	-0.30*	-0.20*	-0.10 ^{NS}

‘r’ represent correlation coefficient computed between altitude of seed source and seedling length including shoot length, root length and root/ shoot length ratio.

*Significant at P < 0.05, ** Significant at P < 0.01.

Table 8 Periodic growth Number of leaves/ seedling (Mean $\pm$ S.D) of *B. variegata* at nursery stage

Seed source	Altitude (masl)	Number of leaves/ seedling			
		3 months (May-July)	6 months (Aug.-Oct.)	9 months (Nov.-Jan.)	12 months (Feb.-April)
Dugadda	668	3.70 $\pm$ 0.12 ^{def}	6.62 $\pm$ 0.18 ^b	4.64 $\pm$ 0.17 ^{abc}	7.02 $\pm$ 0.22 ^{cd}
Langasu	815	3.64 $\pm$ 0.22 ^{ef}	6.54 $\pm$ 0.26 ^b	4.56 $\pm$ 0.81 ^{bc}	6.68 $\pm$ 0.36 ^{de}
Khadi	898	3.94 $\pm$ 0.15 ^{cd}	6.74 $\pm$ 0.18 ^{ab}	4.94 $\pm$ 0.21 ^{ab}	7.34 $\pm$ 0.21 ^{bc}
Gajeli	960	4.62 $\pm$ 0.13 ^a	6.94 $\pm$ 0.17 ^a	5.08 $\pm$ 0.29 ^a	7.88 $\pm$ 0.20 ^a
Chinyalisaur	1033	3.46 $\pm$ 0.11 ^f	6.20 $\pm$ 0.12 ^c	4.28 $\pm$ 0.65 ^{cd}	6.22 $\pm$ 0.33 ^{fg}
Harmani	1151	3.68 $\pm$ 0.08 ^{ef}	5.88 $\pm$ 0.22 ^d	4.00 $\pm$ 0.48 ^d	6.12 $\pm$ 0.25 ^g
Tela	1254	3.80 $\pm$ 0.25 ^{de}	6.74 $\pm$ 0.19 ^{ab}	4.54 $\pm$ 0.11 ^{bc}	6.92 $\pm$ 0.30 ^{de}
Khandikhal	1556	4.36 $\pm$ 0.30 ^b	6.74 $\pm$ 0.26 ^{ab}	4.60 $\pm$ 0.43 ^{bc}	7.72 $\pm$ 0.29 ^{ab}
Pabo	1620	4.08 $\pm$ 0.29 ^c	6.62 $\pm$ 0.24 ^b	4.52 $\pm$ 0.24 ^{bc}	7.06 $\pm$ 0.30 ^{cd}
Maun	1875	3.64 $\pm$ 0.21 ^{ef}	6.18 $\pm$ 0.41 ^c	3.90 $\pm$ 0.45 ^d	6.58 $\pm$ 0.49 ^{ef}
Mean		3.89	6.52	4.51	6.95
CV		5.02	3.43	8.10	4.38
‘r’		0.13 ^{NS}	-0.12 ^{NS}	-0.15 ^{NS}	-0.02 ^{NS}

‘r’ represent correlation coefficient computed between altitude of seed source and number of leaves/ seedling.

*Significant at P < 0.05, ** Significant at P < 0.01; NS = Non-significant

irrespective of seed sources. Thus after one year of growth, seedlings of Gajeli source exhibited maximum (7.88 ± 0.20) leaves per seedling. Seedlings raised from Harmani, however, lowest recorded (6.12 ± 0.25) number of leaves per seedlings (Figure 8).

Coefficient of variation (CV %), which helps in comparing the variability for different number of leaves/ seedling, periodic months exhibited that there was (55.97 %) difference between lowest and highest values for number of leaves per seedling.

During the course of present investigation, the seedling growth was comparatively higher and it may be attributed to the fact that, seeds were harvested from promising ideotypes which resulted into high seedling vigour. Several studies have been carried out to sources in different species in Garhwal Himalaya viz., *Terminalia tomentosa*, *T. bellerica* and *T. chebula* (Chauhan *et al.*, 2007), *Grewia optiva* (Uniyal *et al.*, 2002), *Albizia chenensis* (Dhanai *et al.*, 2003), *Celtis australis* (Singh and Bhatt, 2008) and the present finding was in conformity with the finding of these earlier workers.

4.6 Biomass of seedling traits on dry weight basis (g)

The data on shoot, leaves, root, root/ shoot ratio biomass production (dry weight basis) of one-year- old seedlings grown from different seed sources showed (Table 9). Significant ($p < 0.05$) variation have been recorded for dry weight of seedling among different seed sources. Among various components of seedlings, shoot partitioned highest biomass (58.82 %), followed by roots (45.24 %) and leaves (38.47 %) accordingly, irrespective of seed sources. On average value of shoot dry weight were recorded (2.84 ± 0.36 g/plant) with highest at Khadi (3.34 ± 0.47 g/plant) followed by Khandikhal (3.34 ± 0.47 g/plant), whereas lowest was recorded at Maun (2.12 ± 0.10 g/plant) respectively. Similarly the average leaves dry weight were recorded (1.79 ± 0.20 g/plant) irrespective of seed sources, with highest dry weight was recorded at Khadi (2.10 ± 0.52 g/plant) followed by Gajeli (1.93 ± 0.55 g/plant), whereas lowest dry weight found at Khandikhal (1.46 ± 0.42 g/plant) respectively. On average, root dry weight ranged from (1.35 ± 0.20 to 2.70 ± 1.05 g/plant), among seed sources with average value observed (1.94 ± 0.40 g/plant). The root dry weight was recorded highest at Khandikhal (2.70 ± 1.05 g/plant) followed by Khadi (2.20 ± 0.37 g/plant), whereas lowest root dry weight found at Tela (1.35 ± 0.20 g/plant) seed sources respectively.

