EFFECT OF PROVENANCE AND PRE-SOWING TREATMENT ON SEED GERMINATION OF *Celtis australis* UNDER LABORATORY CONDITION IN GARHWAL HIMALAYA

Thesis by

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CERTIFICATE- I

This is to certify that the thesis entitled **"Effect of provenance and pre-sowing treatment on seed germination of *Celtis australis* under laboratory condition in Garhwal Himalaya"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science Forestry** in the Discipline of **Tree Improvement** of VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand is a bonafide research work carried out by **Mr. Sachin Negi, I.D. No. UUHF/20353** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

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Place: Ranichauri
Dated: 12/07/2023

CERTIFICATE-II

This is to certify that the thesis titled, **"Effect of provenance and pre-sowing treatment on seed germination of *Celtis australis* under laboratory condition in Garhwal Himalaya"** submitted by **Mr. Sachin Negi, ID.No. UUHF/20353** to VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, Pauri Garhwal, Uttarakhand, India in the partial fulfillment of the requirements for the degree of Master of Science **Forestry** in the discipline of **Tree Improvement** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner on **15.03.2023.**

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LIST OF ABBREVIATIONS USED

S. No.	Symbol/Notation	Meaning
1.	%	Percent
2.	/	Per
3.	°C	Degree Celsius
4.	C.D.	Critical Difference
5.	cm	Centimeter
6.	g	Gram
7.	m asl	Mean above sea level
8.	mm	Millimeter
9.	MGT	Mean Germination Time
10.	MDG	Mean Daily Germination
11.	S.D.	Standard Deviation
12.	SE(m)±	Standard Error Mean
13.	Min.	Minimum
14.	Max.	Maximum
15.	Temp.	Temperature
16.	PV	Peak Value
17.	S. No.	Serial Number
18.	ANOVA	Analysis of Variance

Abstract

Name	: Sachin Negi	**I.D. No.**	: UUHF/20353
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Title: "Effect of provenance and pre-sowing treatment on seed germination of *Celtis australis* under laboratory condition in Garhwal Himalaya"

Celtis australis is one of the important multipupose tree species in Western Himalaya belonging to the family Cannabaceae. It is the multipurpose tree grown for fodder, fuel and timber etc. The present investigation, **"Effect of provenance and pre-sowing treatment on seed germination of *Celtis australis* under laboratory condition in Garhwal Himalaya",** was carried out in the Forestry laboratory, College of Forestry, Ranichauri, Tehri Garhwal. In the study, fruits (drupes) were collected from 10 different seed sources (Srinagar, Tilwara, Nainbagh, Naranbhagar, Barkot, Kot, Devikhet, Maun gaon, Sonprayag, and Bhatwari) from the Garhwal Himalaya region. Pre-treatment with GA_3 growth hormone having five different concentrations (500 ppm, 750 ppm, 1000 ppm, 1250 ppm, and 1500 ppm) was conducted under laboratory conditions to enhance the seed germination and growth of *Celtis australis*. Among the morphological variations of fruit, maximum values of fruit length, fruit thickness, and fruit weight were recorded in the Tilwara seed source. The maximum fruit width was recorded in Kot, followed by the Tilwara seed source, whereas the Bhatwari seed source showed the highest value for fruit moisture percent. Seed length and seed thickness were recorded at their maximum in the Tilwara seed source. Pre-treatment on seed germination showed significant variation among all the seed sources. Overall best seed germination percentage, germination value, peak value, mean daily germination and germination speed were recorded in seed source Srinagar with 1250 ppm GA3 concentration. Plumule and radicle length were recorded maximum in the Srinagar seed source with 1250 ppm GA3 concentration and Bhatwari with 1250 ppm GA_3 concentration. During the investigation, it was concluded that the Tilwara seed source proved to be the best regarding morphological characteristics among all seed sources. The Srinagar seed source with 1250 ppm concentration showed the best results in relation to seed germination and growth parameters.

