

**Evaluation of ten seed sources of
Shisham (*Dalbergia sissoo*)
saplings of 3 years age at zonal
Research Station Chianki, Palamau**

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**By
ARUN KUMAR**

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It is further certified that such help or information received during the course of investigation and preparation of the thesis has been duly acknowledged.

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Place :

Date :

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ABSTRACT

The present experiment was conducted on a provenances/seed source trial of *Dalbergia sissoo* raised in 2005 in the field of Zonal Research Station, Chianki of Birsa Agricultural University, Kanke, Ranchi. Out of ten seed sources, seven seed sources were from Jharkhand and three were from Bihar state.

Nursery grown uniform seedlings of approximately 45 cm length from different seed sources were planted in Randomized Block Design (RBD) in the month of July 2005 at a spacing of 2m x 2m in plot size of 6.0 m x 16.0 m. The data on different parameters such as Height (m), Diameter at breast height (cm), Clear Bole (without forking) height (m), Crown width (cm), Branch Angle (degree), Incidence of termite attack, Incidence of flowering, Mortality, Bole Volume (cu. m.) etc. were collected in month of August 2008, i.e. at the age of 3 years for all provenances/seed source using standard method. Comparison of different growth parameter of different seed sources was also made with that local Daltonganj seed sources.

Maximum mortality (19.4%) was found for Daltonganj (P_2) source and no mortality was found for Jamshedpur (P_4) Source. The present finding indicates many variations in height of different seed sources at 3 years age. Maximum height (6.84m) was found for Garhwa, Jharkhand (P_1) source. In comparison to Daltonganj seed source, Bhagalpur seed source showed less height, whereas other eight seed sources showed more height.

Maximum d.b.h. (6.69 cm) was found for Jamshedpur, Jharkhand (P_4) source followed by 6.35 cm for Garhwa, Jharkhand (P_1) source, and minimum d.b.h. of 4.80 cm was found for Daltonganj, Jharkhand (P_2) source. The percentage increase in Jamshedpur seed source over Daltongang seed source was found maximum 39.37%.

The clear bole height of Garhwa (P₁) and Sahebganj (P₇) seed sources was found maximum (3.51m) and the percentage increase in bole height of Garhwa and Sahebganj seed source in comparison to Daltonganj seed source was 18.98%. In comparison to local Daltonganj seed source five seed sources showed more crown width, whereas other four seed sources showed less crown width. Over Daltonganj seed sources maximum percentage increase in crown width was for Deoghar seed source (20.00%). Out of the total seed sources, maximum average branch angle 55.22° was found for Sahebganj (P₇) followed by 55.05° for Deoghar (P₅) and minimum average branch angle of 45.17° was found for Katihar (P₉) Source.

The incidence of termite attack at basal portion was maximally (16.29%) was notice for Katihar (P₉) source followed by 15.4% for Bhagalpur (P₈) source and minimum occurrence of 9.9% was found for Daltonganj (P₂) Source. The Katihar, Bhagalpur and Dumka seed sources showed more flowering occurrence as compared to local Daltonganj seed source. The flowering occurrences for Garhwa and Jamshedpur seed source were 32.45% and 83.42% respectively more than Daltonganj seed source. Maximum bole volume was found for Garhwa and Jamshedpur seed sources

From the score matrix, the Jamshedpur seed source was found as best seed source for all the growth parameters followed by Garhwa seed source. However, the Ranchi and Bhagalpur seed sources scored lesser value (34) as compared to other seed source.

CHAPTER – I

INTRODUCTION

The success of establishment and productivity of forest trees plantation is mainly dependent on the species planted and the source of seed used for the concerned species (Lacaze, 1978). Many studies on provenances or seed sources have indicated its bearing on success of tree improvement programme (Wells and Wakely, 1970).

In general seed source refers the places where tree stand is growing or the area where mother-tree is growing. The importance of provenance/seed source is very well recognized by tree growers because suitability of a provenance within the same species is decided according to the objectives of raising plantation as well as the seed collection will be done only from known and proven provenance to have desired character of tree species.

The word 'provenance' derived from Latin word 'pro-venio' meaning 'place of origin' signifies the geographic region where a type is found within its climatic and physiographic conditions. The first work of provenance study was also initiated from the European Continent,. Over a century ago Valmorin raised plantations of *Pinus sylvestus* from seed from Germany, France, Scotland and Russia, all side by side (Verma, 1949). In general, provenance refers to the geographic source of seed or plant material from such a source. It is generally true that tree species with a wide geographical distribution exhibit considerable provenance variation in anatomy, morphology and physiology.

Provenance trials are carried out to test a given species with the objectives to identify those provenances/seed source which will produce well-adapted and productive forests. Besides, other important criteria considered are survival, resistance to adverse environmental

factors or pests, wood quality and seed production capacity. Seed source studies rest upon the establishment of test plantations of seeds from various sources in extensively replicated plots, with a thorough knowledge of the ecological factors operating in the place of origin and planting locality.

Common definitions given for provenance and seed source are- (a) Provenance- the original geographic area from which seed or other propagules are where obtained (Jones and Burley, 1973), and (b) Seed source- location of the parent trees from which seed was used for establishing a plantation.

According to Kanowski and Nikles (1989) a single collection should ideally involve a minimum of 20 trees per provenance. Berley and Wood (1976) suggested that a single collection should contain between 10 and 30 trees, since it is assumed that this will provide a representative sample of the same magnitude as that of nature. These guidelines have been developed from experiences with provenance collections and testing (Kemp, 1976).

In provenance trials productive and descriptive characters are assessed usefully in both the range-wide and restricted sampling phases include height, diameter, bark thickness, crown depth and width, branch number, angle and length, survival, uniformity. Straightness of stem should be assessed either by some quantified continuous measurement or by categorical classification. These traits should be evaluated at three-to five-year intervals throughout the test period with more frequent (half-yearly or annual) sampling in the first two or three years.

Survival of test plots must be optimum when making assessment of difference in growth rates usually square or rectangular plots with border rows are considered best. Alternatively, a short term survival screening test can first be made using row plots and then a

subsequent long term growth test establishes using only those sources that have acceptable initial survival (Newman, 1981).

Proper evaluation and accurate recording of field data are fundamental to the success of the tests. What to measure depends on the objective of each organization and the traits of interest in the test. However, some of the common variables measured in all tests are- (a) Survival, (b) Breast height diameter, and (c) Total height.

In provenance tests of *Gmelina arborea* in coastal Colombia, early growth was very good (Ladrach, 1986), but seed production was poor near sea level. The limits of provenance should be known especially to extreme sites or stressed sites where tolerances to unique or extreme condition are critical e.g. Cold tolerance, drought tolerance, insect or disease tolerance and adaptation to very acidic or very alkaline soils. The most useful measurements of yield are height, diameter, form/taper, and bark thickness. Wood quality comparisons can best be made at the end of this stage although preliminary information can be made in the earlier testing phases. Other important traits that should be assessed in all phases are phenology of growth and flowering, and seed productivity which may require intensive observation over several years. Reaction to adverse environmental and biotic factors must be recorded throughout all stages; when biotic damage is observed, the causal organism must be identified.

Dalbergia sissoo Roxb. or Sissoo or Shisham (Family- Leguminisae, Sub- family- Papilionaceae) one of the important indigenous multipurpose tree species of northern India occurs naturally in the foothills of Himalayas mostly in tarai and bhabhar areas up to 1404 m above mean sea level from Jammu and Kashmir in the west to Bangal Dwar in the east (Troup, 1986). Commonly found in boulder alluvial soils adjoining rivers, it can grow up to a height of 30m and 80cm diameter having often crooked trunk. It fixes atmospheric nitrogen and is among the villagers most preferred plantation species. Its high quality sawn timber is used for furniture

manufacture and building construction. It can be lopped for fodder and small branches can be used as fuel wood. The basic idea of sissoo improvement is to improve its growth and form because the tree has an undesirable crooked bole with many bends.

Dalbergia sissoo is best known internationally as a premier timber species of the rosewood genus. However, sissoo is also an important fuel wood, shade, shelter and fodder tree. With its multiple products, tolerance of light frosts and long dry seasons, this species deserves greater consideration for agro-forestry applications.

Sissoo is among the finest cabinet, furniture and veneer timbers. The heartwood is golden to dark brown, and sapwood white to pale brownish white. The heartwood is extremely durable (Specific Gravity = 0.7- 0.8), and is very resistant to dry-wood termites; but the sapwood is readily attacked by fungi and borers. The calorific value of the sapwood and heartwood is reported to be 4908 Cal/kg and 5181 Cal/kg, respectively (Anon, 1952). As a fuel wood it is grown on a 10 to 15-year rotation and it has excellent coppicing ability, although a loss of vigor after two or three rotations has been reported in Nigeria (NAS, 1983). Sissoo wood makes excellent charcoal for heating and cooking.

The sissoo have been used culturally for a variety of ailments including: skin diseases, blood diseases, syphilis, stomach problems, dysentery, nausea, eye and nose disorders, aphrodisiac, expectorant, among others (Duke, 1983). The efforts to select the suitable provenance of *Dalbergia sissoo*, to achieve better growth and timber, have been made in India (Singh and Danayak, 1999) and abroad (White *et al.*, 1990). However, Sharma *et al.* (2001) carried out a study to identify the site – matched provenance of *Dalbergia sissoo* for sodic soil of Uttar Pradesh.

Keeping in view the significance of provenance/seed source and multiple use of *Dalbergia sissoo* present study is designed to evaluate different provenances/seed sources of *Dalbergia sissoo* with the following objectives:

1. To study growth and development of *Dalbergia sissoo* plants of different provenances.
2. To screen out best *Dalbergia sissoo* provenance for timber production.

CHAPTER – II

REVIEW OF LITERATURE

2.1 Provenance/Seed source in General

In general provenance refers to the original geographic area from which seeds or others propagules are obtained (Callaham, 1964; Jones & Burley, 1973). On the other hand seed source refers to the locations of parents trees from which seeds are used for establishing a plantation. However, these two words have been and variably among scientist and forester. Therefore, a clear understanding of these two terms is critical in front research, but their significance is for selection of best seed source for planting on or specific site to have desired characteristics of the plantations

Systematic provenance testing was initiated in Europe and North America long back. The basic aim of provenance testing was to estimate the probability that any better genes or population can be found for at least on trait (Namkoog, *et al.* 1988). So that it can be used to improve the productivity of planting programmes. Some of the characters, which are aimed in provenance study of forest tree species are- (a) Survival on test locality, (b) Growth performance on the locality, and (c) Adaptability in test locality.

The first need in provenance study is the realization of the full extent of natural variability of a type over its entire range of distribution. It has been increasingly realized that those types which were hitherto considered as pure are in reality a complex of genotypes with very variable characters. The differences may, however, be so slight and so different to detect, that it may not be possible to identify them on purely morphological characters, but yet significant enough for one to define them as climatic or local races (Varma, 1949).

According to Varma (1949) provenance studies rest upon the establishment of test plantation of seeds from various sources in extensively replicated plots with a though

knowledge of ecological factors operating both in place of origin and the planting locality. An ecological approach is essential in order to strip off the mask of environment form over any local type.

Statistically sound experimental designs are employed in provenance trials to assure that precise and exact estimates can be made of population differences among different environmental conditions and among silvicultural treatments that may be super imposed (Andrew, 1976). Many statistical designs are useful for provenances testing, but the randomized complete block design is perhaps the most common and simplest method for use (Ladarch, 1983a, 1985).

In India provenance trial on two important native species viz. Teak (*Tectona grandis*) and Chir Pine (*Pinus roxburghii*) was initiated by Late Prof. M. L. Laurie and Sir Harry Champion, during 1928-30 at a number of locations in India, which have yielded useful information. International provenance trial of *Tectona grandis* and *Gmelina arborea* were established in different states in India during 1928-30 in collaboration with the DANIDA (Danish International Development Agency), forest seed centre. The ICFRE (Indian Council of Forestry Research and Education) initiated national level provenance experiments on *Tectona grandis*, *Pinus roxburghii* and *Bombax ceiba*. ICFRE has also collaborated in International provenance testing of *Eucalyptus* particularly *Eucalyptus tereticornis*, *E. camaldulensis*, and *E. grandis*. Trials were also laid for *Acacias* and tropical pines like *Pinus ocarpa*, *P. caribaea* and *P. kesija* etc. Technical input extended to state forest department to lay out provenance test of species of interest like *E. grandis*, *E. globules* (Mandal and Gibson, 1998).

To improve the productive potential of *Eucalyptus* plantation an important tree species for agroforestry in India a species-cum- provenance trial constituting 16 species was conducted by Aulokh and Sandhu(1990).Growth data of 6 year old plantations was studied and some provenances have given significantly higher height and diameter over others. However, no

significant difference has been found between the volume of the various provenances and species.

Chaturvedi *et al.* (1989) presented findings of the trials of several provenances of *Eucalyptus tereticornis* and *Eucalyptus camaldulensis* carried out in Khammam district of Andhra Pradesh. No single provenance has shown its superiority over others and none can be recommended for large scale planting in these edepho-climatic conditions.

Rao *et al.* (2001) reported findings of International Provenance Trial of *Casuarina equisetifolia* established in 1996 with 27 provenances at Regional Forest Research Centre, Rajahmundry, East Godavari District, Andhra Pradesh. Based on ANOVA significant difference among provenances for height, GGL, GBH and straightness at $P=0.05$ level of significance was observed. Genetic analyses showed heritability estimates for the characters axis persistence and straightness (below 15%) while moderate estimates of heritability for height, GGL and GBH (between 40-60%). It is suggested that selections could be made from superior trees of individual provenances in order to have broad base for genetic improvement of *Casuarina equisetifolia* in Andhra Pradesh.

Rockwood and Meskinen (1992) in an international provenance trial of *Eucalyptus grandis* established in S. Florida in 1980 have compared growth and frost tolerance of 20 Australian provenances after 8.8 years with that of seed orchard stock from Florida and South Africa. Florida orchard seedlots grew better than nearly all other material including a South African clonal seed orchard lot. Provenance variability was significant for growth, survival and frost tolerance. Some of the Australian provenances were more frost tolerant than some provenances previously introduced into the Florida breeding population. Only the Heberton provenance compared favourably with advanced-generation Florida seedlots in all critical growth traits. Superior provenances at one year also usually exhibited the greatest growth at

8.8 yr; however, the tallest seedlings in the nursery did not maintain superiority in the field. Provenance X soil type interactions were common.

Lugo and Francis (1990) tested five provenances of *Eucalyptus deglupta* and *E. urophylla* at two sites in Puerto Rico, viz. (1) Rio Abajo (300 m altitude) in the subtropical wet forest life zone with an annual rainfall of about 2500 mm, mean annual air temperature about 25°C, and loamy soils with high nutrient content, and (2) Yabucoa (50 m) in the subtropical moist forest life zone with an annual rainfall of 2200 mm, mean annual air temperature about 26°C, and loamy soils of low nutrient content. At Rio Abajo, regardless of provenance, *E. deglupta* grew faster in diameter, height and stem wood volume than did *E. urophylla*. At Yabucoa, *E. urophylla* outperformed *E. deglupta* numerically but not statistically. Observation of tree health and survival at 15 yr old followed the same pattern. Short-term observations (2-5 yr) are suitable for assessing initial growth and survival of these species but not for determining which provenances are best. Until 8 year old, growth projections from early observations could overestimate some provenances and underestimate others.