Table 9 Biomass attributes (dry weight basis) (g/plant $\pm$ S.D.) of *B. variegata* at nursery stage

Seed sources	Altitude (masl)	Biomass (g)				
		Shoot dry weight (g)	Leaves dry weight (g)	Root dry weight (g)	Root/ shoot dry weight (g)	Total dry weight (g)
Dugadda	668	2.98 $\pm$ 0.62 ^{abc}	1.85 $\pm$ 0.45 ^{NS}	2.11 $\pm$ 0.30 ^{bc}	0.74 $\pm$ 0.23 ^{NS}	6.94 $\pm$ 0.73 ^{ab}
Langasu	815	2.64 $\pm$ 0.26 ^c	1.81 $\pm$ 0.34 ^{NS}	1.85 $\pm$ 0.23 ^{bcd}	0.71 $\pm$ 0.15 ^{NS}	6.29 $\pm$ 0.37 ^{bc}
Khadi	898	3.34 $\pm$ 0.47 ^a	2.10 $\pm$ 0.52 ^{NS}	2.20 $\pm$ 0.37 ^b	0.67 $\pm$ 0.18 ^{NS}	7.64 $\pm$ 0.79 ^a
Gajeli	960	3.10 $\pm$ 0.52 ^{ab}	1.93 $\pm$ 0.55 ^{NS}	2.07 $\pm$ 0.33 ^{bc}	0.69 $\pm$ 0.20 ^{NS}	7.10 $\pm$ 0.76 ^{ab}
Chinyalisaur	1033	2.58 $\pm$ 0.28 ^c	1.89 $\pm$ 0.45 ^{NS}	1.71 $\pm$ 0.30 ^{cde}	0.68 $\pm$ 0.17 ^{NS}	6.17 $\pm$ 0.46 ^{bc}
Harmani	1151	2.86 $\pm$ 0.59 ^{bc}	1.77 $\pm$ 0.34 ^{NS}	1.79 $\pm$ 0.31 ^{bcd}	0.66 $\pm$ 0.22 ^{NS}	6.41 $\pm$ 0.63 ^{bc}
Tela	1254	2.62 $\pm$ 0.32 ^c	1.67 $\pm$ 0.43 ^{NS}	1.47 $\pm$ 0.20 ^{de}	0.57 $\pm$ 0.10 ^{NS}	5.75 $\pm$ 0.62 ^{cd}
Khandikhal	1556	3.27 $\pm$ 0.47 ^{ab}	1.46 $\pm$ 0.42 ^{NS}	2.70 $\pm$ 1.05 ^a	0.84 $\pm$ 0.32 ^{NS}	7.43 $\pm$ 1.50 ^a
Pabo	1620	2.84 $\pm$ 0.49 ^{bc}	1.90 $\pm$ 0.44 ^{NS}	2.19 $\pm$ 0.36 ^b	0.80 $\pm$ 0.24 ^{NS}	6.92 $\pm$ 0.70 ^{ab}
Maun	1875	2.12 $\pm$ 0.10 ^d	1.51 $\pm$ 0.51 ^{NS}	1.35 $\pm$ 0.20 ^e	0.64 $\pm$ 0.11 ^{NS}	4.98 $\pm$ 0.51 ^d
Mean		2.84	1.79	1.94	0.70	6.56
CV		12.23	24.91	18.53	19.91	11.17
‘r’		-0.40 ^{**}	-0.66 ^{**}	-0.12 ^{NS}	-0.40 ^{**}	0.13 ^{NS}

‘r’ represent correlation coefficient computed between altitude of seed source and seedling dry weight including shoot, leaves, root and root/ shoot dry weight ratio .

*Significant at P < 0.05, ** Significant at P < 0.01, NS = Non-significant.

Likewise, also recorded root/ shoot dry weight ratio ranged from (0.57 ± 0.10 to 0.84 ± 0.32 g/plant), among seed sources with average value observed (0.70 ± 0.08 g/plant) respectively. The root/ shoot dry weight ratio was recorded highest at Khandikhal (0.84 ± 0.32 g/plant) followed by Pabo (0.80 ± 0.24 g/plant), whereas lowest dry weight recorded at Tela (0.57 ± 0.10 g/plant). Total dry weight of seedlings exhibited average value estimated (6.56 ± 0.81 g/plant) with highest dry weight recorded at Khadi (7.64 ± 0.79 g/plant) followed by Khandikhal (7.43 ± 1.50 g/plant), whereas lowest total dry weight found at Maun (4.98 ± 0.51 g/plant), seed source respectively. Coefficient of variation (CV %), which helps in comparing the variability for different seedling dry weight viz., shoot, leaves, root, root/ shoot ratio and total dry weight exhibited that there were (12.23, 24.91, 18.53, 19.91 and 11.17 %) difference between lowest and highest values. Dry weight of seedling among seed sources were found (shoot, leaves and root/ shoot dry weight ration) significant and inverse correlation among altitude respectively.