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शीर्षकः ''गढ़वाल हिमालय में प्रयोगशाला की स्थिति के तहत सेल्टिस ऑस्ट्रेलिया के बीज अंकुरण पर उद्‌भव और बुवाई पूर्व उपचार का प्रभाव''

खड़ीक (सेल्टिस ऑस्ट्रालिस) पश्चिमी हिमालय में कैनाबेसी कुल का महत्वपूर्ण बहुउद्देशीय वृक्ष प्रजातियों में से एक है। यह चारा, ईंधन और लकड़ी आदि के लिए उगाया जाने वाला बहुउद्देशीय वृक्ष है। शीर्षक ''गढ़वाल हिमालय में प्रयोगशाला की स्थिति के तहत सेल्टिस ऑस्ट्रेलिया के बीज अंकुरण पर उद्‌भव और बुवाई पूर्व उपचार का प्रभाव'' के अन्तर्गत वानिकी महाविद्यालय की प्रयोगशाला में वर्तमान परिक्षण किया गया था। अध्ययन में गढ़वाल हिमालय क्षेत्र से 10 विभिन्न बीज स्रोतों (श्रीनगर, तिलवाड़ा, नैनबाग, नारायनबगड़, बड़कोट, कोट, देवीखेत, मौण गांव, सोनप्रयाग और भटवाड़ी) से फल (ड्रूप्स) एकत्र किए गए थे। खड़ीक (सेल्टिस ऑस्ट्रालिस) की उपज को बढ़ाने के लिए बीज अंकुरण पर जिवरलिक एसिड (जी.ए.$_3$) पूर्व–उपचार करते हुए वृद्धि हारमोन जी.ए.$_3$ की 5 सांद्रताओं से प्रयोगशाला परिवेश में बीज अंकुरण का शोध कार्य किया गया (500 पीपीएम, 750 पीपीएम, 1000 पीपीएम, 1250 पीपीएम, और 1500 पीपीएम) प्रयोगशाला तहत आयोजित किया गया था। फलों की रूपात्मक विविधताओं के अन्तर्गत, तिलवाड़ा बीज स्रोत में फलों की लंबाई, फलों की मोटाई और फलों के वजन में अधिकतम मान प्राप्त किए गए। अधिकतम फल की चौड़ाई कोट बीत स्रोत से प्राप्त की गई, तदोपरान्त तिलवाड़ा बीज स्रोत में नाई गई जबकि भटवाड़ी बीज स्रोत में फलों की नमी प्रतिशत का उच्चतम मान प्राप्त किया गया। तिलवाड़ा बीज स्रोत में बीज की लंबाई और बीज की मोटाई के अधिकतम अधिकतम मान प्राप्त किए गए। बीज के अंकुरण पर पूर्व–उपचार में सभी बीज स्रोतों में महत्वपूर्ण भिन्नता दिखाई। बीज अंकुरण प्रतिशत, अंकुरण मान, शिखर मान, औसत दैनिक अंकुरण, अंकुरण गति श्रीनगर बीज स्रोत से 1250 पीपीएम जी.ए.$_3$ सांद्रता के पूर्व उपचार अधिकतम पाई गई 1250 पीपीएम जी.ए.$_3$ सांद्रता से भटवाड़ी बीज स्रोत में प्लम्यूल लंबाई और रेडिकल लंबाई अधिकतम प्राप्त की गई थी। शोध से यह निष्कर्ष निकालता है कि तिलवाड़ा बीज स्रोत सभी बीज स्रोतों में से रूपात्मक विशेषताओं में उत्कृष्ठ है। श्रीनगर बीज स्रोत से वृद्धि हारमोन जी.ए.$_3$ के परिक्षण द्वारा बीज अंकुरण और विकास मानकों के सर्वोत्तम परिणाम प्राप्त किए गए।

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INTRODUCTION

The tree improvement programmes which are going throughout the world provides us a definite and known source of the seeds, saplings or the seedlings for the better establishment of the forest. Its main aim is the improvement of the heritable, usefulness of the forest tree population in one hand and maintaining the genetic diversity on the other hand. The genetic improvement is working only at the basic population level than the improvement of breeds and the inbred lines of the forest trees. All around the world, tree testing program are linked with the definite range of silviculture system which are most commonly integrated with the plantation. Tree improvement programme are designed not only for the organization's schedule of planting, yearly budget and cultivation goals but also knowing for the life history and the species range. **(Tiwari *et al.*, 2021)**