Raebild *et al.* (2003) described results of a trial including 16 provenances of *Acacia nilotica* and 5 provenances of *A. tortilis*, established in 1989 with a spacing of 4x4 metres at Gonse, Burkina Faso. The assessment took place after four years in 1993, and included a number of vegetative and growth characters. The provenances of *A. nilotica* represented a selection from Burkina Faso, Senegal, Sudan and India, whereas the provenances of *A. tortilis* were from Burkina Faso and Sudan. Differences between the provenances were highly significant. For *A. nilotica*, the provenances from Burkina Faso and Senegal had by far the best performance, and the growth of provenances from India was very poor. The provenances from Burkina Faso and Senegal were also clearly separated from the rest of the provenances in the multivariate analysis, but whether this is due to differences between varieties or due to the geographical origin is not clear. The best provenances had a growth rate corresponding to 1.1 t

ha-1 y-1. Growth in *A. tortilis* was somewhat slower, and in the university analyses no difference could be found between the provenances. In the multivariate analysis, however, it appeared that the provenance from Burkina Faso was different from the provenances from Sudan.

Variation in the entire range of species distribution and delimitation of population capable of providing best tree of Teak (*Tectona grandis*) was done by the provenance tests Puri (1984). In the North Raipur Division of Madhya Pradesh Teak plantations were raised from the seeds obtained from Maharashtra (Kanara origin), Burma, Kerala (Nilanbur), Madhya Pradesh (Betul and Tenduchua) and Karnataka (Kakankoti) and sample plots were laid out in 1938 as part of the All India Teak seed origin co-operative experiment. Quantitative and qualitative analysis of the growth performances of these provenances indicated that teak seed origin of Nilanbur is the most suitable and adaptable.

2.2 Provenance study of *Dalbergia sissoo*

Sagta and Nautiyal (2001) studied 59 provenances of *Dalbergia sissoo* collected from natural distribution zone (latitudes 24° 42' N to 32° 36' N, longitude 74° 30' E to 94° 36' E, altitude 76 m to 460 m msl) from India and Nepal. Seedlings were raised in polythene bags at four nurseries in India under randomized block design. The data on growth and survival were recorded after one and half year. Significant variation was observed among all the provenance as well as nursery sites for all observed characters at 1% level of significance. Provenance from eastern part of Uttar Pradesh showed average to best results at the four nursery sites. The overall performance of provenances was best at the Lucknow nursery. Average growth in all 4-nurseries exhibited that Shahbad, Pilibhit, Mainpuri, Laxmipur from Uttar Pradesh and Simblewala from Jammu and Kashmir provenance to be the best. Minimum growth observed in Firozabad, Sultanpur and Kunda provenances from Uttar Pradesh and Rohtak provenance

from Haryana. Correlation showed that the increasing or decreasing pattern of latitude, longitude, altitude and rainfall did not have any positive or negative effect on the provenance variation.

In tarai area, shisham has been widely planted on large- scale because it great potential as a valuable afforestation species, but remarkably, little work has been done on its provenance testing, plus tree selection etc. These activities were initiated by Vakshasya (1988). Vakshasya *et al.* (1992), Bangarwa (1993), Tewari and Sharma (1994) and ShivKumar *et al.* (1994) in India, Rehman and Hussain (1986), Rehman *et al.* (1994) in Pakistan and Neil (1990), Hawkins (1986) and White *et al.* (1990, 1994) in Nepal. However, these trials did not have representation of provenance from the entire natural range of distribution of this species nor were those tests carried at multiple sites.

Devagire *et al.*(1998) investigated genetic information on traits related to seed germination and vigor among different provenances of *Dalbergia sissoo*. High heritability coupled with same intensity of genetic gain exhibit by speed of germination, germination value. This signifies the fact that these traits could be considered reliable for affecting selection and further improvement of this species. Only 1000 seed weight showed highly significant positive correlation with seed germination and vigor parameters indicating that selection for increased 1000 seed weight may enhance the germination and seedling vigor.

Prasad *et al.* (1996) observed that natural genetic diversity of *Dalbergia latifolia* offers a rich germplasm for future selection and breeding to evolve highly decorative veneer producing quality timber. About 110 accessions/provenance collections of *D. latifolia* and about 60 provenance collections of other *Dalbergia spp.* have been made from the Western Ghats. Genetic variation in different species and populations in their natural stands has also been studied, and different provenances of *D. latifolia* have been shown to have a significant degree of variation in morphology, growth, wood anatomy and acclimatization to different ecosystems.

'Plus' tree selections of *D. latifolia* have been made from different regions of Karnataka in order to identify genetically superior stock for a future breeding programme and a preliminary provenance trial is in progress. Sporadic attempts to maintain a genetic stock of superior elites by inducing root suckers have also been successful.

Devagiri, *et al.* (2001) studied twenty nine seed sources representing natural distribution range of *Dalbergia sissoo* in India and in Nepal were screened to evaluate the variations in mycorrhizal colonization and nutrient uptake and to identify good mycorrhizas forming seed sources. VAM [vesicular arbuscular mycorrhizas] colonization rate varied significantly between 24 to 54% and 17 to 46% while mycorrhizal root length ranged from 6-32 and 5-22 cm among seed sources during the first and second year, respectively. This showed influence of seed source on mycorrhizal colonization. Variations in number of nodules and nodule dry weight were significant and were positively correlated with mycorrhizal colonization and seed source. Seedling growth, dry matter accumulation and nutrient uptake varied significantly and improved in seed sources with good mycorrhizal formation which indicated mycorrhizal effect and this response was likely to be seed source dependent. Among the seed sources tested, Lukhimpurkheri, Tanakpur, Allahabad, Badaun and Kalpi appeared to be the best germplasms with regard to mycorrhizal formation, seedling growth and biomass production. Therefore, these seed sources could be considered while making selection of genotypes with good symbiotic response and for raising nursery stock for afforestation of degraded lands. The utility of seed source/fungus genotype-dependent differences in VAM symbiosis in tree breeding is discussed.

Devagiri, *et al.* (1998) sixty *Dalbergia sissoo* seed sources covering most of the natural range in India and Nepal were studied. Significant variation among sources was observed for several pod and seed traits. Variation was greatest for 1000-seed weight and number of seeds per pod, which could be important criteria in selecting and classifying seed sources. Variation in

the above traits did not show any particular trend and appeared to be discontinuous or non-clinal. The possible explanations for such variations are discussed.

Singh and Pokhriyal (2001) conducted to elucidate the pattern of variation in pods, seed characteristics and germination behaviour among *Dalbergia sissoo* seed sources to develop selection criteria for future tree improvement programmes. Six seed sources were selected to represent widely divergent areas. All pod traits (except number of seeds per pod), seed characters, i.e. length, width, weight (except seed thickness) and germination parameters, i.e. germination percentage, germination value, germination period, etc., varied significantly among different seed sources. The variation observed among different seed sources may probably be influenced by different intensities of natural constraints acting upon these traits in the prevailing geographic/climatic conditions. Among the six different seed sources, Gonda (Tulsipur, east Uttar Pradesh) showed the best performance followed by Kankai (Nepal), Chiriyapur (west Uttar Pradesh), Simblewala (Jammu), Hissar (Haryana) and Sibsagar (the poorest). Seed weight and thickness showed highly positive and seed length negative correlation with germination percentage; hence, these can be considered as important traits for the selection of superior seed source.

Bangarwa (2002) presented finding of an intensive survey conducted on selection of plus tree of *Dalbergia sissoo* in Rajasthan, Haryana, Punjab and Uttar Pradesh, India and in the southwestern regions of Nepal during January-February 1998. A total of 63 plus trees were selected based on height, diameter, clear bole (without forking), stem straightness, aggressive apical dominance, compact crown, low branch angle, and resistance to pest and diseases.

Nursery studies were conducted by Singh and Pokhriyal (2000) on *Dalbergia sissoo* seedlings raised from six provenances within the natural distribution range, namely Sibsagar (Assam), Gonda (eastern Uttar Pradesh), Chiriyapur (western Uttar Pradesh), Hissar (Haryana), Simblewala (Jammu) in India, and Kankai (Nepal) during 1995-97. A significant

variation existed among different seed sources for growth characters, i.e., height, collar diameter, leaf number, root length and biomass production, after 3-4 months. The Gonda seed source had the best performance with respect to growth and biomass production, followed by Nepal and Chiriyapur. Significant differences were observed during the 2nd year of growth among different seed sources. The study also indicated that multitrait selection criteria and environmental parameters play an essential role in evaluating the seed sources in *Dalbergia sissoo*.

2.3 Timber characteristics of tree provenances/seed source

For any breeding programme selection of best possible genetic material is very important. As per Thomson (1994) the criteria for selection were- (1) Vigour and health, (2) Dominance, (3) Straight, cylindrical bole of superior diameter, (4) Strong apical dominance, (5) No ramicom branching habit, (6) Light branches growing more or less at 90° to the stem, and (7) a tendency to self prune.

Neil (1989) and Joshi and Thapa (1997) have indicated some local adaptations in terms of growth and development of *Dalbergia sissoo* at Nepal. Indigenous provenances in Nepal were compared with Pakistan provenances in different sites (Neil, 1989 at Adhabar; Baral *et al.*, 1997 at Tarahara and Shankar Nagar, Rupandehi). The Nepali provenances were significantly better than Pakistan provenance.

In Nepal a 9.5-year-old stand thinned to 867 trees/ha at 6.5 years produced an annual increment of 18.1 M³ for *Dalbergia sissoo* (Jackson, 1987). Species trials have indicated that total biomass yields for sissoo are usually lower than that of other species (NAS, 1983; Sheikh and Haq, 1982; Sheikh, 1988b). Therefore, sissoo should be used in areas where a high-value timber market is available, or on sites unfavorable for other species. Increasingly, indigenous leguminous trees are being planted in India because of their high biomass per unit area, their survival on nutrient poor sites and for their nutrient conservation efficiency.

Ranjeet *et al.* (2006) studied 42 seed sources of *Pinus roxburghii* for seed length, seed width, 100 seed weight, germination, germinative value and germination energy index under laboratory condition as well as in nursery. After six month of growth in the nursery, data were recorded on 10 randomly selected seedlings per treatment for field germination, seedling height, collar diameter, needle length, dry shoot weight, total carbohydrate, total sugar, starch, reducing sugar, non reducing sugar Phenol and amino acids. The study revealed that all seed traits, laboratory germination traits, morphological traits and biochemical traits showed significant variation.

Mathur *et al.* (1984) studied 12 provenances of *Acacia nilotica* var. *jaquemontii*, three provenances of var. *cupressiformis* and three provenances of var. *vediana* during January-February, 1984 at seed testing Laboratory, Forest Research Institute, Dehra Dun. The morphological variations and physiological differences and their effect on germination behavior of seeds of different varieties/provenances of *Acacia nilotica* have been recorded and requirements of pretreatments to hasten the germination have been prescribed. Hard seed coat of *Acacia nilotica* retards germination and treatment with hot water gave the best results. The results of study indicate that out of the various provenances of *A. nilotica* var. *jaquemontii*, Fazilka, Paratwara, Rohtak and Kurushetra provenances have proved to be the best.

Ngulube (1989) has evaluated variation within *Gliricidia sepium* through provenance trial. The nursery trial showed significant differences in seed germination and seedling survival between provenances. Seedling growth varied significantly between provenances, but none of the traits assessed (height, diameter and dry-weight) was related with any of site characteristics (latitude, longitude and altitude). The nursery results demonstrate considerable genetic variation in *G. sepium*, emphasizing the importance of a nursery-evaluation phase in provenance- elimination trials, and suggested to obtain useful gains through breeding techniques.

Jayasankar *et al.* (1999) collected data on 7 provenances of Teak (*Tectona grandis*) from Kerala for germination, seedling performance in the nursery, and also on root growth potential using stumps in field. Germination characteristics did not vary significantly among the provenances in the nursery. Root growth potential of the provenances was highly variable in most of the attributes, such as number of lateral and tertiary roots, length of three longest lateral roots and dry weight of lateral roots. Nilambur and Malayattur provenances were superior in this respect, while the local provenance (Trichur) produced the lowest means. Performance of the provenances in the field followed nursery growth patterns, confirming that growth was under strong genetic control.

Significant differences in tree volume of *Eucalyptus microtheca* in Charcas San Luis Potori, Mexico after 10 years age is observed by Ramirez and Martineza (1994).

Wright and Osorio (1992) studied a total of 13 trials comprised of 24 provenance and more than 520 families planted to date with CAMCORE (Central America & Mexico Coniferous Research Co-operative) for *Pinus tecunumanii*. Provenances and families differed significantly for volume per tree in 5-year-old trials and for total height in 3-year-old trials. Provenances of *Pinus tecunumanii* produced significantly more volume per tree than provenance of *Pinus oocarpa*. Four trials measured at 8 year of age, correlations of family ranking were statistically significant for volume per tree at ages of 8 & 5 years.

Studies on progeny performance of different provenances of khair suggested that plants height, collar diameter, no. of branches per plant and number of leaves per plant should be given greater consideration while caring out genetic Improvement through selection (Chouhan and Verma, 1993).

Purkayasthan *et al.* (1982) studied the wood properties of *Eucalyptus tereticornis* grown at different sites. This study exhibited a trend of increasing specific gravity from pith to periphery in a linear fashion. However, the differences were not always found statistically

significant, the deviations observed from the expected normal trend for increase from pith to outwards. Jenner et al. (2003) reported variation among the 23 one parent families of Mahua [*Madhuca latifolia* (Roxb.) Macbride] representing different agro-climatic zone of Tamil Nadu. With respect to seed characters like seed length and breadth, seed length vs seed breadth ratio, hundred seed weight & oil content and seedling traits like shoot length, basal diameter, root length, number of leaves and total dry weight. Out of 23 one- parent families studied, TNAU and Paiyur-I were found to be suitable for short rotation forestry practices.

Suhaendi (1989) reported trials of 6 provenances of *Gmelina arborea* for 2 sites in West Java (Pasirhantap and Haurbentes), using 15mx10m plots with 9 trees at 2mx3m spacing. In 1986, stem traits (total and clear bole height, stem diameter at breast height (b. h.), stem bark thickness at b.h., forking and branching, bole straightness and axis dominance) and susceptibility to pests and diseases ('tree health') were assessed. Observations were also made on the phenology of flowering and fruiting. On the basis of these assessments, provenance 4040 (from Miquel, Brazil) was promising for Pasirhantap, and provenances 4045 (from Sankos, India) and 4004 (from Chisapo, Malawi) were promising for Haurbentes.

2.4 Growth characteristics of provenance/seed source of tree species

Khosla et al. (1995) examined provenance variation in two *Racosperma* spp. (*R. auriculiformis* and *R. mangium*) on four test sites in Zaire. Seeds for the two species were obtained from Northern territory and Queensland of Australia, Papua New Guinea, Indonesia, Conge and Zaire Growth and morphological characters (height diameter, survival) were measured at ages 3, 9, 15, 21 months, significant provenance differences existed in all trails. The rank of provenance changed across sites, indicating significant genotype x environment interaction. Correlations of field growth traits (diameter, height) at different ages were positive but negatively correlated with nursery results. Clonal variation was observed especially for

survival rate. The reforestation programs in Zaire and other tropical countries sharing similar bio-geoclimatic condition. Additional genetic gain in growth could be obtained through selection and breeding of superior individual from these provenances.

Chauhan and Verma (1993) suggested that plant height, collar diameter, number of branches, per plant and number of leaves per plant should be given more emphasis while carrying out genetic improvement through selection in *Acacia catechu* (khair).

Ginwal *et al.* (1995) conducted variability study among the seedlings of 32 provenance of *Acacia nilotica* belonging to 5 sub-species namely tomentosa, indica var. jaquemontii, indica var. cupressiformis, nilotica and indica from 5 countries namely India, Sudan, Pakistan, Yaman, and Senegal under nursery conditions. The existence of significant genetic variation among seed sources for some growth characteristics namely shoot length, collar diameter, and seedling dry weight has been observed. *A. nilotica* spp. indica var. jaquemontii provenance from Nizamabad (Adilabad) Andhra Pradesh, India was found to be outstanding in respect of growth height (152.30 cm) and biomass production (122.45 gm seedling⁻¹). All the provenances differed significantly from each other in respect of the studied parameters. Study also indicates that multi-traits selection might be essential in ranking the desired seed source.