Parallel, finding revealed Dhanai (2002) in *A. chinensis*; Singh (2004) in *Celtis australis*. The above results support the findings Hosalli (1997) in *Leucaena* species; Manga and Sen (1998) in *Prosopis cineraria*; Jha (2001) in *Dalbergia sissoo*. Saklani *et al.* (2011) in *Q. leucotricophora* significantly ($p < 0.05$) variations have been recorded for biomass allocation of seedlings among seed sources. On average shoot partitioned the highest biomass followed by root and lowest leaves dry weight shoot irrespectively of seed source.

4.7 Correlation coefficient for various characteristic of *B. variegata*

Correlation coefficient (Karl Pearson's) for 19 parameters of pod-seed morphology, germination, growth and dry weight characteristics in nursery was presented (Table 10). Significant positive relationship ($p < 0.01$) was recorded for all seed traits and growth parameters such as pod length- pod breadth, no. of seed/ pod, seed length, seed breadth, seed thickness, seed length/ breadth ratio, seed weight, seed moisture content, germination percent, shoot length, collar diameter, no. of leaves, root length, root/ shoot length ratio, shoot dry weight, root dry weight, root/ shoot dry weight ratio except seed length - root dry weight, seed breadth - root dry weight, seed thickness- leaves dry weight, seed moisture-root dry weight, germination percent-leaves dry weight, collar diameter-leaves dry weight, root/ shoot ratio-root/ shoot dry weight, root dry weight-root/ shoot dry weight ratio. Significant ($p < 0.05$) positive correlations were recorded between seed breadth-seed thickness, seed thickness- root

Table 10 Correlation coefficient between various pod, seed and seedling characteristics of *B. variegata*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	0.95**																	
3	0.74**	0.64**																
4	0.80**	0.66**	0.83**															
5	0.64**	0.48**	0.59**	0.86**														
6	0.59**	0.52**	0.36**	0.46**	0.32*													
7	0.72**	0.63**	0.84**	0.79**	0.38**	0.49**												
8	0.88**	0.75**	0.83**	0.83**	0.62**	0.52**	0.80**											
9	0.81**	0.69**	0.49**	0.64**	0.48**	0.86**	0.63**	0.78**										
10	0.44**	0.26*	0.48**	0.44**	0.29*	0.36**	0.52**	0.74**	0.57**									
11	0.89**	0.75**	0.77**	0.81**	0.58**	0.58**	0.81**	0.96**	0.86**	0.73**								
12	0.68**	0.48**	0.69**	0.74**	0.53**	0.58**	0.75**	0.85**	0.82**	0.73**	0.92**							
13	0.76**	0.59**	0.78**	0.78**	0.62**	0.66**	0.72**	0.86**	0.79**	0.79**	0.90**	0.88**						
14	0.49**	0.34*	0.37**	0.47**	0.40**	0.49**	0.36**	0.36**	0.53**	0.35**	0.52**	0.57**	0.69**					
15	-0.68**	-0.62**	-0.66**	-0.62**	-0.38**	-0.37**	-0.72**	-0.88**	-0.64**	-0.62**	-0.80**	-0.69**	-0.59**	0.08				
16	0.70**	0.56**	0.67**	0.76**	0.65**	0.12	0.59**	0.71**	0.39**	0.53**	0.69**	0.54**	0.67**	0.59**	-0.38**			
17	0.46**	0.62**	0.42**	0.18	-0.09	-0.20	0.41**	0.28*	-0.02	-0.07	0.27*	-0.01	0.06	0.03	-0.27*	0.40**		
18	0.62**	0.47**	0.64**	0.86**	0.76**	0.30*	0.65**	0.66**	0.43**	0.50**	0.61**	0.51**	0.67**	0.47**	-0.39**	0.86**	0.12	
19	0.35**	0.25*	0.39**	0.69**	0.58**	0.33*	0.54**	0.38**	0.29*	0.26*	0.33*	0.28*	0.42**	0.20	-0.25	0.48**	-0.09	0.85**

Key to abbreviation: 1. Pod length; 2. Pod breadth; 3. No. of seed/ pod; 4. Seed length; 5. Seed breadth; 6. Seed thickness; 7. Seed length/ breadth ratio; 8. Seed weight; 9. Seed moisture %; 10 germination; 11. Shoot length; 12. Collar diameter; 13. No. of leaves; 14. Root length; 15. Root/ shoot length ratio; 16. Shoot dry weight; 17. Leaves dry weight; 18. Root dry weight; 19. Root/ shoot dry weight ratio.

*Significant at $p < 0.05$, ** significant at $p < 0.01$.

dry weight, seed thickness- root shoot dry weight ratio, seed weight-leaves dry weight, seed moisture-root shoot dry weight ratio, germination- root shoot dry weight ratio, GI- root shoot dry weight ratio, shoot length- root shoot dry weight ratio, collar diameter- root shoot dry weight ratio. Similar finding revealed correlation coefficient Dhanai (2003) in *Albizia chinensis*. Out of 171 correlation coefficient 159 were found significant at ($p < 0.01$ and $p < 0.05$ level of probabilities. These relationships were expected because of inter dependence of all the combination. Singh *et al.* (2008) also found similarly trends of relationship in *Dalbergia sissoo*.

4.8 Genetic and phenotypic variability for seedlings survival and growth traits in nursery

Significant variations were observed among seed sources with respect to pod size, seed size, seedling growth and biomass characteristics transited data were used for computing variability estimates and genetic studies of different characters. Variability was estimated in term of coefficient of variation, analysis of variance (phenotypic, genotypic, and environmental) along with co-efficient of phenotypic, genotypic and environmental variation. Genetic parameters were also worked out with regard to estimates of heritability (broad sense), genetic advance (at five percent selection intensity) and genetic gain (genetic advance as percent of mean). The results obtained for variability and genetic parameters was described herewith.