Foresters in the past have seen agroforestry mainly in the terms of improving the supply of forest products; agriculturists have seen it as a logical extension of traditional intercropping practice, as an aid to soil conservation measures, and as plantation agriculture. In rural development, however, the improvement of land use systems and thus of rural incomes and well being is a primary objective. Thus in broader sense, the major function of agroforestry is associated with sustainability for the farmers, stability of resources, population and income, and minimization of risk. The objective of sustainability is probably the most important function of agroforestry as it involves a symbiosis between the properties of the ecosystems and the management activity that results in no decline and relatively stable outcomes **(Chavan *et al*., 2015).**

However, great success has been achieved in enhancing tree species productivity through different plant improvement techniques. Therefore, it is pertinent to assess the success of provenance selection on productivity of multipurpose tree species. The high biotic pressure, such as indiscriminate and unscientific loping and pruning have severely affected growth, development, quality **(Kumar *et al*., 2016b)**

The natural variation present in different geographical regions induces variation in plant characters in a particular species; as a consequence, plant depicts variation in its character in new region compared to the original geographical region. In general, improvement in plant character through provenance selection is of great significance

for meeting afforestation needs, which can provide greater climatic and economic benefits such as controlling soil erosion, mitigating climate change, improved carbon stock and provision of fuel wood, fodder, fruit and timber **(Oliveira *et al.*, 2015).**

Celtis australis Linn. locally known as *Kharik*, family Cannabaceae is an indigenous species of the Western Himalaya **(Singh *et al.*, 2006),** Mediterranean region and southwestern Asia **(Quattrocchi, 2000)**. It has a fairly wide range of distribution that extends eastward to Nepal and is commonly cultivated in N-W Himalayan region (J&K, H.P. and Uttarakhand) and parts of the North East Hill region. Throughout the globe, multipurpose species are subjected to severe anthropogenic pressure making them less productive with large number species are threated with extinction **(Amagnide *et al.*, 2015).** The indiscriminate harvest for fuelwood, fodder, timber and other uses have severely affected growth, quality and development of plants **(Kumar *et al.*, 2014, Kumar *et al.*, 2016a).** Celtis is truly a multipurpose tree grown for fodder, fuel, timber and various other uses in or around agricultural fields in rainfed agriculture and plays a vital role in socioeconomic structure of hill people by supplying highly palatable, nutritious and tannin-free green fodder particularly during the period of scarcity of green fodder to livestock **(Yadav and Bisht, 2013).** It is commonly cultivated in Himachal Pradesh and Uttarakhand as an agroforestry tree-crop. *C. australis* is a moderate sized deciduous tree attains approximate 25 m height. It grows well in the region with the maximum shade temperature up to 38^0C and temperature as low as -8^0C and rainfall from 1200-2500 mm. This broad leaved species plays a vital role in the socio-economic structure of hill people and hill-farming by supplying highly palatable, nutritious and tannin free green fodder for livestock during periods when other green material is in short supply **(Singh, 2004).** Crown is irregular, round, spreading, moderate, fast growing and medium texture. Leaves are alternate, simple, serrate, ovate, bowed, pinnate, reticulate, deciduous and green. Bark smooth, light grey, somewhat warty and a wide, broad, rounded canopy, throughout the year fading to a pale yellow before falling in autumn. Flowers are inconspicuous and not showy. Fruits are tiny, round, fleshy, purple hang in short clusters and are extremely popular among birds and other wildlife. Fruit, twigs, or foliage produces high amount of litter. Trees can be very long- lived, perhaps to 1000 years. Plants in this genus are notably resistant to honey fungus. **(Yadav and Bisht. 2015)**

Timber of *Celtis* is excellent and used for making tool and whip handles, cups, spoons, agricultural implements, etc **(Bhatt and Verma, 2002).** Despite its great importance, the efforts for the genetic improvement of *Celtis australis* are scanty. There are about 60 species of Celtis in temperate and tropical regions. **(Luna, 1996)**. Indian traditional medicine uses the plant for treating bone fractures, pimples, contusions, sprains, and joint pains. Humans have relied on plants for many years for natural products to maintain their health. *Celtis australis* is an important agroforestry species on a wide range of sites in Garhwal Northwest Himalaya region **(Gaur, 1999).**