Awang *et al.* (1994) had conducted 25 provenances of *Acacia auriculiformis* in International trials on seven sites in four countries with respect of survival & growth at 3 year age. Significant growth differences were found (i) among provenance at four sites, (ii) among the sites (iii) and between provenance regions. Interaction between sites and provenance and vice-versa existed. The poorest growth was recorded in Kanchanaburi, Thailand and best growth was in Banjarbaru, Indonesia.

Hossain *et al.* (1996) studied comparative survival percentage, growth and biomass production of 15 different provenances of the exotic multipurpose tree species *Gliricidia sepium* from an international provenance trial established at Charaljani Silvicultural Research Station,

Madhupur, Tangail, Bangladesh, in August 1988. Provenances were from Venezuela, Costa Rica, Panama, Nicaragua, Guatemala, Colombia and Mexico. Results are analysed at 5.5 yr old. All the provenances showed promising survival percentages (75-97%) with differences among them not statistically significant. The highest plant height (8.87 m) was found in the provenance 16/84, and the highest diameter at breast height (7.7 cm) in provenance 36/85. The total maximum biomass production (93.81 t/ha) was found in provenance 16/84, although differences from provenances 1/86, 14/86, 24/86, 35/85, 40/85, 58/87 and 60/87 were not statistically significant.

Jha (1991) studied a species cum provenance trial of *Eucalyptus* species at Forest Research Centre, Jalna under rainfed condition without any addition of fertilizer. Data collected 3 years after planting has been analyzed for survival percentage, height and girth. *Eucalyptus tereticornis* provenance "Kennedy River" has produced the best average height and *Eucalyptus camaldulensis* provenance "East Leichardt River" has shown the best average girth.

Fonweban *et al.* (1997) studied performance of 10 *Gmelina arborea* provenances (from Malawi (1), Cote d'Ivoire (1), India (7) and Brazil (1)) in a trial at Mangombe, Cameroon, in which they were planted at 3X3 m spacing for tree characteristics such as survival rate, circumference, tree height, volume yield, form factor and percentage branchiness. Results after 12 years of two provenances from Brazil and Malawi were found as most promising for large-scale plantations which was derived on the basis of 12-years data.

Toky *et al.* (1996) studied twelve provenances of *Albizia lebbek*, a multipurpose tree, collected from 9°N to 32°N latitude, 72°E to 85°E longitude and 40 to 400 cm rainfall zones in India at Hissar, in north-western India (29°N, 75°E, 215 m alt., 60 cm rainfall). Significant variations in height, diameter (DBH), branch number and biomass were observed among most of the provenances at 3-years age. Wide ranges in the means were exhibited by height (3.4 to

5.6 m), DBH (3.3 to 6.3 cm) and biomass (2.7 to 9.4 kg/tree). Provenances from north-western and central India, in general, were superior to those from south India. There were significant correlations between height or DBH with the latitude of seed source origin ($r = 0.64$ and 0.80 , respectively; $P < 0.05$). The heritability estimates were: 23.6% for height, 20.3% for DBH, 24% for crown spread and 17.3% for bole biomass.

Thirteen provenances of *Eucalyptus tereticornis* from Australia Forest Research Institute, Dehra Dun, including a local provenance of *Eucalyptus tereticornis* was studied at Marakkanam Research Garden, Tamil Nadu, during 1982 by Sundararaju *et al.* (1995) in provenance study. Although the results were not statistically significant, data collected until 1990, showed that 3 provenances (viz. I.W. of Mt. Garmet; 20 km North of Mount Molley; and West of Mackey (Seed lot No.13014) performed better than the others in respect of average height, clean bole height, basal area and survival.

Nor Aini *et al.* (1994) assessed a trial of 28 provenances of *Acacia auriculiformis* for survival and growth at 12 months age at the UPM campus, Selangor, Peninsular Malaysia. Of these provenances, 7 were from Queensland and 15 from Northern Territory, Australia, and 6 from Papua New Guinea. All provenances survived very well (>92%), but they differed very significantly ($p < 0.001$) in their growth performance. A selection of provenances from Northern Territory and Queensland were among the top performers with East Alligator River (16152) being the best. The results indicate the presence of genetic diversity in this species and support the need for genetic improvement.

Significant variation was observed among the ten provenances (Amarkantak, Bilaspur, Betul, Dhar, Dewas, Indore, Jagdalpur, Jabalpur, Seoni and Ujjain) with respect to germination percentage, height, collar diameter and survival for *Azadirachta indica* by Jalil *et al.* (2000) Seoni (MP). The provenance Betul showed best results with respect to height and survival percentage after four years of growth. Amarkantak provenance was found superior in terms of

collar diameter while germination percentage was recorded highest in Indore provenance. Based on the results obtained after four years, provenances of Betul and Bilaspur can be ranked as overall best. Except provenance of Ujjain (the lowest growth performer) all the provenance are suitable for the plantation with fastest growth rate.

Johari and Chew (1990) made a preliminary analysis on the performance of 21 provenances of *Acacia mangium* (17 from Queensland, Australia, and 2 each from Papua New Guinea and Indonesia) at 2 yr old at 4 locations with respect to survival, growth and stem form. Survival was generally good, with the average percentage ranging from 83 to 95. There were significant differences in mean height between provenances at all sites except one, with the MAI (mean annual increment) ranging from 4.7 to 5.4 m. There were also significant differences in mean diameter growth between provenances for 2 sites, with the MAI ranging from 4.3 to 5.3 cm. There was great variability in stem form between sites. Various possibilities that might have contributed to this great difference are suggested. In general, the provenances from Claudie River and Jullatan (Queensland) and from Ontario River and West of Morehead (Papua New Guinea) showed better performance than other provenances.

Kapur (1987) found *Eucalyptus* hybrid as an important species under the social forestry programme of Punjab and with a view to get more yield per unit area species-cum-provenance trials of *Eucalyptus* were taken up. Data regarding a four year old species/provenance trial involving three species viz. *E. camaldulensis*, *E. tereticornis* and *E. microtheca* and five treatments have been analyses. No significant difference between treatments has been observed though the Gilbert river provenance of *E. camaldulensis* has, so far, given the highest basal area and volume.

Kapur and Dogra (1987) undertook a range-wide provenance trial of *Eucalyptus camaldulensis* in Ferozepur Forest Division in August, 1982. Data collected about 3.5 years after planting has been analyzed. Out of a total of 16 treatments, 8 treatments (provenances)

were found to be significantly superior to the control (*Eucalyptus hybrid*) in term of volume production. Most of these provenances with the exception of Lake Albacutya are from the northern latitude of Australia with latitude of below 26° S.

2.5 Adoptability or suitability of provenances/seed sources

Johansson and Tuomela (1994) studied growth and survival of 16 provenances of *Eucalyptus microtheca* to assess their adaptability in regularly irrigated conditions. Statistically significant differences between provenances were found in MAI and basal area. The best provenance could be detected as late as 5 year of age, emphasising the importance of long lasting experiments in provenance selection. Eastern Australian provenances are most suitable for regularly irrigated conditions owing their great capacity to harvest available water very quickly. Western and Northern provenances may be most suitable for areas where long drought periods dominate.

Gagadishchandra *et al.* (1994) conducted provenance trial to find out suitable and superior provenances in *Eucalyptus camaldulensis* as a replacement for *Eucalyptus hybrid* on drier tracts of shimoga. 14 provenances were tried in the trial at two different locations. Of the provenances tested in the trial, Emu Creek, Petford, QLD, Gibb River, WA and Katherine, NT has promising growth rate under prevailing climatic and site conditions. However, the performance of *Eucalyptus hybrid* tried as a control is also satisfactory. Result of these trials indicates that the performance of *E. camaldulensis* provenance varied considerably with the site and climatic conditions.

Pinyopusarek *et al.* (1996) conducted species and provenance trial consisting of 4 Eucalypts (*Eucalyptus camaldulensis*, *E. tereticornis*, *E. pellita* and *E. urophylla*) and 4 Acacias (*Acacia aulacocarpa*, *A. auriculiformis*, *A. crassicaarpa* and *A. mangium*) established near Vientiane, Lao, to screen suitability of species that might be grown commercially in plantations. Each species was represented by 6-8 provenances (55 provenances in total). Results up to 2

yr old showed considerable differences between species, and between provenances within species. A ranking of the species in order of magnitude based on tree volume was *E. camaldulensis* > *E. urophylla* > *A. mangium* > *E. tereticornis* > *A. crassicarpa* > *A. aulacocarpa* > *E. pellita* > *A. auriculiformis*. The results have implications for selection of most potential species and provenances for further detailed investigation. Future studies would desirably include yield estimation involving more sites, larger plots and alternative management regimes.

Puri *et al.* (1989) screened four main types of *Leucaena leucocephala* viz. Hawaii, Salvador, Peruvian and Cunningham in an arboretal study and found that F-205 (k-8), F-206 (Peruvian) and F-132 (Salvador) are suitable for afforestation in Doon Vally.

Sharma *et al.* (2000) conducted a provenance trial of *Acacia nilotica* in sodic soil of Sultanpur district in Utter Pradesh. Out of the ten provenances under test the Solapur (Maharashtra) was found to be most suitable provenance followed by Dhaund (Maharashtra) for the sodic soil site. Haldwani (Utter Pradesh) provenance proved to be most inferior for this site.

In 1993, as a part of the pilot studies seeds of provenances of *Azadirachta indica* var *siamensis* from Thailand and Neem from Pakistan, Nepal, Senegal, Tanzania and Myanmar were exchanged for provenance trials at AFRE, Jodhpur (Mishra, 1995). The selection and breeding criteria targeted in this trial was enhanced out puts of oil, azadirachtin and biomass as well as adaptability to stress conditions.

Ramesh and Khurana (2003) studied natural variation in *Populus alba* Linn. to determine the range of variation in Himachal Pradesh and Jammu & Kashmir states. The character studied were height, diameter and general shape at the base of the leaf blade. Analysis of co-variance showed significant differences for different provenances of *P. alba* Linn. for height, d.b.h, taper, clear bole, and leaf area. Strong correlation was obtained between height and d.b.h. The species showed more genetic variation among the natural stands and needs genetic improvement.

CHAPTER – III

MATERIAL AND METHODS

The details of material and methods employed during the course of present investigation are given below.

3.1 Experimental site

The material for present study was from a provenances trial of *Dalbergia sissoo* laid out in 2005 in the field of Zonal Research Station, Chianki of Birsa Agricultural University, Kanke, which is located in western part of Jharkhand State in Palamau District and lies between 83°07' E longitude and 24°02' latitude in Agro-climatic Zone IV of an altitude of about 254m above MSL. The climate of the locality is humid-subtropical with average rainfall of 1636 mm/annum.

3.2 Climate

The common features of the region are late onset of monsoon, long gap during rainy season and an early withdrawal of monsoon. The rain starts at the end of June, and very active & highest rain is noticed during July and August. In general, May – June are the hottest months while Dec-Jan are the coldest months of the years. The temperature goes as low of 5°C and as high as 45°C during winter and summer seasons, respectively.

The details of meteorological data obtained from meteorological observatory of Birsa Agricultural University from start of experiment (July 2005) to the period when data was collected (August 2008) are presented in Table-3.1

Table- 3.1: Meteorological data recorded from July 2005 to August 2008

S.N.	Parameters		Value
1	Average Temperature (°C)	Maximum	32.59
		Minimum	19.43
2	Average humidity (%)	Maximum	78.09
		Minimum	52.25
3	Average monthly rainfall (mm)		94.08

3.3 Seed source of *Dalbergia sissoo*

The plantation of Shisham was raised out in July 2005, taking 10 seed sources/provenances. The details of seed sources collected from different areas are given in Table-3.2.

Table 3.2: Seed sources of *Dalbergia sissoo*

Seed Sources	Place of origin	State	Latitude	Longitude
P ₁	Garhwa	Jharkhand	24° 09' N	83° 52' E
P ₂	Daltonganj	Jharkhand	24° 02' N	83° 07' E
P ₃	Ranchi	Jharkhand	23° 22' N	85° 20' E
P ₄	Jamshedpur	Jharkhand	22° 47' N	86° 12' E
P ₅	Deoghar	Jharkhand	24° 31' N	86° 42' E
P ₆	Dumka	Jharkhand	24° 17' N	87° 15' E
P ₇	Sahebganj	Jharkhand	26° 25' N	87° 10' E
P ₈	Bhagalpur	Bihar	25° 14' N	86° 59' E
P ₉	Katihar	Bihar	25° 33' N	87° 34' E
P ₁₀	Purnea	Bihar	25° 47' N	87° 31' E

Nursery grown uniform seedlings of approximately 45 cm length from different seed sources were selected for planting in the field in Randomized Block Design (RBD) as per following field layout in the month of July, 2005 at a spacing of 2m x 2m in individual plot size of 6.0 m x 16.0 m. Thus, having 24 plants, i.e. 2500 trees/ha as initial stocking.

Location	- ZRS, Chianki
Design	- Randomized Block Design (RBD)
Replication	- Three
Number of Seed sources	- Ten (10)
Size of plot	- 6.0 m X 16.0 m
Spacing	- 2.0 m X 2.0 m
Year of planting	- July, 2005

Rep I		:	Rep II		:	Rep III	
P ₅	P ₉		P ₄	P ₁₀		P ₁	P ₆
P ₃	P ₆		P ₅	P ₈		P ₂	P ₇
P ₄	P ₁₀		P ₂	P ₆		P ₃	P ₈
P ₂	P ₈		P ₁	P ₇		P ₄	P ₉
P ₁	P ₇		P ₃	P ₉		P ₅	P ₁₀

Field Layout

3.4 Observations

The data on different parameters were collected in month of August 2008, i.e. at the age of 3 years for all provenances/seed source using standard method as described below -

3.4.1 Height

The height of individual tree from ground level to the top of crown was considered as height, which was measured with a graduated bamboo marked in cm and meter. The height is expressed in meter.

3.4.2 Diameter at breast height (d. b. h.)

The diameter of individual tree at breast height level, i.e. at the height of 1.37 m from ground on tree trunk was measured with the help of tree caliper and expressed in terms of cm.

3.4.3 Clear Bole (without forking) height

The vertical length on main tree trunk from ground level to the place of first prominent green branch was considered as Clear Bole height. The Clear Bole height of each tree was measured with graduated bamboo bole and is expressed in meter.

3.4.4 Crown width

The spread of the crown along its widest diameter is considered as Crown Width. The Crown width was measured using two poles and Meter tape. For this first of all, the wider diameter point was marked on ground with bamboo poles and the horizontal distance between two points is measured with tape in cm.

3.4.5 Branch Angle

The branch angle which represent deviation of branched from the main stem is the indicator of spread of crown or compactness of crown, is measured with the help of a protractor. For this, angle of first three lower branches were taken individually and average branch angle per tree was calculated from this and value is represented in '0' (degree).

3.4.6 Incidence of Termite attack

The Sissoo is very sensitive to pest and diseases. In the entire experimental area only infestation of termite is noticed at base of tree and no other kind of damage either by disease or insect is observed. Individual tree of each seed sources in the experimental plot was observed for infestation of termite attack by visual observation and trees infested by termite were counted for each replication and is computed into percentage.

3.4.7 Incidence of flowering

The flowering, i.e. the reproductive phase of different provenances/ Seed sources was recorded by observing number of individual that has flowered in each replication, which was later converted into percentage. The early age to start reproductive phase is not considered as a desirable character for timber species.