Variability estimates for seedling survival in nursery and growth attributes of different seed source of *B. variegata* has been shown in (Table 11). It have been recorded that among various growth traits and seedling survival, maximum genotypic (68.96) and phenotypic variance (70.41) were recorded for total seedling length and environmental variability (1.84) for shoot length followed by shoot length (51.32), shoot length (53.16) and root length and total seedling length (1.45) accordingly. Whereas minimum values for genotypic variation of leaves dry weight (0.01), phenotypic variation of root/ shoot length ratio (0.01) and environmental variation for root/ shoot length ratio respectively. Root dry weight exhibited highest values for genotypic (20.20), phenotypic (26.28) and environmental (24.98) coefficient of variability for leaves dry weight followed accordingly by root dry weight (18.59), leaves dry weight (24.35) and leaves dry weight (24.98) respectively, while leaves dry weight had lowest values for genotypic (0.56), phenotypic (4.55) for root/ shoot length ratio and environmental variability for shoot length (2.90).

Table 11 Estimation of variance and coefficient of variance for various seedling growth attributes of *B. variegata*

Characters	Variance			Coefficient of variance			Broad sense heritability (%)	Genetic advance (%)	Genetic gain (%)
	Genotypic	Phenotypic	Environmental	Genotypic	Phenotypic	Environmental			
Survival (%)	0.12	0.51	0.39	2.72	5.61	4.90	23.53	34.62	2.72
Shoot length (cm)	51.32	53.16	1.84	15.33	15.60	2.90	96.53	198.85	4.26
Root length (cm)	3.37	4.82	1.45	9.04	10.82	5.93	69.91	316.18	15.58
Total seedling length (cm)	68.96	70.41	1.45	12.40	12.52	1.80	97.94	1692.95	25.26
Collar diameter (mm)	0.11	0.15	0.04	7.80	9.11	4.70	73.33	58.50	13.76
No. of leaves/seedling	0.32	0.41	0.09	8.14	9.21	4.32	78.04	102.94	14.81
Shoot dry weight (g)	0.11	0.23	0.12	11.68	16.89	12.20	47.83	47.25	16.64
Leaves dry weight (g)	0.01	0.19	0.20	0.56	24.35	24.98	5.26	4.72	2.64
Root dry weight (g)	0.13	0.26	0.13	18.59	26.28	18.58	50	52.51	13.15
R/S length ratio	0.02	0.01	0.01	4.55	4.55	22.72	99.80	29.13	66.20
R/S dry weight ratio	0.01	0.02	0.01	20.20	19.98	20.20	99.96	29.13	41.61

On the other hand broad sense heritability was calculated highest (99.96 %) for root/shoot dry weight ratio, followed by root/shoot length ratio (99.80) and least survival (23.53 %) followed by leaves dry weight (5.26 g). While genetic advance ranged from (1692 % to 4.72 %) in total seedling length and leaves dry weight of seedlings respectively. As far as genetic gain is concerned it was found maximum (66.20 %) in root/shoot length ratio and minimum (2.64 %) in leaves dry weight.

These estimates indicate that total seedling length, shoot length, root dry weight and, leaf dry weight were more controlled by site and environmental parameters. The information on the nature and magnitude of variability and correlation in a population owing to genetic and non-genetic factor was one of the prerequisites in any hybridization programme for selecting parents with desirable characters (Majumder *et al.*, 2012). According to Falconer (1989), the study of correlation was required to obtain the response of various traits to the characters interesting for selection. Based on the estimation of genotypic and phenotypic correlations the breeder decides the breeding methodology to be followed so that the useful correlations can be exploited and the undesirable ones modified by generating fresh variability to obtain new recombinants.

Thus it has been observed that total seedling length was strongly governed by genotypic variance. Genetic advance was also highest in total seed length as compared to other seed traits. Hence total seedling length could be considered a best trait for selection of superior genotype of *B. variegata*. Seedling growth, however, exhibited highest genetic gain in root/shoot length, followed by root/shoot dry weight ratio and total seedling length.

Although heritability in broad sense may give useful indication about the relative value of selection in the material at hand to arrive at a more reliable conclusion, heritability and expected genetic gain should be considered jointly. Volker *et al.* (1990) has shown that heritability estimates along with genetic gain was more useful than the heritability alone in predicting the resultant effect for selecting the best genotypes for given trait. Higher heritability values accompanied by high genetic gain have earlier been reported for seed weight in *Grewia optiva* (Uniyal, 1998) and *Celtis australis* (Singh, 2004). Variation in seed and seedling traits among and within sources suggest that selection among sources might result in rapid genetic gain for the traits (Dhillon and Khajuria, 1995). Related finding revealed Dhanai (2002) in

Albizia chinensis; Singh (2004) in *Celtis australis*, and Rawat and Bakshi (2011) in *Pinus wallichiana*. Latest study was conducted Anand and Dwivedi (2014) in *Bauhinia variegata* a strong simple, genotypic and phenotypic correlation was observed between biomass traits and some morphological traits especially collar diameter, plant height and leaf area. The phenotypic correlation coefficients were lower than their corresponding genotypic values, which revealed that magnitude of correlation coefficient at genotypic level was higher than their corresponding phenotypic coefficient of correlations. Present study indicates that collar diameter, plant height and leaf area was the common causal factor that influences biomass productivity of *Bauhinia variegata* genotypes.