Flowering, fruiting and sprouting of new shoots vary considerably with elevation and climatic differences, may also vary from year to year in some localities. The old leaves are shed in December- January, while the young shoots appear from March to April. The small greenish flowers appear with the new leaves and trees at the foothills, start flowering in early March. Those located at higher elevations usually flower late in April **(Luna, 1996).** The fruits are formed rapidly after flowering, and reach full-size by June- July **(Yadav and Bisht, 2015).**

In order to improve the plant growth and productivity, several techniques such as breeding, biotechnology and vegetative propagation has been tested and adopted for different tree species. However, selection of suitable species followed by the selection of suitable provenance within species has been considered as one of the most important tool to improve tree characters. Moreover, provenance selection in tree species improved growth and carbon stock, and also provide greater resilience against climate change **(Whittet *et al*., 2016).**

Seed treatment is to ensure fast and uniform germination **(Azad *et al*., 2006).** Stratification, moist chilling or cold stratification is widely used for breaking seed dormancy and increasing the rate of germination percentage of dormant seeds of many species **(Wang and Berjak, 2000).** Suitable pre sowing techniques of seed germination can enhance germination rate and over all process **(Koirala *et al*., 2000; Alamgir and Hossain, 2005; Azad *et al*., 2006).**

Different plant regulator treatments have also been tried to improve the seed germination in many tree species with varying success. Gibberellins (GA3) are the hormones proposed to control primary dormancy (the form of dormancy that is acquired during seed development) by inducing germination **(Hilhorst and Karssen, 1992).**

Gibberellic acid (GA3) is an exogenous growth regulator that promotes germination by stimulating the activation of food-mobilizing enzymes **(Hartman and Kester, 2009).** Seed dormancy is due to several factors and may persist in definitely unless certain specific treatments are given.

Keeping in view the above mentioned facts, This study was aimed to study the effect of provenance and pre- sowing treatments on germination of *Celtis australis* an economically important tree with following objectives:

1. Morphological variation in seeds of *Celtis australis* collected from different provenances.
2. Effect of genetic variation on fruit and seed character of *Celtis australis.*
3. Effect of pre- treatment on seed germination and growth of *Celtis australis* under laboratory conditions.

REVIEW OF LITERATURE

"Provenance" is a synonym for "origin" or "source". The word has been used commonly by tree breeders to mean "ultimate origin". A provenance test is an experiment in which seeds are collected from number of widely scattered stands and seedlings are grown (Wright, 1976). The literature pertinent to the topic entitled "Effect of provenance and pre-sowing treatment on seed germination of *Celtis australis* under laboratory condition in Garhwal Himalaya." is given in this chapter.

1. **Effect of seed source on fruit and seed morphology.**

Roy *et al.* (2004) found a wide range of variability for cone traits cone length, cone width, fresh weight and number of seeds per cone, seed traits (1000 seed weight, seed length, seed width) and nursery traits germination percent, survival percent, days taken for bud break, collar diameter, one year extension growth) among provenances of *Pinus roxburghii.*

Sheikh and Matin (2007) reported on *Dalbergia sissoo* Roxb. is a fast growing, nitrogen fixing, deciduous tree used in agroforestry, afforestation programmer and farm forestry. Morphological characteristics of the fruits and seeds, seed germination and seedling growth performance of the species were studied in the nursery. The length, breadth, thickness and weight of the fruits and seeds were measured and were found highest in 4-seeded and lowest in 1 -seeded fruit.

Sankhyan *et al.* (2008) studied morphological variations in *Grewia laevigata* revealed that some of the traits, viz., branch length, number of leaves per branch, branch nodal length, leaf length, leaf area and seed weight, exhibited variation between the sites but not among the trees. However, leaf width, number of seeds per fruit, seed length and seed width showed non-significant variations. Genotypic correlation coefficients were found greater then phenotypic for almost all the morphological traits.