3.4.8 Mortality

The mortality percent of each provenance/seed source was calculated by counting total number of dead tree (not a live) in each replication in the month of September, 2008 and compared this number to the total number planted initially at the start of experiment. The mortality percent was calculated by following formula.

$$\text{Mortality (\%)} = \frac{\text{Total Number of Tree Not Alive}}{\text{Total Number of Tree Planted Initially}} \times 100$$

3.4.9 Bole Volume

The Bole Volume was also calculated to evaluate individual provenance/seed source for the production of commercial timber. It was measured using following formula and is expressed in cubic meter (cu.m. or m³)

$$V = \pi \frac{d^2}{4} h$$

Where d = diameter at breast height (d.b.h.) in cm
 h = Bole height (m)

3.5 Score Matrix

The scoring system was performed for selection of best seed source using Thomson (1994) method. According to him out of total score of 100, 25 for vigour, 30 for stem characters, 25 for branching behaviour, 10 for resistance for disease and pests and 10 for seed characteristics were given. However, in present study score matrix was prepared based on performances of individual seed source with respect to different parameters on a total score of 81.

3.6 Statistical analysis

The data recorded on various parameters were subjected to statistical analysis for interpretations. The main objective of Analysis of Variance (ANOVA) technique was to examine if there is any significant difference between the mean values for different parameters relating to each provenances/seed source.

Standard error of mean (S. E_m), Critical difference at 5% (C.D.5%) and Coefficient of variation (C.V %) were calculated for each parameter to draw inferences. For statistical calculation Excel Package of M.S. Office was used in a computer.

CHAPTER –IV

RESULT AND DISCUSSION

4.1 Mortality of different seed sources

The mortality (%) of different seed sources is recorded at 3-years age and is presented in the Table 4.1. Perusal of data has indicated that the mortality (%) of 10 seed sources of *Dalbergia sissoo* varied from 0% to 19.4%. Out of the total provenances, maximum mortality 19.4% was found in for Daltonganj (P₂) followed by 18.1% for Deoghar (P₅) and no mortality was found in Jamshedpur (P₄) Source.

Based on mortality (%), difference seed sources are grouped into two types as follows-

- (i) **Group 1** (0% to 10%)- Six seed sources belonging different climatic zones namely Garhwa (V), Ranchi (V), Dumka (IV), Bhagalpur (III) and Purnea (II) showed less mortality, i.e. within 10%. Jamshedpur is only provenance from zone VI showed no mortality.
- (ii) **Group 2** (10% to 20%)- Four seed sources are kept under this group which included Daltonganj, Deoghar, Sahebganj and Katihar seed source. Among the four sources, Daltonganj source was more sensitive because more mortality was noted in these sources.

The local Daltonganj seed source, gave highest mortality, which was significant comparison to other seed sources.

Similar to the present study Dutta and Jamwal (1995) observed survival percentage of *Pinus caribaea* as quite high in Tikri (67.3%), Lanquin (64.0%) and La Brea (62.0%), moderate in Poptun (51.2%) but quite low (34.0%) in Las Sa Banas. Similar information was also given by Lahiri and Roy Choudhuri (1990) for *Pinus carabaea* In a provenance study of *Dalbergia sissoo*

at Nepal, Neil (1990) found 85-97% survival at 3.5 years old stand with poor growth Pakistan Provenances.

Survival and growth of *Acacia radiana*, *Acacia Senegal*, *Acacia nilotica* and *Prosopis cineraria* were studied at 6 - years age at Central Arid Zone Research Institute, Jodhpur and significance difference in survival among four species were found, but no significant different were found among provenances within the species (FAO, 1985) . In Uttar Pradesh high mortality areas (60 – 90 % mortality) for *Dalbergia sissoo* was identified as Deoria, Kushinagar, Ballia and Maharajganj (Dubey and Mishra, 2002).

4.2 Height

The data recorded on height of different provenances is presented in the Table 4.2. Perusal of data has indicated that the height of 10 different seed sources of *Dalbergia sissoo* varied from 5.02 m to 6.84 m. Out of the total seed sources, maximum height 6.84 m was found for Garhwa, Jharkhand (P₁) source followed by 6.80 m for Sahebganj, Jharkhand (P₇) source, and minimum height of 5.02 m was found for Bhagalpur, Bihar (P₈) Source.

Based on height growth, difference seed sources are grouped into two types as follows-

- (i) **Group 1** (seed sources showing height between 5 to 6 m)- Six provenances are placed under this group which are Dumka, Deoghar, Katihar, Ranchi, Daltonganj and Bhagalpur provenances with a height of 5.87m, 5.82m, 5.77m, 5.52m, 5.47m, and 5.02m, respectively.
- (ii) **Group 2** (seed sources showing height between 6 to 7 m)- Four provenances are kept under this group which included Garhwa, Sahebganj, Jamshedpur, and Purnea provenances showing a height of 6.84m, 6.80m, 6.64m, and 6.06m, respectively.

From the above grouping it is found that in first group height ranges from 5.02 to

5.87m, whereas in the second group, it varied from 6.02m to 6.84, which is statistically non-significant.

On the basis of agro climatic zones of Bihar and Jharkhand, the height performances of different seed sources are described as below-

- (i) **Agro climatic zone II:** From this zone two seed sources Purnea and Katihar showed different height performances. The Purnea source (6.06m) attained more height in comparison to Katihar (5.77m), which was found statistically non-significant.
- (ii) **Agro climatic zone III:** From this zone the Bhagalpur seed source showed less height (5.02m) than the seed sources of Zone II.
- (iii) **Agro climatic zone IV:** Out of the three evaluated seed sources of this Zone maximum height (6.80m) was in case of Sahebganj source followed by Dumka (5.87m) and Deoghar (5.82m) sources.
- (iv) **Agro climatic zone V:** From this zone, Garwha source attained maximum height (6.84m) followed by Ranchi (5.52m) and Daltonganj (5.47m) sources, which was significantly superior to others.
- (v) **Agro climatic zone VI:** Jamshedpur provenance showed more height (6.64m) in comparison to local Ranchi provenance (5.52 m).

The comparative highest heights of different agro climatic zones are given in Figure 4.1 to indicate superiority of zone VI.

In comparison to local seed source of Daltonganj, other seed sources gave enhanced height, whereas only one seed source (Bhagalpur) showed less height. Statistically analysis revealed that all provenances were at par with each other.

The percentage increase/decrease in height of different seed sources as compared to local Daltonganj is depicted in Figure 4.2. Maximum percentage increase was found in Garhwa

provenance (25.05%) followed by 24.31% in Sahebganj seed sources. Negative percentage increase in comparison to local Daltonganj seed sources was found only in Bhagalpur (-8.23%) source.

Nautiyal *et al.* (2003) found significant inter clonal variation in height and collar diameter of *Dalbergia sissoo* clones under Dehra Dun conditions. Similarly, Subas and Nshubemuki (1988) found significant different in height of 12 provenance of *Eucalyptus camaldutensis* of Australian and local origin. Das and Tavitayya (1982) have indicated that Los Limones (Hond) provenances of *Pinus caribaea* was performing best at Koraput (Orissa) with a MAI of 83 cm for height and 1.6 cm for DBH.

4.3 Diameter at breast height (d.b.h.)

Data on d.b.h. (diameter at breast height level) of different seed sources of *Dalbergia sissoo* is presented in the Table 4.3. Perusal of the data has indicated that the d.b.h. of 10 different seed sources of *Dalbergia sissoo* varied from 4.80 cm to 6.69 cm. Among all seed sources, maximum d.b.h. (6.69 cm) was found for Jamshedpur, Jharkhand (P₄) source followed by 6.35 cm for Garhwa, Jharkhand (P₁) source, and minimum d.b.h. of 4.80 cm was found for Daltonganj, Jharkhand (P₂) Source.

Based on dimension of d.b.h., difference seed sources are arranged into three groups as follows-

- (i) **Group 1** (seed sources showing d.b.h. between 6 to 7 cm)- Two seed sources are kept under this group which included Garhwa, and Jamshedpur provenances having d.b.h. of 6.35 cm and 6.69 cm, respectively.
- (ii) **Group 2** (seed sources showing d.b.h. between 5 to 6 cm)- Six seed sources viz. Ranchi, Deoghar, Dumka, Sahebganj, Katihar, and Purnea with d.b.h. of 5.26 cm, 5.30 cm, 5.41 cm, 5.73 cm, 5.82 cm, and 5.97 cm, respectively are grouped in this. Thus, maximum numbers of seed sources showed d.b.h between 5cm to 6cm.

(iii) Group 3 (seed sources showing d.b.h. between 4 to 5 cm)- Two seed sources, i.e. Daltonganj and Bhagalpur are kept under this group with a d.b.h. of 4.80 cm and 4.86 cm, respectively.

The differences in different group were found statistically significant.

Comparative diameter growth of different seed sources, were also discussed on the basis of agro climatic zones as-

- (i) **Agro climatic zone II:** Under this zone Purnea seed source attained more d.b.h. (5.97cm) as compared to Katihar source (5.30cm).
- (ii) **Agro climatic zone III:** Bhagalpur seed source from this zone showed a d.b.h. growth of 4.86cm.
- (iii) **Agro climatic zone IV:** Under this zone Dumka attained maximum d.b.h. (5.82cm) followed by Sahebganj (5.73cm), while Deoghar source showed minimum d.b.h. growth (5.41cm).
- (iv) **Agro climatic zone V:** Under this zone Garwha source attained maximum d.b.h. (6.35cm) whereas Daltonganj source gave minimum d.b.h. growth (4.80cm).
- (v) **Agro climatic zone VI:** Under this zone Jamshedpur seed sources showed highest d.b.h. growth (6.69cm) in comparison to all sources.

In comparison to local Daltonganj seed source no other source showed less d.b.h. the other seven seed sources showed more d.b.h. Statistical analysis revealed that all provenances are at par with each other.

The percentage increase/decrease in d.b.h. of different seed sources as compared to local Daltonganj source is depicted in Figure 4.3. Maximum percentage increase was found in Jamshedpur seed sources (39.37%) followed by 32.30% in Garhwa seed sources.

Similarly, findings of Ramesh and Khurana (2003) to determine the range of variation in Himachal Pradesh and Jammu & Kashmir states for *Populus alba* Linn. has indicated

significant differences with respect to d.b.h. for different provenances. Vakshasya *et al.* (1988) also found significant differences among fourteen provenances of *Eucalyptus teriticornis* Sm. and 15 of *Eucalyptus camaldulensis* Dehnh. with respect to the collar diameter.

The basal diameter growth of *Populus ciliata* under a provenance study of seven provenances were found higher in Uttar Pradesh provenances followed by provenances from Himachal Pradesh and Jammu & Kashmir, respectively.

4.4 Clear Bole Height

The data on clear bole height was also recorded for all the seed sources seeing the timber value of *Dalbergia sissoo* and presented in the Table 4.4. Perusal of data has indicated that the clear bole height of 10 different seed sources of *Dalbergia sissoo* varied from 2.59 m to 3.51 m. Out of the total provenances, maximum clear bole height 3.51m was found in for Garhwa (P₁) and Sahebganj (P₇) sources followed by 3.44m for Jamshedpur (P₄) source, and minimum clear bole height of 2.59 m was found for Bhagalpur (P₈) Source. The difference in bole height was statistically found non significant.

Although difference in clear bole height was less but to compare the merchantable timber, among the seed sources they are grouped into two categories-

(i) **Group 1** (Bole height between 2 to 3m)- Six seed sources are placed under this group.

Out of this, two provenances showed a bole height of 2.99m for Deoghar and Dumka source respectively, while Katihar source gave maximum bole length (3.0m) in this group.

(ii) **Group 2** (Bole height between 3 to 4m)- Four seed sources are included in this group

indicating maximum clear bole height of 3.51m for Garhwa and sahebganj seed source. The comparative seed sources of bole height of different provenances with respect to agroclimatic zones are shown in Figure 4.4. The clear bole height of seed sources belonging to zone IV was found more followed by zone V and VI.

In comparison to local Daltonganj seed source Ranchi and Bhagalpur seed sources showed less clear bole height, whereas other seven provenances showed more clear bole height.

The percentage increase/decrease in clear bole height of different seed sources as compared to local Daltonganj seed source is depicted in Figure- 4.5. Maximum percentage increase (18.98%) was found for both in Garhwa and Sahebganj seed source. Negative percentage increase (-12.20 %) in comparison to local Daltonganj seed source was found for Bhagalpur.

Sundararaju *et al.* (1995) showed that out of thirteen provenances (viz. I.W. of Mt. Garnet; 20 km North of Mount Molley; and West of Mackey (Seed lot No.13014) of *Eucalyptus tereticornis* performed better than the others in respect of average height, clean bole height, basal area and survival.

Chaukiyal *et al.* (1995) borer free plants with straight bole and fewer branches of *Populus ciliata* for provenances of Jammu & Kashmir origin, followed by the plants of Himachal Pradesh and Uttar Pradesh, respectively.

4.5 Crown Width

The data recorded on crown width of different seed source of *Dalbergia sissoo* is presented in the Table 4.5. Perusal of data has indicated that the crown width of different seed sources varied from 2.31 m to 3.06 m, and maximum crown width of 3.06m was found for Deoghar (P₅) followed by 2.95 m for Sahebganj (P₇) and minimum crown width of 2.31m was found for Bhagalpur (P₈) Source.

Broadly on the basis of crown width difference seed sources are grouped into two types as follows-

- (i) **Group 1** (Seed sources showing crown width between 3 to 4m)- Only one seed

sources, i.e. Deoghar (P₅) having a crown width of 3.06m could find place in this group. This indicates that Deoghar source exhibited wider crown, which is not characteristic for timber trees.

- (ii) Group 2 (Width between 2 to 3m)- Nine seed sources are placed under this group. Minimum crown width obtained for Bhagalpur seed source (2.31m) was found as a good character for timber species. Statistically, the differences between seed sources with respect to crown width was found non significant.

Comparative performance of different seed sources of the Jharkhand and Bihar are depicted in Figure 4.6. Three seed sources from Bihar falling in Agro-climatic Zone II (Purnea and Katihar) and III (Bhagalpur) showed less crown width as compared to the Jharkhand sources, i.e from IV (Deoghar, Sahebganj and Dumka), from V (Garwha, Ranchi and Daltanganj) and from VI (Jamshedpur) Agro-climatic Zone. The Deoghar seed source belonging to Agro-climatic Zone IV attained maximum crown width and Dumka (2.52m) attained minimum crown width.

In comparison to local Daltonganj seed source, Garhwa, Ranchi, Jamshedpur, Deoghar and Sahebganj showed more crown width, whereas remaining four seed sources showed less crown width. Statistical analysis revealed that all provenances are at par with each other.

The percentage increase/decrease in crown width of different seed sources as compared to local Daltonganj source is depicted in Figure 4.7. Maximum percentage increase was found in Deoghar provenance (20.00%) followed by 15.68 % in Sahebganj source. Negative percentage increase in comparison to local Daltonganj seed source was found in Bhagalpur (-9.41%).

Similar to present study, Bangarwa (2002) screened out 63 plus trees of *Dalbergia sissoo* from different localities of India and Nepal on the basis of various growth parameters

including compact crown. Similarly, significantly more number of branches were produced in *Acacia nilotica*, which got pruned automatically from below, thereby increasing the clear bole length. (Bagchi and Dobriyal, 1992).

4.6 Average Branch Angle

The on average branch angle of different seed sources are presented in Table 4.6. Perusal of data has indicated that the average branch angle of different seed sources of *Dalbergia sissoo* varied from 45.17° to 55.22°. Maximum angle 55.22° was found for Sahebganj (P₇) followed by 55.05° for Deoghar (P₅) and minimum average branch angle of 45.17° was found for Katihar (P₉) Source. The differences in branch angle for different provenances is statistically found non significant.

The branch angle of four provenances viz. Garhwa, Sahebganj, Deoghar, and Ranchi were found from 50° to 60°, whereas remaining six provenances it was between 40° to 50° indicating more compact crown. Sahebganj seed source showed maximum average branch angle 55.22° minimum was found in Katihar seed source (45.17°).

Depending upon the Agro climatic zones of seed sources, it is also observed that all the seed sources from Agro climatic zone IV (Sahebganj, Deoghar and Dumka) showed higher branch angle. On the other hand branch angle of Agro climatic zone II was found less. Statistically analysis revealed that all provenances are at par with each other.