SUMMARY AND CONCLUSION

The present investigation entitled “**Seed source variation in pod, seed and seedling characteristics of *Bauhinia variegata* Linn. from Garhwal Himalaya, Uttarakhand**”, covers the following aspects:

On basis of following three broad objectives:

1. Variation in pod and seed morphological characteristics of *B. variegata*.
2. To study the variation in seed germination of *B. variegata* at nursery condition.
3. Variation in growth performance and biomass yield of seedlings, raised from different seed sources.

The experiment site College of Forestry, V.C.S.G. Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal, is located at 10 km away from Chamba (Rishikesh–Gangotri Road) at an altitude of about 2100 meter above mean sea level, lying between 30° 15' N latitude and 78° 30' E longitudes under mid hills of Uttarakhand, India. The field parameter was carried out in the experimental block of nursery at College of Forestry, Ranichauri.

The experiments were carried out in the College of Forestry V.C.S.G. Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal, during June 2015 to May 2016. Climatically different and geographically isolated 10 seed sources, representing the entire range of natural distribution of *B. variegata* were sampled to conduct experiments on seed and seedling characters. In all, Pods were collected from three different sources of Pauri Garhwal; three from Tehri Garhwal, two from Chamoli, one from Rudraprayag and one from Uttarkashi, Uttarakhand. In natural stands of each of the seed sources, 5 representative candidate plus trees (CPT's) were selected for pod collection in order to observe variation in pod, seed, seed germination, seedling growth, survival and biomass yield under nursery condition. Some major findings are discussed here with:

1. Pods and seed characteristics

Significant ($p < 0.05$) variations have been observed for pod traits. However, among various characters, pod length exhibited maximum variation between seed source as compared to other morphological characters. On average, Khadi seed source exhibited the highest pod length (22.38 ± 1.01 cm) and Harmani the lowest (16.72 ± 0.72 cm), with average value (19.26 ± 1.97 cm). Significant ($p < 0.05$) negative correlation was found between morphological characters of pods including pod length, pod breadth and pod thickness with altitude range of seed source (-0.10, -0.11 and -0.10 %) respectively. Whereas, there was significant ($p < 0.05$) inverse correlation were found between number of seeds/ pod and altitude of seed source respectively.

- Significant ($p < 0.05$) variations have been observed for seed traits. However, among various characters, seed weight exhibited maximum variation between seed sources as compared to other morphological characters. On average, Khadi seed source exhibited the highest (50.70 ± 1.47 g/100 seeds) and Harmani the lowest (33.72 ± 1.05 g/100 seed) seed weight respectively, with average value (44.21 ± 6.18 g/100 seeds). Significant ($p < 0.01$ and $P < 0.05$) positive correlation was found between morphological characters of seeds including seed thickness and seed moisture content (0.59 and 0.27) with altitude of seed source. Whereas, there was significant ($p < 0.05$) inverse correlation between altitudes of seed source including seed length/ breadth ratio and seed weight.

2. Seed germination characteristics

- There were strong seed source variation recorded in seed germination. Non-significant ($p < 0.05$) variations have been observed for seed germination traits. Further, seed germination was highest recorded at Gajeli (86 %) and lowest at Chinyalisaur (77 %) irrespective of seed source. On average, Gajeli seed source exhibited the highest (86 ± 4.18 %) and Chinyalisaur have been lowest (77 ± 9.75 %) seed germination respectively, with average value (81.50 ± 3.03 %). Significant ($p < 0.05$) inverse correlation was found between seed germination (-0.28) with altitude of seed source indicating that with increasing elevational range of seed source the germination percent decreased.

- Significant ($p < 0.05$) variation were also observed for mean germination time (MGT) among seed sources. However, mean germination time was recorded highest (12.30 days) at Harmani, followed by (12.07 days) at Pabo. Whereas, mean germination time exhibited minimum value (11.41 days) at Dugadda, irrespective of seed sources. Significant ($p < 0.05$) positive correlation was recorded among seed sources (0.29) respectively.
- Non-significant ($p < 0.05$) variation were also observed for germination index (GI) among seed sources. However, germination index was recorded highest (0.31 ± 0.03) at Khadi, followed by (0.31 ± 0.03) at Gajeli. Whereas, germination index exhibited minimum value (0.27 ± 0.03) at Harmani with average value (0.30 ± 0.01), irrespective of seed sources. Significant ($P < 0.05$) inverse correlation was recorded among seed sources (0.29) respectively.
- Non-significant ($p < 0.05$) variation were also observed for seedling vigour index (SVI) among seed sources. However, seedling vigour index was recorded highest (6760.40 ± 264.91) at Gajeli, followed by (6286.10 ± 256.30), at Khandikhal. Whereas, seedling vigour index exhibited minimum value (4382.93 ± 486.65) at Chinyalisaur with average value (5475.63 ± 835.06), irrespective of seed sources. Non-significant ($p < 0.05$) inverse correlation was recorded among seed sources respectively.

3. Seedling growth characteristics

- Growth performance of *B. variegata* seedlings was measured till one year in the nursery. Significant ($p < 0.05$) variations have been observed for all seedling growth characteristics of *B. variegata*. Average shoot and root growth was 46.72 and 20.29 cm, respectively, irrespective of seed source variation. However, among various seed source, Gajeli, Khandikhal, Khadi, Pabo, Tela and Dugadda source exhibited the total growth length > 70 cm within a year. On average, Gajeli seedling growth exhibited the highest (78.64 cm) followed by Khandikhal (74.02 cm) and Harmani the lowest (56.74 cm) seedling growth respectively. Similar, root/ shoot length ratio have been maximum recorded at Harmani (0.58 ± 0.03) followed by (0.53 ± 0.03), whereas minimum root/ shoot length ratio found at Maun and Tela (0.39 ± 0.04) respectively seed source. Significant ($p < 0.05$) positive

correlation was found between growth performance of root/ shoot length ratio and altitudes of seed source respectively.