The percentage increase/decrease in branch angle of different seed source in comparison to local Daltonganj seed source is depicted in Figure 4.8. Maximum percentage increase was found in Sahebganj provenance (18.01%) followed by Deoghar (17.65%), while maximum negative percentage increases was found in Katihar seed source (-3.46%).

Various growth characteristics have been given for selection of plus tree in different species e.g. in case of Teak straight and persistent axis, clear cylindrical bole, light and operating branches with angles approaching to 90° are found as suitable character, while

compact crown was considered as best for selection of 63 plus trees of *Dalbergia sissoo* by Bangarwa (2002). Vidakovic and Ashan. (1970) mentioned vigorous growth, no forking, symmetrical crown, resistance to biological and physical injuries, straight stem, thin fine branches, cylindrical stem with 2/3 clear bole of total height of tree and capable of producing seeds as a criteria for plus tree selection of *Dalbergia sissoo*.

Bangarwa (2002) reported five progenies of *Dalbergia sissoo* viz. PT28 and PT12 from Haldwani, PT283 from Gonda, PT84 from Nepal and PT9 from Tankpur where found most promising for straightness, basal diameter, total height and unforked height progenies of PT27 and PT25 from Haldwani, PT80 from Sirsa, PT8 from Tanakpur and PT56 from Ftehpur were also found superior for most of the characters.

4.7 Incidence of termite infestation

In the study area heavy infection of termite at root zone was noticed and data pertaining to termite attack at base of stem was collected by observing each and every tree of different seed sources of *Dalbergia sissoo* and presented in terms of percent (Table 4.7). For this observation was recorded if there is occurrence of termite mound around the bark of main trunk, which varied from 9.9% to 16.29%. Out of the total seed sources, maximum termite infestation (16.29%) was found in for Katihar (P₉) source followed by 15.4% for Bhagalpur (P₈) source, and minimum occurrence (9.9%) was found for Daltonganj (P₂) Source. The difference was found statistically non significant.

The sensitivity of termite attack on difference seed sources are grouped into three types -

- (i) **Group 1** (Termite attack between 15% to 20%): Two seed sources namely Katihar and Bhagalpur, outside Jharkhand State showed higher attack which was 16.29% and 15.40%, respectively.
- (ii) **Group 2** (Termite attack between 10% to 15%): Seven seed sources are placed under

this group and Dumka seed source showed maximum (13.92%) while minimum attack was obtained for Garhwa seed source (10.02%).

(iii) **Group 3** (Termite attack between 5% to 10%): The only seed source of Daltonganj has very little (9.9%) termite attack.

The termite infestation on different seed sources is also shown with bar diagram (Figure 4.9) to project a comparative increase or decrease in comparison to local Daltonganj seed source. Maximum percentage increase was found in Katihar source (64.54%).

Manaturagimath *et al.* (1991) found no pest and disease occurrence in five different provenances of *Eucalyptus cloeziana* in a high rainfall zone of Western Ghats of India, which receives 2000 mm to 3500mm of rainfall annually. Dutt and Jamwal, (1995) found high percentage of defective and irregularly formed trees of different provenances of *Pinus caribaea* as highest in Las Sa Banas (50.0%), moderate in Lanquin (35.7%), La Brea (29.8%) and Poptun (26.0%) and least in Tikri (19.8%).

4.8 Incidence of Flowering

Data on flowering incidence of different seed sources of *Dalbergia sissoo* is presented Table 4.8. Perusal of data has indicated of flowering incidence for all the seed sources, which varied from 43.23% to 98.61%. Maximum occurrence of flowering (98.61%) was found for Jamshedpur (P₄) source followed by 82.62% for Katihar (P₉) source, while minimum occurrence (43.23%) was found for Deoghar (P₅) Source. Statistically the differences was found non significant.

Based on flowering incidence, the seed sources are grouped into two types-

(i) **Group 1** (Occurrence of flowering above 50%)- The flowering incidence in nine seed sources was found more than 50%, i.e. more than 50% trees of these provenances were in flowering stage at 3-years age. Almost all the trees of Jamshedpur source i.e. higher percentage of tree (98.61%) showed flowering thus showing high flowering

percentage (98.61%), while Ranchi source showed less flowering.

(ii) Group 2 (Occurrence of flowering below 50%): In this group only one seed source the Deoghar showed flowering incidence to the tune of 43.23%.

Therefore, irrespective of agroclimatic zone of seed sources flowering is noticed in almost all seed sources.

In comparison to local Daltonganj provenance, the percentage increase/decrease in flowering incidence of different seed sources (Figure 4.10) has indicated maximum increase for Jamshedpur (83.42%), while negative percentage increase was found maximum in case of Deoghar seed source.

Similar to the present findings Gupta *et al.* (1995) indicated that 206 Neem trees (25.52%) exhibited fruiting in the third year and 30 plants (3.72%) exhibited flowering at the time when the other tree were fruiting. In 2 plants (0.25%) flowering and matured fruit were observed occurring at the same time.

4.9 Bole Volume

Clear bole volume was also calculated depending upon average clear bole length and corresponding d.b.h. of each seed source to find out timber producing ability at 3 years age. The data pertaining to bole volume of different seed sources is presented in the Table 4.9. Perusal of data has indicated variation in bole volume of different provenances of *Dalbergia sissoo* from 0.09 cu.m. to 0.18 cu.m. Out of total seed sources, maximum bole volume (0.18 cu.m.) was found for Garhwa (P₁) and Jamshedpur (P₄) and minimum (0.09 cu.m.) was for Bhagalpur (P₈) Source.

The four seed sources viz. Garhwa, Jamshedpur, Deoghar and Sahebganj were identified as high timber volume producing seed source, which belonged to both Jharkhand (Garhwa, Jamshedpur and Deoghar) and Bihar (Sahebganj) states.

In comparison to local Daltonganj seed source, seven sources showed more bole volume (Figure 4.11), whereas Bhagalpur source gave low volume.

Similar to the present findings Ramirez and Martineza (1994) found significant differences in volume production of 10 Australian provenances of *Eucalyptus microtheca* in Charcas, San Luis Potosi, Mexico at 10 years. The North – West of Cardwell QLD provenance of *Eucalyptus cloeziana* showed best performance with respect to height, d.b.h. and volume followed by south east of Gympie QLD source.

4.10 Evaluation matrix of seed source of *Dalbergia sissoo*

Evaluation matrix of difference seed source at 3-years age is calculated on the basis of values of different parameters and is presented in the Table 4.10. Perusal of matrix data has indicated maximum value for Jamshedpur. Therefore, Jamshedpur seed source was found as best with respect to all study parameters. On the other hand Ranchi and Bhagalpur seed source have least value matrix, indication low growth. The Jamshedpur seed source has better growth in all the parameters except in mortality and termite attack. The Garhwa seed source, which stands second position in the matrix, was better growth in term of height, diameter, bole volume, bole height, and least results was found in mortality and termite attack. Based on matrix, the different seed source may be arranged in order of- $P_4 > P_1 > P_{10} > P_7 > P_6 > P_5 > P_2 = P_9 > P_3 = P_8$.

IMPLICATION OF RESULT

Keeping in view, the importance of provenance/seed source data generated in present study for *Dalbergia sissoo* (Shisham/Sissoo) will be helpful to identify variability with respect to different growth parameters for genetic improvement of this species by selecting superior seed source. Also, it will be helpful in the breeding research programme of *Dalbergia sissoo*.

CHAPTER –V

SUMMARY AND CONCLUSION

5.1 Summary

On the basis of result obtained in the present investigation are summarized below-

1. Out of ten seed sources, maximum mortality (19.4%) was found for Daltonganj (P₂) source followed by 18.1% for Deoghar (P₅) source. No mortality was found for Jamshedpur (P₄) Source. In comparison to local Daltonganj seed source the mortality of other seed sources were found less.
2. The present finding indicates much variations in height of different seed sources at 3 years age. Maximum height (6.84m) was found for Garhwa, Jharkhand (P₁) source followed by 6.80 m for Sahebganj, Jharkhand (P₇) source, and minimum height of 5.02 m was found for Bhagalpur, Bihar (P₈) Source. In comparison to local Daltonganj seed source only Bhagalpur source showed less height, whereas other eight seed sources showed more height. Maximum percentage increase in height over Daltonganj source was found in Garhwa seed source (25.05%).
3. Maximum d.b.h. (6.69 cm) was found for Jamshedpur, Jharkhand (P₄) source followed by 6.35 cm for Garhwa, Jharkhand (P₁) source, and minimum d.b.h. of 4.80 cm was found for Daltonganj, Jharkhand (P₂) Source. In comparison to local Daltonganj seed source, all other nine seed sources showed more d.b.h. The percentage increase in Jamshedpur seed source over Daltonganj seed source was found maximum (39.37%).

4. The clear bole height of Garhwa (P₁) and Sahebganj (P₇) seed source was found maximum (3.51m) followed by 3.44m for Jamshedpur (P₄) source and minimum clear bole height of 2.59 m was found for Bhagalpur (P₈) Source. The percentage increase in bole height of Garhwa and Sahebganj seed sources was (18.98%) in comparison to Daltonganj seed source while Ranchi and Bhagalpur seed sources showed negative increase.
5. The crown width for Deoghar (P₅) seed source was found maximum (3.06m) followed by 2.95 m for Sahebganj (P₇) and minimum crown width of 2.31m was found for Bhagalpur (P₈) Source. In comparison to local Daltonganj seed source five seed sources (Garhwa, Ranchi, Jamshedpur, Deoghar and Sahebganj) showed more crown width whereas other four seed sources (Dumka, Bhagalpur, Katihar and Purnia) showed less crown width. Over Daltonganj seed source maximum percentage increase in crown width for Deoghar seed sources was 20.00%.
6. Out of the total seed sources, maximum average branch angle 55.22° was found for Sahebganj (P₇) followed by 55.05° for Deoghar (P₅) and minimum average branch angle of 45.17° was found for Katihar (P₉) Source. In comparison to local Daltonganj seed source seven seed sources (Garhwa, Ranchi, Deoghar, Sahebgand, Dumka, Bhagalpur and Purnia) showed more average branch angle, while Jamshedpur and Katihar seed sources showed less value.
7. The incidence of termite attack at basal portion was maximally (16.29%) noticed for Katihar (P₉) source followed by 15.4% for Bhagalpur (P₈) source, and minimum infestation of 9.9% was found for Daltonganj (P₂) Source. In comparison to Daltonganj seed source, more incidence of termite attack was noticed for all seed sources.

8. Maximum occurrence of flowering (98.61%) was found for Jamshedpur (P₄) source followed by 82.62% for Katihar (P₉) source, and minimum occurrence of flowering of 43.23% was found for Deoghar (P₅) Source. The Katihar, Bhagalpur and Dumka seed flowering occurrence was found more in other seed sources except Ranchi and Deogarh seed sources as compared to local Daltonganj seed source.
9. Maximum clear bole volume of 0.18 cu.m. was found for both Garhwa (P₁) and Jamshedpur (P₄) sources followed by 0.17cu.m. for Sahebganj (P₇) and minimum bole volume of 0.09 cu.m. was found for Bhagalpur (P₈) Source. All provenances had more bole volume in comparison to than Daltonganj seed source while Bhagalpur seed source gave less volume.
10. From score matrix, the Jamshedpur seed source was found as best seed source for all the growth characteristics followed by Garhwa seed source. However, the Ranchi and Bhagalpur seed sources scored lesser value (34) as compared to other seed source.

5.2 CONCLUSION

The finding obtained from the present study has guided to draw the following conclusions-

- (1) The cumulative value of growth parameters such as height, d.b.h., and bole height of Garhwa seed source was found more followed by Jamshedpur seed source. However, maximum individual growth parameters varied from source to source, e.g. height for Garhwa, diameter for Jamshedpur and bole height for Sahebganj source. In case of Jamshedpur seed source no mortality was found.

- (2) On the basis of over all parameters studied, Jamshedpur seed source was found as best one for this region.

IMPLICATION OF RESULT

Keeping in view, the importance of provenance/seed source data generated in present study for *Dalbergia sissoo* (Shisham/Sissoo) will be helpful to identify variability with respect to different growth parameters for genetic improvement of this species by selecting superior seed source. Also, it will be helpful in the breeding research programme of *Dalbergia sissoo*.

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Table 4.1: Mortality percentage of different seed sources of *Dalbergia sissoo* at 3 years age

SI. No.	Provenances/Seed source	
	Name	Mortality (%)
P1	Garhwa, Jharkhand	9.7
P2	Daltonganj, Jharkhand	19.4
P3	Ranchi, Jharkhand	9.7
P4	Jamshedpur, Jharkhand	0.0
P5	Deoghar, Jharkhand	18.1
P6	Dumka, Jharkhand	9.7
P7	Sahebganj, Jharkhand	12.5
P8	Bhagalpur, Bihar	9.7
P9	Katihar, Bihar	12.5
P10	Purnea, Bihar	6.9

Table 4.2: Average height of difference seed sources of *Dalbergia sissoo* at 3 years age

Sl. No.	Provenances/Seed source	
	Name	Height
P1	Garhwa, Jharkhand	6.84
P2	Daltonganj, Jharkhand	5.47
P3	Ranchi, Jharkhand	5.52
P4	Jamshedpur, Jharkhand	6.64
P5	Deoghar, Jharkhand	5.82
P6	Dumka, Jharkhand	5.87
P7	Sahebganj, Jharkhand	6.80
P8	Bhagalpur, Bihar	5.02
P9	Katihar, Bihar	5.77
P10	Purnea, Bihar	6.06
	<i>S. Em</i>	<i>0.700</i>
	<i>C.V. %</i>	<i>20.27</i>
	<i>C.D. 5%</i>	<i>NS</i>

Table 4.3: Average d.b.h. of difference seed sources of *Dalbergia sissoo* at 3 years age

SI no.	Provenances/Seed source	
	Name	d. b. h. (cm)
P1	Garhwa, Jharkhand	6.35
P2	Daltonganj, Jharkhand	4.80
P3	Ranchi, Jharkhand	5.26
P4	Jamshedpur, Jharkhand	6.69
P5	Deoghar, Jharkhand	5.41
P6	Dumka, Jharkhand	5.82
P7	Sahebganj, Jharkhand	5.73
P8	Bhagalpur, Bihar	4.86
P9	Katihar, Bihar	5.30
P10	Purnea, Bihar	5.97
	<i>S. Em</i>	0.456
	C.V. %	13.83
	C.D. 5%	2.100

Table 4.4: Clear bole height of difference seed sources of *Dalbergia sissoo* at 3 Years age

Si. No.	Provenances/seed sources	
	Name	Clear Bole Height (m)
P1	Garhwa, Jharkhand	3.51
P2	Daltonganj, Jharkhand	2.95
P3	Ranchi, Jharkhand	2.86
P4	Jamshedpur, Jharkhand	3.44
P5	Deoghar, Jharkhand	2.99
P6	Dumka, Jharkhand	2.99
P7	Sahebganj, Jharkhand	3.51
P8	Bhagalpur, Bihar	2.59
P9	Katihar, Bihar	3.00
P10	Purnea, Bihar	3.08
	<i>S. Em</i>	0.360
	<i>C.V. %</i>	20.14
	<i>C.D. 5%</i>	<i>N.S.</i>

Table 4.5: Crown width of difference seed sources of *Dalbergia sissoo* at 3 Years age

Si. No.	Provenances/seed sources	
	Name	Crown Width (m)
P1	Garhwa, Jharkhand	2.79
P2	Daltonganj, Jharkhand	2.55
P3	Ranchi, Jharkhand	2.77
P4	Jamshedpur, Jharkhand	2.71
P5	Deoghar, Jharkhand	3.06
P6	Dumka, Jharkhand	2.52
P7	Sahebganj, Jharkhand	2.95
P8	Bhagalpur, Bihar	2.31
P9	Katihar, Bihar	2.32
P10	Purnea, Bihar	2.42
	<i>S. Em</i>	0.324
	<i>C.V. %</i>	21.21
	<i>C.D. 5%</i>	<i>N.S.</i>

Table 4.6: Average branch angle of difference seed sources of *Dalbergia sissoo* at 3 Year's age

Si. No.	Provenances/seed sources	
	Name	Average Branch Angle (°)
P1	Garhwa, Jharkhand	53.48
P2	Daltonganj, Jharkhand	46.79
P3	Ranchi, Jharkhand	54.20
P4	Jamshedpur, Jharkhand	45.98
P5	Deoghar, Jharkhand	55.05
P6	Dumka, Jharkhand	49.40
P7	Sahebganj, Jharkhand	55.22
P8	Bhagalpur, Bihar	47.20
P9	Katihar, Bihar	45.17
P10	Purnea, Bihar	47.19
	<i>S. Em</i>	4.417
	<i>C.V. %</i>	15.31
	<i>C.D. 5%</i>	<i>N.S.</i>

Table: 4.7: Incidence of termite infestation in difference seed sources of *Dalbergia sissoo* at 3 Years age

Sl. No.	Provenances/seed sources	
	Name	Termite infestation (%)
P1	Garhwa, Jharkhand	10.02 (19.04)
P2	Daltonganj, Jharkhand	9.90 (18.26)
P3	Ranchi, Jharkhand	13.77 (21.59)
P4	Jamshedpur, Jharkhand	12.49 (19.92)
P5	Deoghar, Jharkhand	12.53 (20.42)
P6	Dumka, Jharkhand	13.92 (21.90)
P7	Sahebganj, Jharkhand	12.67 (20.80)
P8	Bhagalpur, Bihar	15.40 (23.14)
P9	Katihar, Bihar	16.29 (23.74)
P10	Purnea, Bihar	13.37 (20.67)
	<i>S. Em</i>	2.549
	<i>C.V. %</i>	21.07
	<i>C.D. 5%</i>	<i>N.S.</i>

(in parenthesis arc sin value)

Table: 4.8: Occurrence of flowering in difference seed sources of *Dalbergia sissoo* at 3 Years age

Sl. No.	Provenances/seed sources	
	Name	Incidence of flowering (%)
P1	Garhwa, Jharkhand	71.21 (62.65)
P2	Daltonganj, Jharkhand	53.76 (48.13)
P3	Ranchi, Jharkhand	50.71 (45.38)
P4	Jamshedpur, Jharkhand	98.61 (86.05)
P5	Deoghar, Jharkhand	43.23 (41.03)
P6	Dumka, Jharkhand	69.72 (56.79)
P7	Sahebganj, Jharkhand	65.32 (54.38)
P8	Bhagalpur, Bihar	54.31 (47.45)
P9	Katihar, Bihar	82.62 (67.28)
P10	Purnea, Bihar	76.34 (61.42)
	<i>S. Em</i>	8.025
	<i>C.V. %</i>	24.36
	<i>C.D. 5%</i>	NS

(in parenthesis arc sin value)

Table 4.9: Bole Volume (cu. m.) of difference seed sources of *Dalbergia**sissoo* at 3 Years age

Sl. No.	Provenances/seed sources	
	Name	Bole Volume (cu. m.)
P1	Garhwa, Jharkhand	0.18
P2	Daltonganj, Jharkhand	0.11
P3	Ranchi, Jharkhand	0.11
P4	Jamshedpur, Jharkhand	0.18
P5	Deoghar, Jharkhand	0.15
P6	Dumka, Jharkhand	0.13
P7	Sahebganj, Jharkhand	0.17
P8	Bhagalpur, Bihar	0.09
P9	Katihar, Bihar	0.12
P10	Purnea, Bihar	0.14

Table 4.10: Evaluation matrix of different seed sources of *Dalbergia sissoo* for growth parameters

Provenances/ Seed source	Mortality	Height	Diameter	Bole height	Bole volume	Termite infection	Branch angle	Crown width	Flowering	Total
<i>Score</i>	1-5	1-10	1-10	1-8	1-8	1-10	1-10	1-10	1-10	81
P ₁	4	10	9	8	8	9	4	3	4	59
P ₂	1	2	1	3	2	10	8	6	8	41
P ₃	4	3	3	2	2	4	3	4	9	34
P ₄	5	8	10	7	8	8	9	5	1	61
P ₅	2	5	5	4	6	7	2	1	10	42
P ₆	4	6	7	4	4	3	5	7	5	45
P ₇	3	9	6	8	7	6	1	2	6	48
P ₈	4	1	2	1	1	2	6	10	7	34
P ₉	3	4	4	5	3	1	10	9	2	41
P ₁₀	4	7	8	6	5	5	7	8	3	53

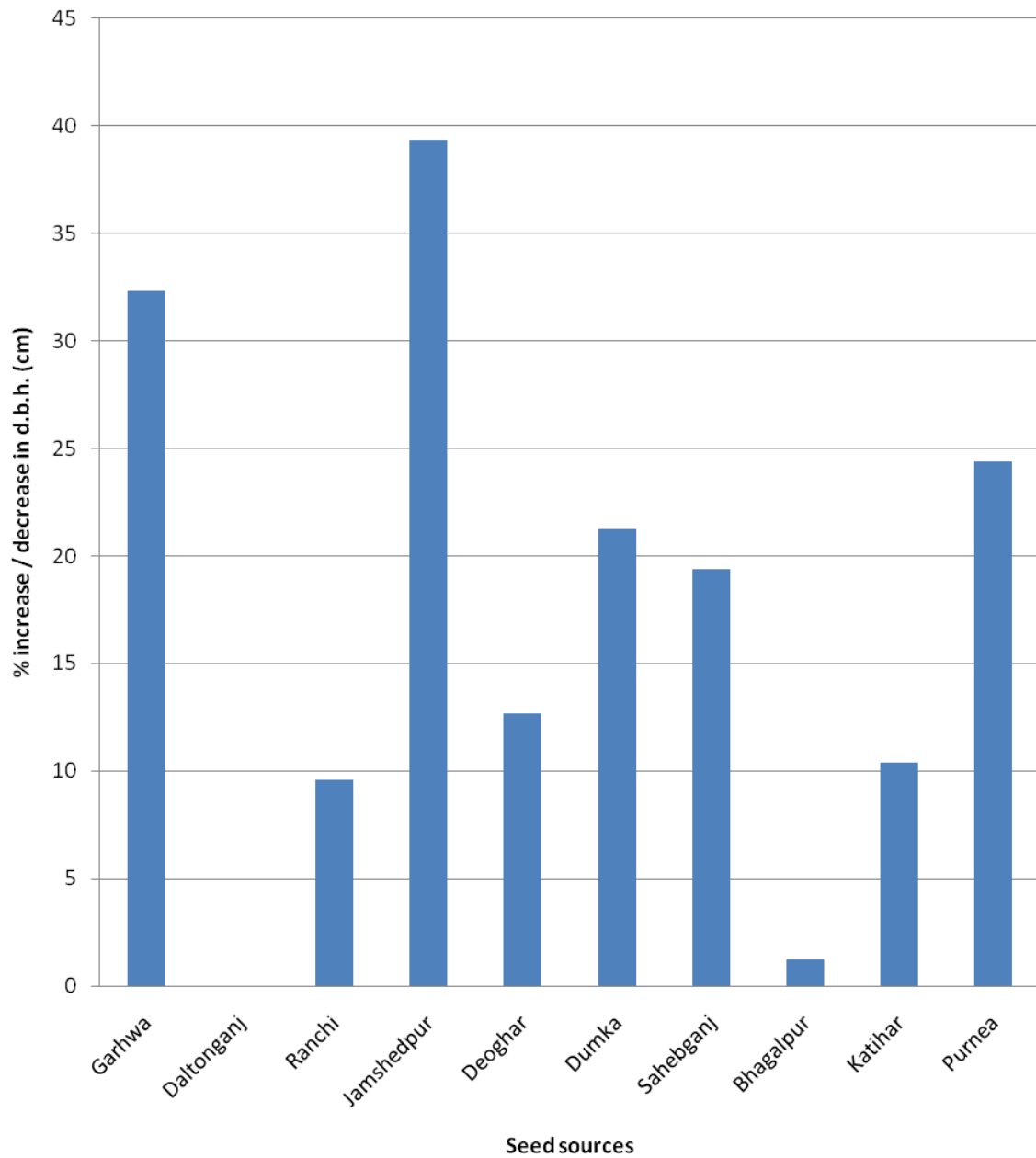


Figure 4.3: Percentage increase/decrease of d.b.h. (cm) of seed sources over local (Daltonganj) seed sources

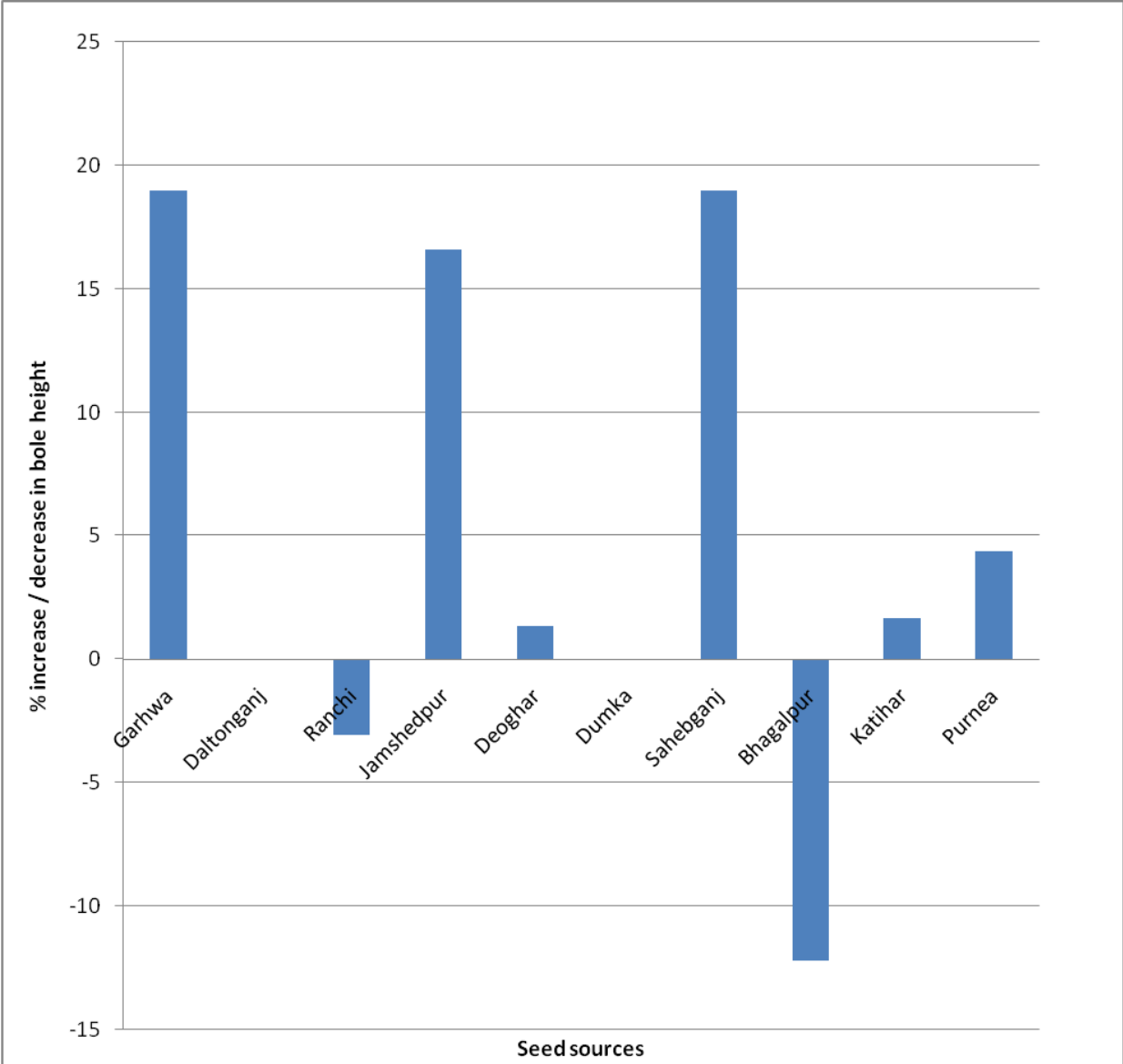


Figure 4.5: Percent increase or decrease in bole height of *Dalbergia sissoo* as compared to local Daltonganj seed source.

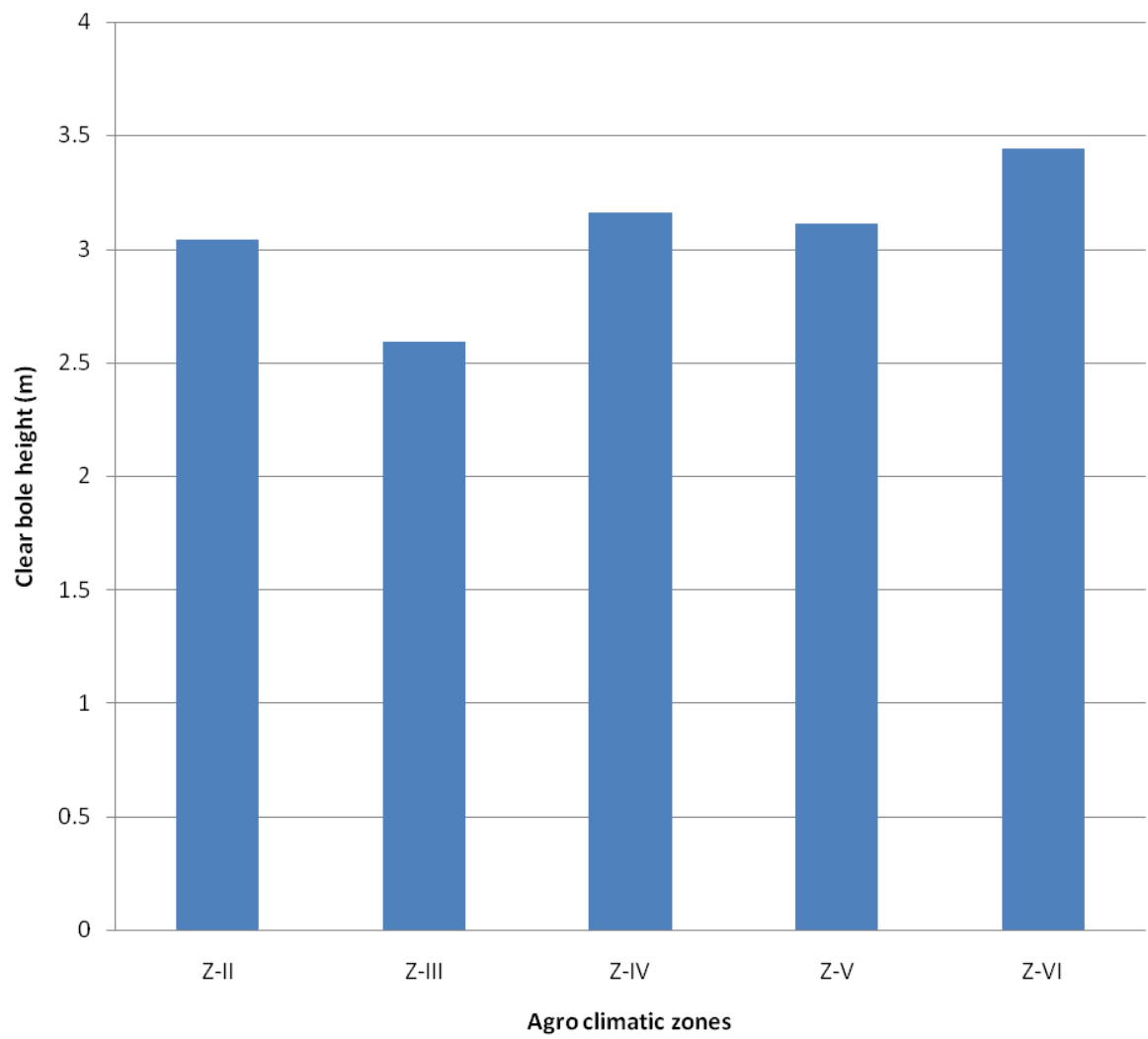


Figure 4.4 : Clear bole height of different seed sources of *Dalbergia sissoo* as per source agro climatic zones.