- Significant variations ($p < 0.05$) have been recorded for periodic growth of collar diameter among seed sources. On average, collar diameter of seedling was highest value recorded at Gajeli (4.68 ± 0.23 mm), whereas lowest value recorded at Harmani (3.72 ± 0.23 mm) respectively with average value (4.25 mm). Significant ($P < 0.05$) inverse correlation was also noticed for collar diameter growth performance with altitude of the seed source respectively.
- Significant variations ($p < 0.05$) have been recorded for periodic growth of number of leaves/ seedling among seed sources. On average, number of leaves/ seedling was highest value recorded at Gajeli (7.88 ± 0.20), whereas lowest value recorded at Harmani (6.12 ± 0.25) respectively with average value (6.95) number of leaves/ seedling respectively. Non-significant ($p < 0.05$) inverse correlation was also noticed for number of leaves/ seedling growth performance with altitude of the seed source.

4. Biomass attributes (dry weight basis)

- Significant ($p < 0.05$) seed source variation was recorded for seedling weight. On average, shoot partitioned highest (58.82 %) biomass, followed by root (45.24 %) and leaves (38.47 %), accordingly, irrespective of seed sources. However, among various sources Khadi, Khandikhal, Gajeli, Dugadda and Pabo produced heavier seedlings weight compared to seedlings of other sources. Seedlings weight exhibited average value of (6.56 ± 0.81 g/plant) after one year of growth with highest recorded at Pabo (7.64 ± 0.79 g/plant) and lowest at Maun (4.98 ± 0.51 g/plant) respectively of seed sources.
- Among various characters survival, seedling traits, seed dry weight (g) and shoot length (cm) was found to be influenced strongly by genetic influences as compared to other characters. Among various seedling parameters, shoot length (cm), total dry weight (g), root/ shoot dry weight (g) and root/ shoot length exhibited high heritability, genetic advance and genetic gain, indicating that these characteristics are most suitable for selecting the plant material for further planting stock improvement in *B. variegata*. Thus, these seed source

could be selected for mass multiplication of this potential tree-crop in Garhwal Himalayan agro ecosystems.

B. variegata is a multipurpose leguminous tree species growing over wide range of geo-climatic conditions throughout India. This study identifies for best sources based upon seed and seedling traits for those places of Gajeli, Khandikhal, Khadi and Dugadda which were sampled. On a short term basis, breeding zones may be set up in these environmentally homogeneous areas. However, this may be preliminary as only seedling traits have been considered. Hence, seed source screening provides a great opportunity to the tree breeder to screen and capture natural variation for success.

In order to meet the exigency of leaf fodders, it is imperative to plant multipurpose trees with high nutritive value on the wasteland and fallow land or to integrate with agricultural and fruit crops under agroforestry systems. One of the important fodder species on which farmers bank up during the winter lean period when the grasses are dry, less digestible and unpalatable. The aim of this investigation was to measure the variability of seed and seedling morphological characteristics and germination in *B. variegata* seeds from throughout the natural range, in order to understand the extent and pattern of variation with respect to seed, seedling characters germination and biomass. Such an investigation may help in selection of most suitable seed source for a given site for conservation, breeding and improvement in this species. The tree exhibits considerable phenotypic variability across its diverse natural range which may indicate high genetic variability that might be exploited for genetic improvement. Thus the result of present study should be helpful for growing quality planting material of this potential tree species in afforestation and reforestation of tropical to subtropical region of Garhwal Himalaya.

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Appendix 1

Appendix -1: Analysis of variance (ANOVA) for pods traits allocation of *Bauhinia variegata*

Source of variation	DF	Pod length (cm)	Pod breadth (cm)	Pod thickness (cm)	Pod length/breadth ratio	No. of seeds/ pod
Treatment	9	34.78*	17.27 ^{NS}	39.76**	1.85 ^{NS}	2.85 ^{NS}
Replication	4	0.20 ^{NS}	1.60 ^{NS}	0.23 ^{NS}	0.80 ^{NS}	1.10 ^{NS}

*Significant at $P < 0.05$, **Significant at $P < 0.01$, NS= Non-significant.

Appendix -2: Analysis of variance (ANOVA) for seeds traits allocation of *Bauhinia variegata*

Source of variation	DF	Seed length (cm)	Seed breadth (cm)	Seed thickness (cm)	Seed length/breadth ratio	Seed weight (g/100 seeds)	Seed moisture content %
Treatment	9	35.99**	17.27 ^{NS}	4.00 ^{NS}	16.04 ^{NS}	145.32**	12.13 ^{NS}
Replication	4	3.15 ^{NS}	1.60 ^{NS}	1.25 ^{NS}	3.97 ^{NS}	1.04 ^{NS}	4.46 ^{NS}

*Significant at $P < 0.05$, **Significant at $P < 0.01$, NS= Non-significant.

Appendix -3: Analysis of variance (ANOVA) for seed germination traits allocation of *Bauhinia variegata*

Source of variation	DF	Germination %	MGT	GI	SVI
Treatment	9	1.17 ^{NS}	1.37 ^{NS}	1.06 ^{NS}	27.76*
Replication	4	11.75 ^{NS}	0.69 ^{NS}	0.26 ^{NS}	3.89 ^{NS}

*Significant at $P < 0.05$, **Significant at $P < 0.01$, NS= Non-significant.

Appendix -4: Analysis of variance (ANOVA) for seedling traits allocation of *Bauhinia variegata*

Source of variation	DF	Shoot length (cm)	Collar diameter (mm)	Number of leaves per seedling	Root length (cm)	Total length (cm)	Root/ shoot length ratio
Treatments	9	140.25**	15.60 ^{NS}	18.30 ^{NS}	12.64 ^{NS}	84.06*	30.27**
Replications	4	1.66 ^{NS}	5.01 ^{NS}	1.04 ^{NS}	1.45 ^{NS}	0.16 ^{NS}	3.72 ^{NS}

*Significant at $P < 0.05$, **Significant at $P < 0.01$, NS= Non-significant.

Appendix -5: Analysis of variance (ANOVA) for dry weight (biomass) traits allocation of *Bauhinia variegata*

*Significant at $P < 0.05$, **Significant at $P < 0.01$, NS= Non-significant.

Source of variation	DF	Shoot dry weight (g)	Leaves dry weight (g)	Root dry weight (g)	Root/ shoot dry weight ratio	Total dry weight (g)
Treatments	9	5.52 ^{NS}	0.97 ^{NS}	6.07 ^{NS}	1.57 ^{NS}	6.09 ^{NS}
Replications	4	7.18 ^{NS}	1.24 ^{NS}	5.63 ^{NS}	11.73 ^{NS}	1.90 ^{NS}

PLATE 1 DIFFERENT PARTS OF *B. VARIEGATA*



1. Large size pods



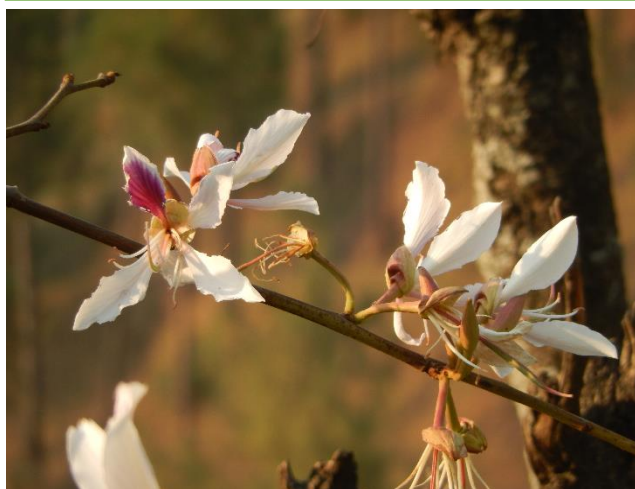
2. Small size pods



3. Large sized seeds



4. Small sized seeds



5. Flowers

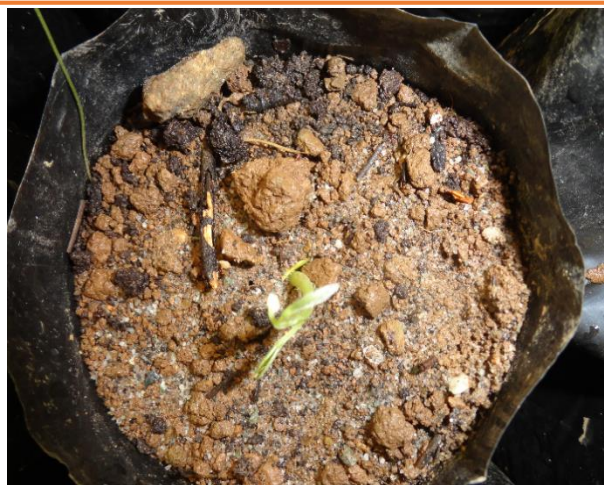


6. *Bauhinia variegata* tree

PLATE 2 GERMINATION AND SEEDLING GROWTH IN NURSERY



1. Polybags filled for seed sowing



2. Initial germination of seed



3. Germination after 25 days



4. Seedling growth after 3 months



5. Seedling growth after 6 months



5. Seedling growth after 12 months

PLATE 3 SEEDLING LENGTH AND BIOMASS ESTIMATION



1. Measurement of shoot length



1. Measurement of root length



3. 10 seedling for biomass estimation



4. Different parts of seedling for biomass



5. One year old seedling at nursery stage



6. 10 seedling in five replications

ABSTRACT

Name : Ambalal Nagar

Id. No. : UUHF/14222

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Department & Major field: M.Sc. (Forestry) (Silviculture)

Advisor : Dr. V. P. Khanduri (Associate Professor)

College & University: College of Forestry, Ranichauri, V.C.S.G. Uttarakhand university of Horticulture and Forestry.

Thesis Title: Seed source variation in pod, seed and seedling characteristics of *Bauhinia variegata* Linn. from Garhwal Himalaya, Uttarakhand.