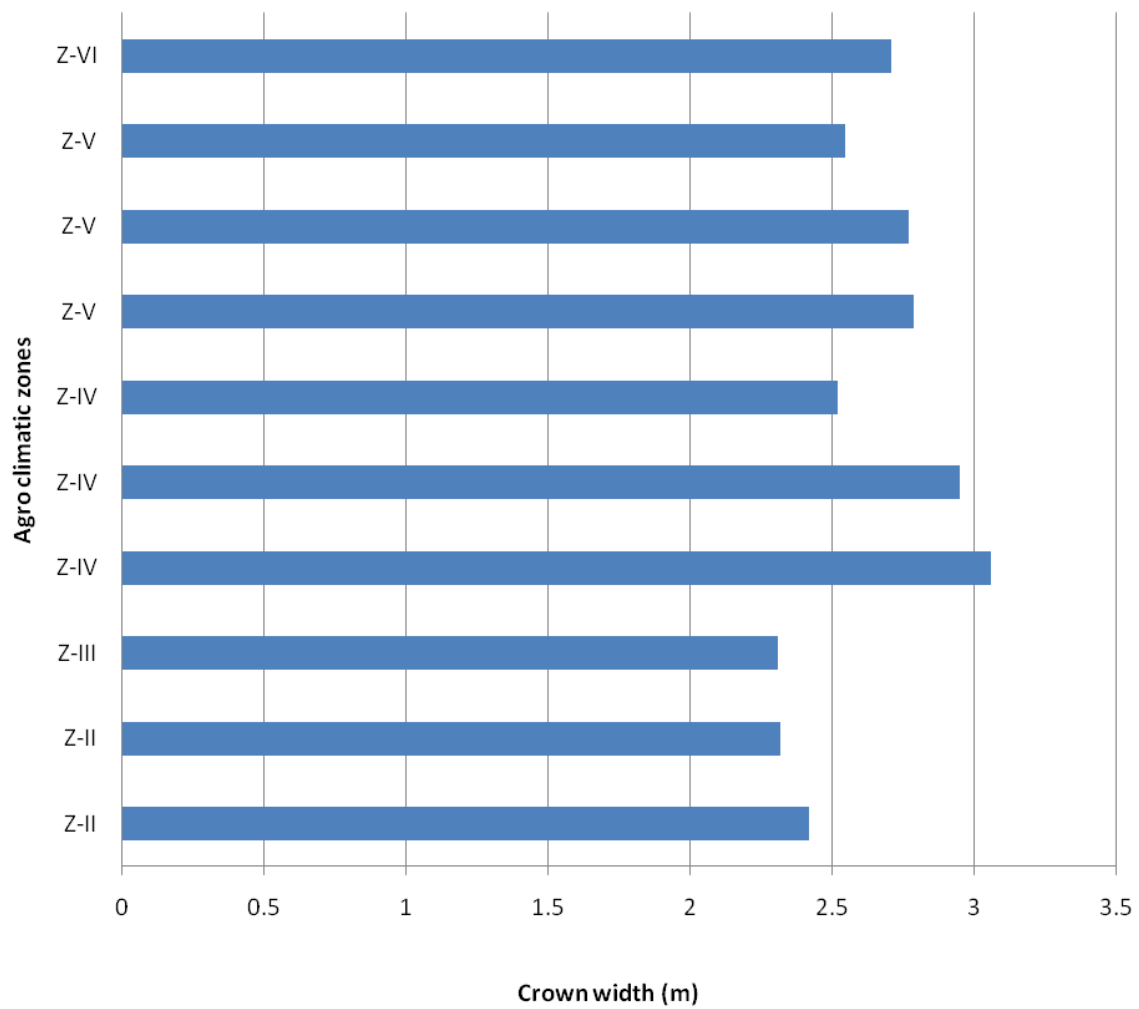


Fig. 4.6: Crown width of different seed sources of *Dalbergia sissoo*.

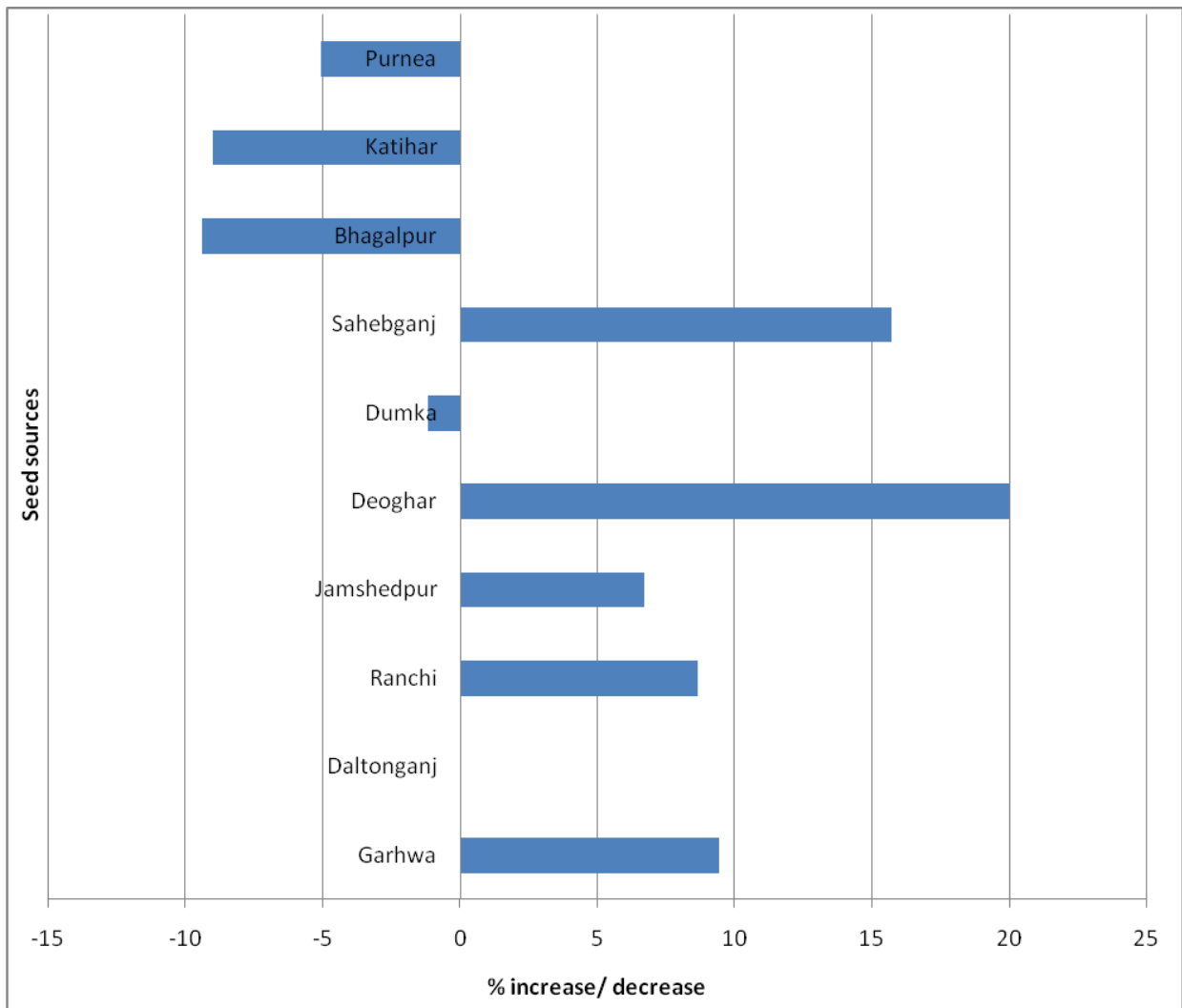


Figure 4.7: Percentage increase / decrease in crown width of different seed sources of Dalbergia sissoo in comparison to local Daltonganj seed source.

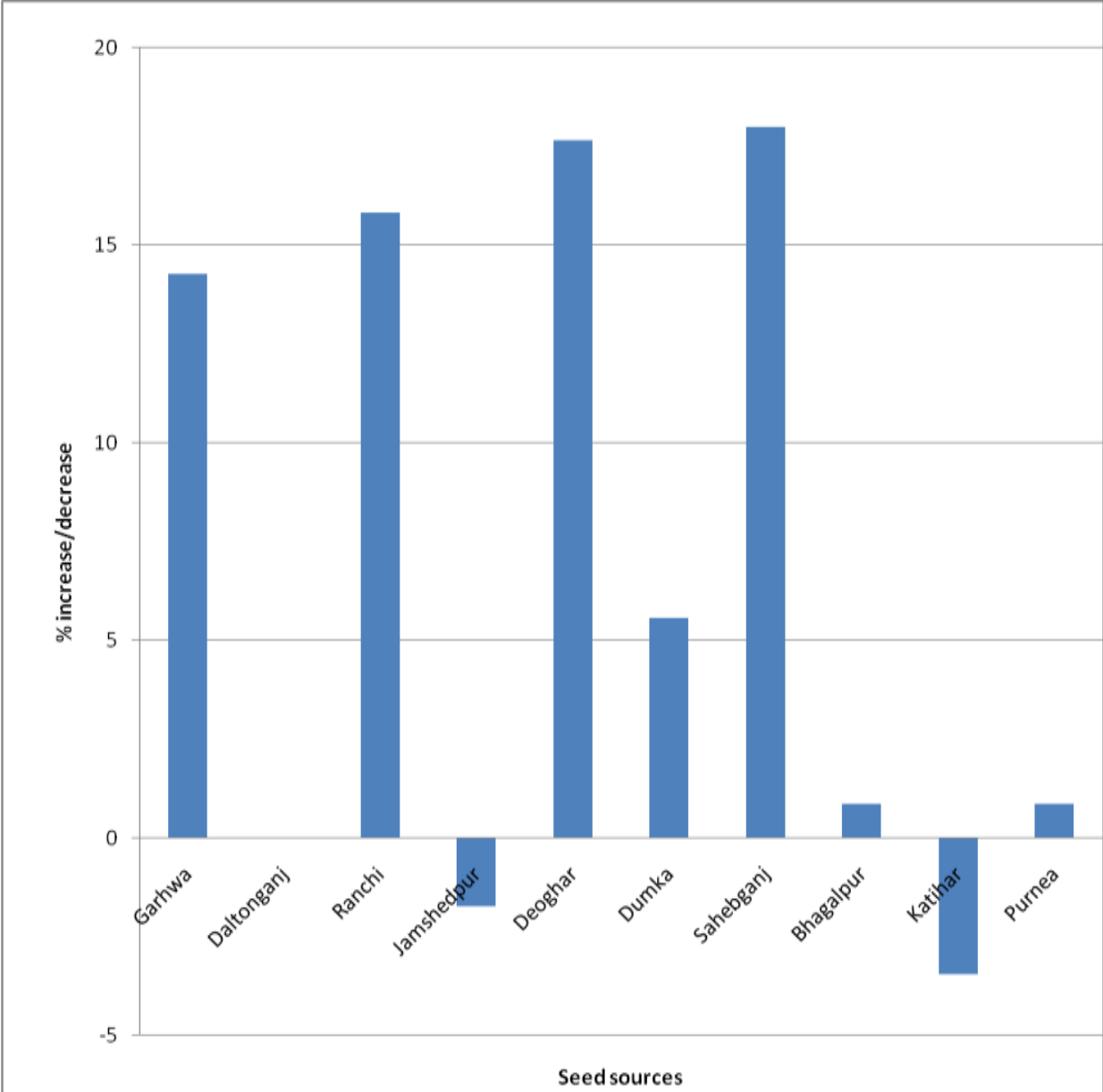


Figure 4.8: Percent increase/decrease of branch angle of different seed sources of Dalbergia sissoo in comparison to local Daltonganj seed source.

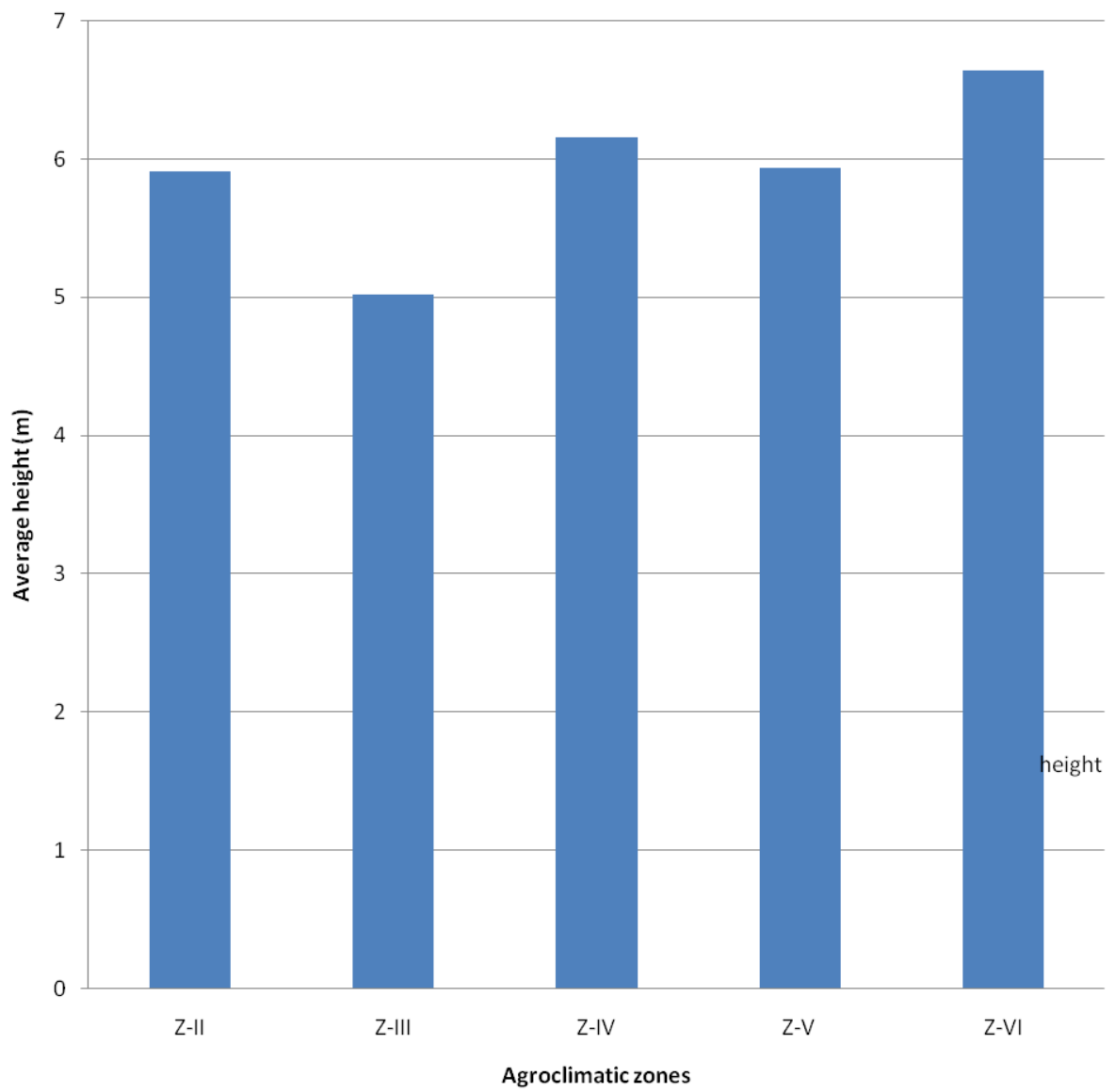


Figure 4.1 : Height of different Seed sources of *Dalbergia sissoo* at 3 years age