Bauhinia variegata (Kachnar) is an important tree species of India which produces nutritive and palatable leaf fodder. The aim of this investigation was to measure the variability of seed and seedling morphological characteristics and germination in *B. variegata* seeds from throughout the natural range, in order to understand the extent and pattern of variation with respect to seed, seedling characters, germination and biomass among ten seed source from Garhwal Himalaya. Pods were collected from ten seed source and sown in nursery under randomized block design to assess the association among different seed, seedling growth characteristics, biomass traits, broad-sense heritability, genetic advance and genetic gain. After 12 month growth, data were recorded and statistically analyzed analysis of variance for association studies. Significant variations ($p < 0.05$) were recorded for different morphological parameters of seed and seedling among the different seed sources. Significant genotypic, phenotypic and environmental variance, coefficient of variation was observed between seed morphological traits especially survival, seedling length, collar diameter, number of leaves/ seedling and biomass traits. Seed weight was the most variable character among morphological characteristics. Shoot/ root ratio and root growth were more variable characters among the seedling traits. Altitude had non-significant positive relationship with seed weight, seed length and germination percent. These parameters could be used as important criteria for seed source selection. Broad-sense heritability (h^2) calculated for different seed and seedling traits showed a considerable portion of genetic variation suggesting the possibility of rapid genetic improvement of these traits. Furthermore, this variability appeared to be geographically structured and would be mainly genetically controlled. Present study identifies four best seed sources based upon seed and seedling traits for those places of Gajeli, Khandikhal, Khadi and Dugadda which were sampled. Hence, seed source screening provides a great opportunity to the tree breeder to screen and capture natural variation for success of afforestation, besides providing information on the raw material for breeding and evolving improved planting stock within a seed source. Such an investigation may help in selection of most suitable seed source for a given site for conservation, breeding and improvement in this species. Thus the result of present study should be helpful for growing quality planting material of this potential tree species in afforestation of tropical to subtropical region of Garhwal Himalaya, India.

Ambalal Nagar

(Author)

सारांश

नाम— अम्बालाल नागर

प्रवेश सत्र— 2014

मुख्य विषय— वानिकी (वनवर्धन)

सलाहकार— डा०वी०पी०खण्डूरी(सह—प्राध्यापक)

शीर्षक— गढ़वाल हिमालय उत्तराखण्ड में, बहुनिया वेरिगाटा लिन० के फली, बीज एवं पौध गुणों में बीज स्रोत की विभिन्नता।

परिचय संख्या— यूयूएचएफ/14222

महाविद्यालय— वानिकी महाविद्यालय—

वीर चन्द्र सिंह गढ़वाली उत्तराखण्ड एवं

वानिकी विश्व विद्यालय,रानीचौरी भरसार।

बहुनिया वेरिगाटा (गुरियाल) एक महत्वपूर्ण व बहुउपयोगी वृक्ष की प्रजाति है, जिससे पोषकीय एवं स्वादिष्ट पत्ती चारा प्राप्त होता है, इस अध्ययन का मुख्य उद्देश्य गढ़वाल हिमालय के दस विभिन्न भागों से प्राप्त बीज का बीजीय, पौध गुण, अंकुरण एवं जीवद्रव्यमान का मापन है। दस विभिन्न भागों से बीजों को एकत्रित कर उन्हें पौधशाला में रेण्डमाइज्ड ब्लॉक डिजाइन विधि से लगाया गया, जिससे ये पता चले कि पौधे की बीजीय, पौध वृद्धि गुण, जीवद्रव्यमान विशेषता, व्यापक अनुवांशिकी, जीन उन्नति एवं जीन लाभ प्रभाव क्या रहा। बारह माह की वृद्धि के आंकड़ों को भेद के निष्कर्ष हेतु सांख्यिकीय रूप से विभेदित किया गया। विभिन्न बीज स्रोतों से प्राप्त बीज एवं पौध में सार्थक उपक्रम ($p < 0.05$) अभिलेखित किया गया। बीज बाह्य आकारिकी विशेषताओं में सार्थक जीनोटाइप, फीनोफाइट एवं पर्यावरणीय उपक्रम तथा जीवद्रव्यमान में उत्तरजीविता, पौध लंबाई, गर्दनीय व्यास, पत्तियों की संख्या/पौध लंबाई, पौध को अवलोकिता किया गया। बाह्य आकारिकी गुणों में बीज भार को सर्वाधिक अपक्रमित पाया गया, जबकि पौध विशेषताओं में तने की लंबाई, तना का भार व उत्तरजीविता सबसे ज्यादा रही साथ ही तना/ जड़ अनुपात एवं जड़ वृद्धि को सर्वाधिक अपक्रमित पाया गया। ऊंचाई के परस्पर, बीज भार, बीज लंबाई एवं अंकुरण प्रतिशित सार्थक नहीं पाया गया। व्यापक अनुवांशिकी (h^2) की गणना, बीज एवं बीज के भाग के जीन सुधार के लिए की गई। इसके अतिरिक्त, परिवर्तन जो कि भौगोलिक ढांचागत है एवं मुख्य रूप से जीन द्वारा नियंत्रित होता है। इस अध्ययन से चार सर्वोत्तर बीज स्रोतों को चिन्हित किया गया, जो कि बीज एवं बीज विशेषताओं पर आधारित थे, एवं वो स्थान गजेली, कांडीखाल, खाडी एवं दुगडडा में बीज स्रोत अच्छे पाये गये। अतः बीज स्रोत का प्रदर्शन, पजनक को प्राकृतिक अपक्रमण एवं उनके प्रदर्शन से वनरोपण को सफल किया जा सकता है। इस प्रकार के अन्वेषण उपयुक्त बीज स्रोतों को चिन्हीकरण में सहायक हो सकता है, जिससे इन प्रजातियों का संरक्षण, प्रजनन एवं सुधारीकरण किया जा सके। अतः यह निष्कर्ष निकलता है, यह अध्ययन गढ़वाल हिमालय के ऊष्ण एवं उप ऊष्ण वनों के वनरोपण हेतु उच्च गुणवत्ता वाले वृक्षों के वृद्धकरण में सहायक साबित होगा।

विद्यार्थी के हस्ताक्षर

नाम— अम्बालाल नागर

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