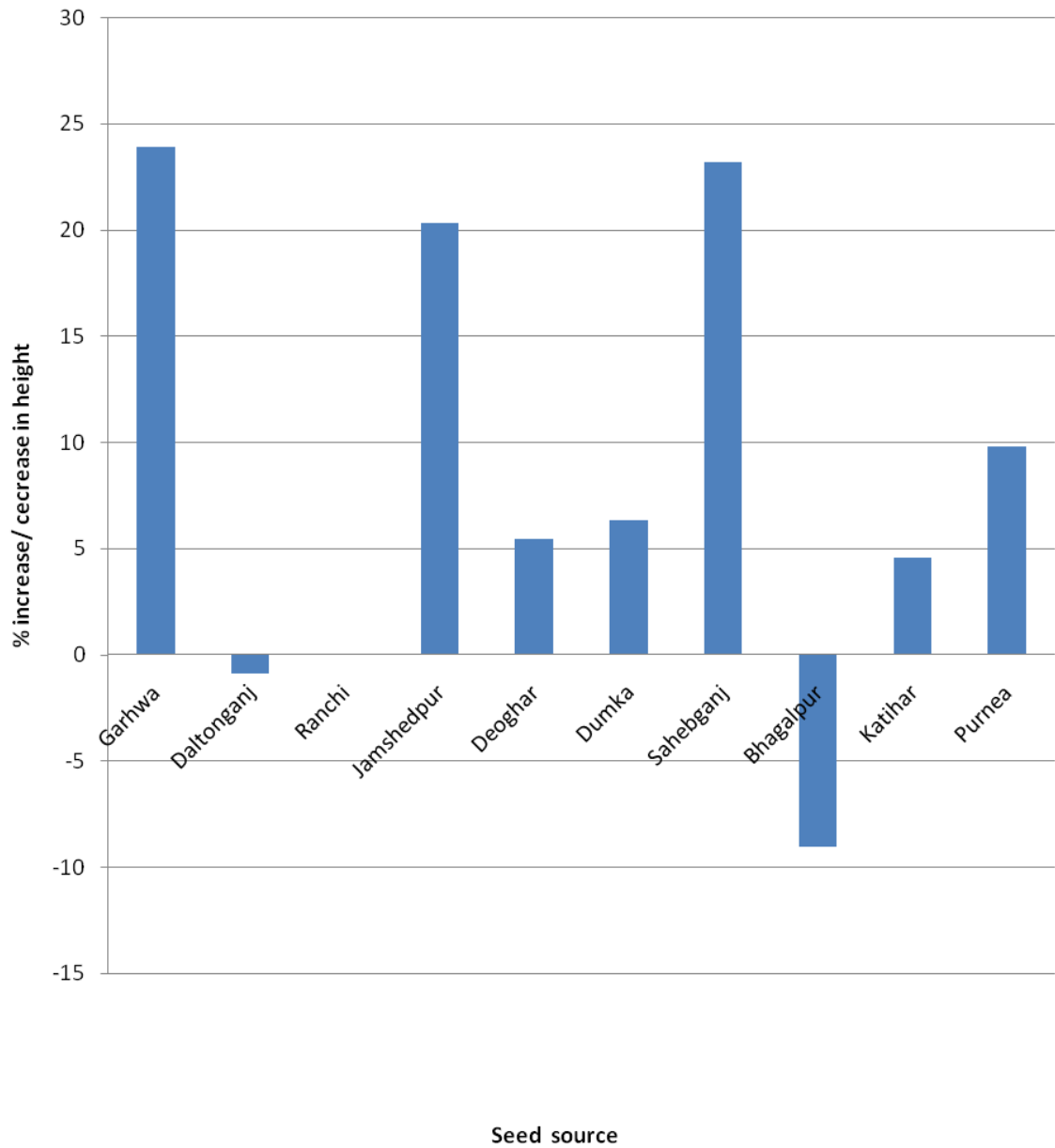


Figure 4.2: Percentage increase/decrease of height of seed source over local (Daltonganj) seed source.

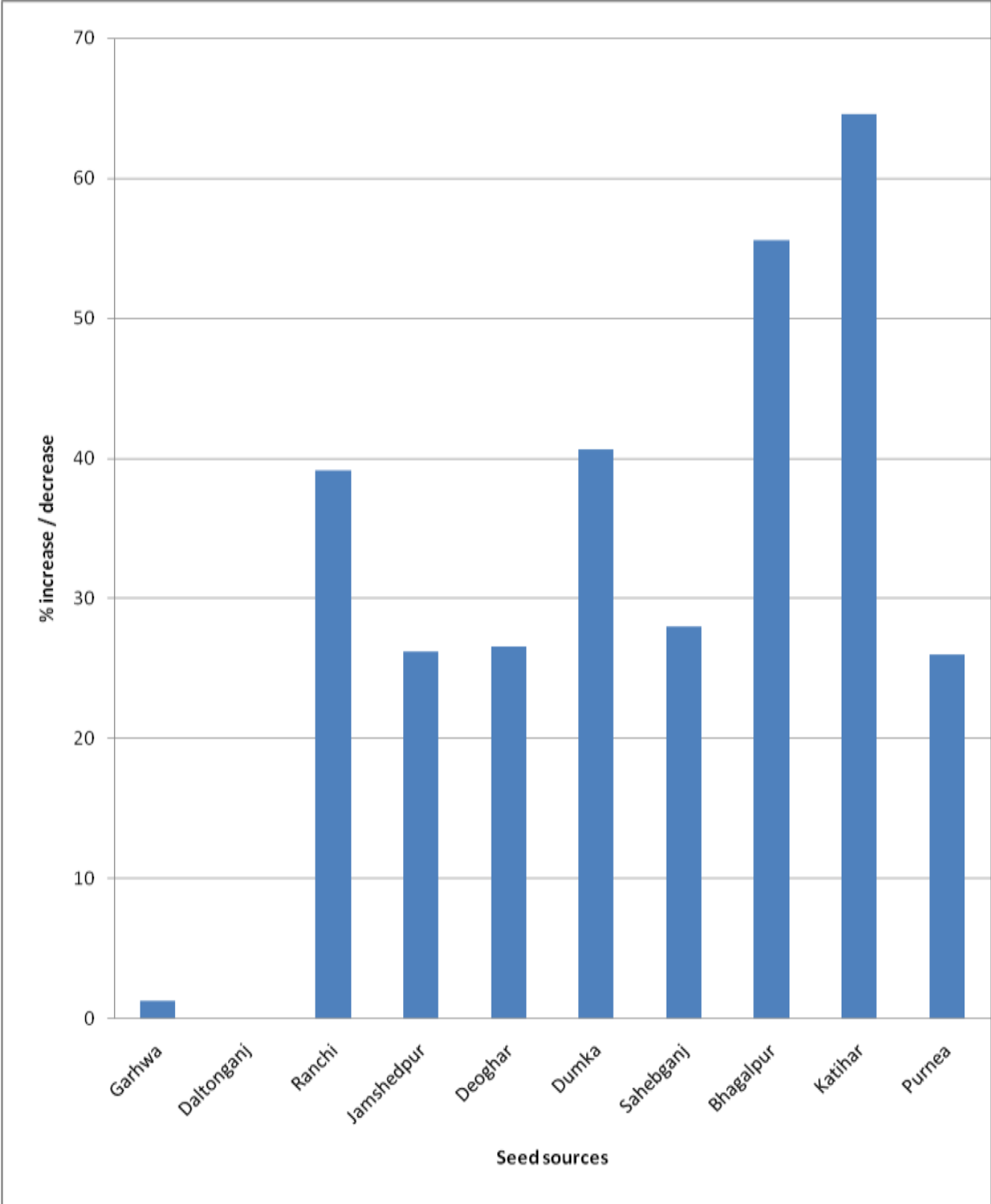


Figure 4.9: Comparative view of termite infestation on different seed sources of Dalbergia sissoo

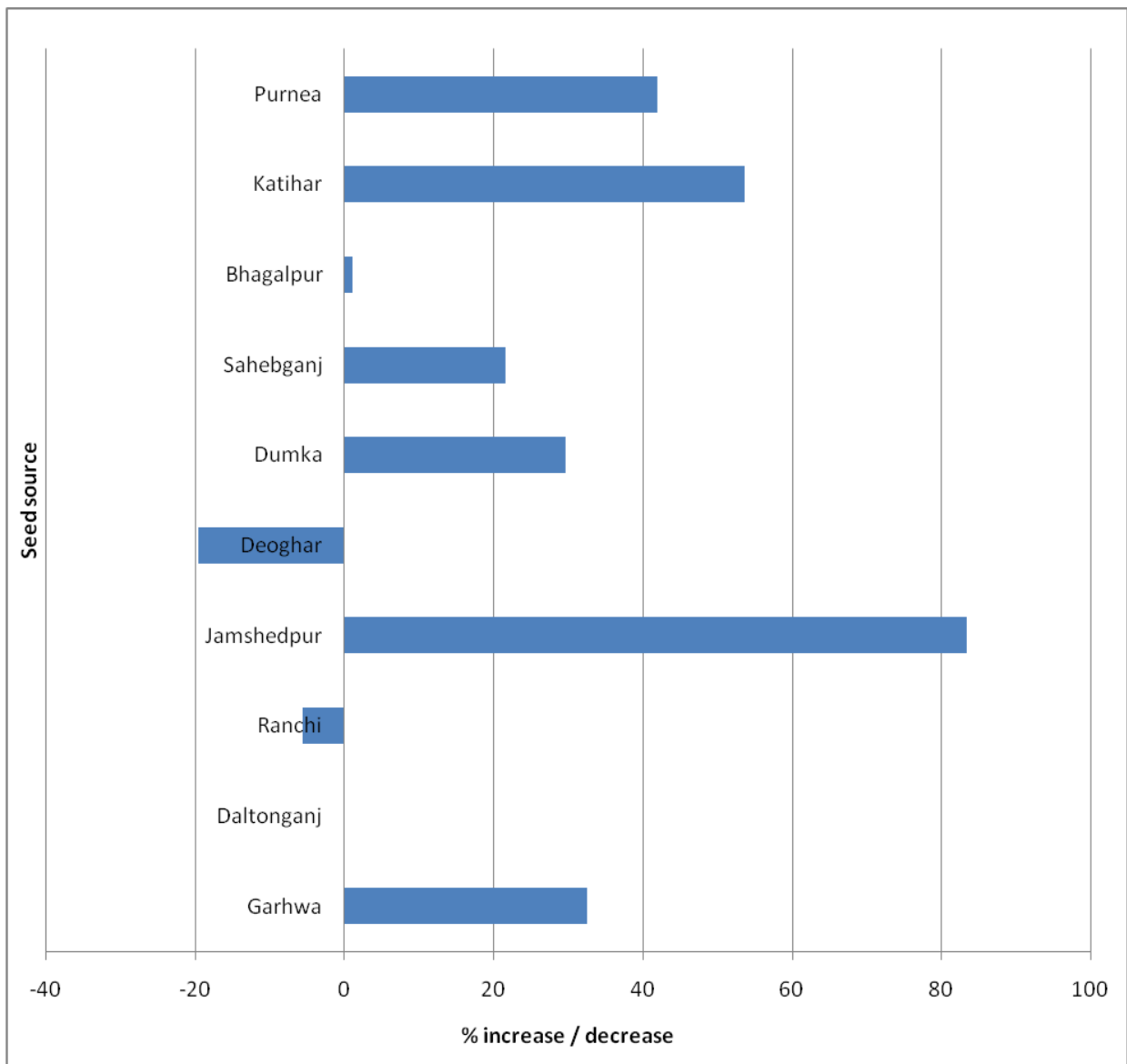


Figure 4.10: Comparative flowering status of different seed sources of Dalbergia sissoo in comparison to Daltonganj source

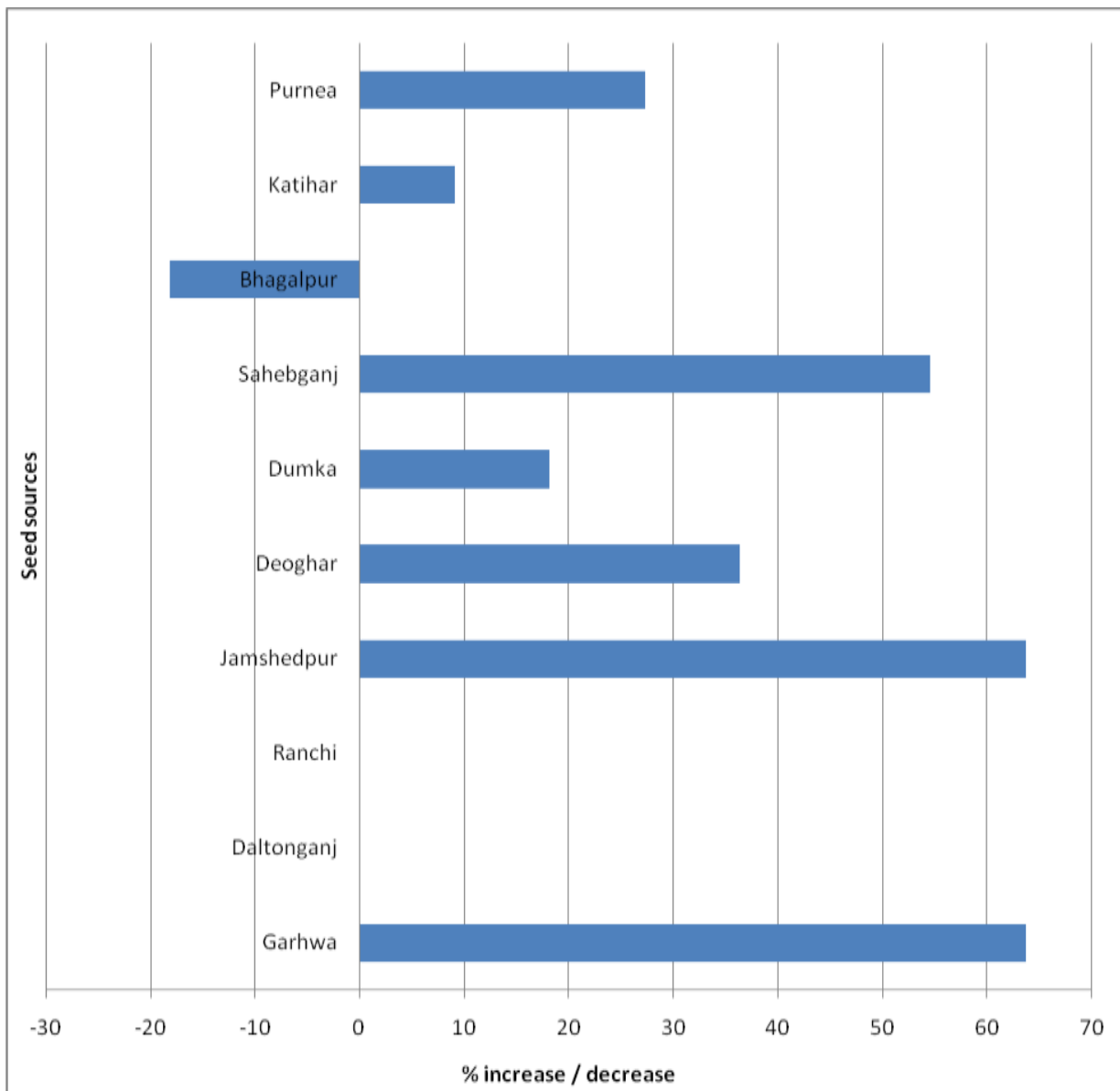


Figure 4.11: Bole volume production of Seed source of Dalbergia sissoo in comparison to local Daltonganj seed source.