Singh and Bhatt (2010) showed that the seeds collected from 19 different altitudinal sources ranging from 120 to 1130m were evaluated for pod / seed morphology, seed weight, seed germination and seedling growth in nursery and also in field trial. Considerable morphological and physiological variations between provenances for all the pod and seed traits including germination, plant height and

collar diameter were found among the seed sources. Among various parameters, seed weight and plant height were most heritable traits, followed by genetic advance and genetic gain. Characters those showed greater genetic influence can be directly screened/ selected for the improvement of this potential tree species in Central Himalaya, India for raising quality plating material. Significant ($P < 0.05$) variations were observed in pod length, breadth and number of seeds per pod among seed sources. Co-efficient of variation (CV %) which helps in comparing the variability for different characters exhibited that there was 75.8% difference between lowest and highest values for pod length; 92.6% in pod breadth; 81.5% number of seed per pod, irrespective of seed sources.

Danquah *et al.* (2011) investigated the pattern of leaf morphometric variation and similarities among populations of two species of African mahoganies (*Khayain ivorensis* and *Khayaan thotheca*) and suggested that two cluster of populations of *Khayain thothera* and one cluster of *Khayain vorensis* were morphologically related . Moreover, it was indicated that the two species of khaya spp. might have existed as separate species, although their distributions overlap in some ecological zones. However, it was being recommended that comprehensive studies involving molecular analysis should be performed on the two species of African mahogany.

Mughal and Thapliyal (2012) carried out a study in Jammu and Kashmir (India) and twelve sites spread across the entire state were selected. Variability studies in different seed sources of *Cedrus deodara* with respect to cone, seed and seedling traits were studies. The studies revealed significant variation in different cone and seed characteristics studied. Besides, a negative correlation existed in cone diameter and cone weight with altitude. Seed morphological characters seed length, width and weight of the study reveals that for delineating seed zones, provenance selection should be within an altitudinal range of 1,500-1,900m and northern aspect seed source be preferred.

Gupta *et al.* (2016) investigated variation in seed and seedling traits of *Pongamia pinnata*. They reported that among the all seed sources, Jhargram source showed superiority regarding seed size and pod size. Seed width negatively correlated with latitude while seed length and seed weight positively correlated with longitude. They concluded that pod size and seed size can be an important criteria for selection of seed sources.

Mendonca *et al.* (2016) studied the morphological characters of fruits, seeds and seedlings, characterized the germination process and verifed that the seed position in the fruit interferes with the seed germination of *Poincianella pyramidalis*. The fruits were collected from five trees in the Castro Alves, Bahia – Brazil in the area near the remnants of Caatinga sensu stricto and Deciduous Forest. The fruit of Poincianella pyramidalis is a type of legume, polyspermic, dehiscent, measuring on average 9.4 ± 0.08 cm in length and can contain up to 8 seeds per fruit, being the average number of seeds, apparently viable fruits per 100 ± 280 29.8. The seed is ellipsoid, yellowish brown color and smooth, polished and hard, being provided testa and internal tegument, with a length of 1.25 ± 0.004 cm. The embryo is axis, invaginated and straight and there was no presence of endosperm. The weight of 1000 seeds were 106.8 ± 12.4 g.

Sundaram *et al.* (2018) studied the variation in *Prosopis juliflora* seeds. They found that highest 2D surface area, seed length (0.365 cm), seed perimeter (1.456 cm) and seed weight (0.225 gm) recorded in Keezhakaral. Maximum weight of 100 seed noticed in Tirunelveli source. Highest (23.05 cm) pod length recorded in Sivaganga The highest (29) number of seed per pod recorded in Rameshwaram. Higher (94.50) viability percentage found in Tuticorin source followed by Tirunelveli (93), Ramnad and Rameshwaram (92). Highest germination percent noticed in Pollachi (90.5%) and Rameshwaram (92%).

Andrew *et al*. (2021) Showed the data on *Entandrophragma bussei* (wooden banana) is a high value indigenous multipurpose tree species prioritized for domestication in Tanzania. The study evaluated the diversity in fruit and seed morphology of three wild populations of *E. bussei* found in three agroecological zones of Tanzania. Data on fruit (length, width, weight and number of seeds per fruit) and seed (length, width and weight) traits were evaluated. To detect differences in means among the populations, one-way Analysis of Variance (ANOVA) was performed. There were variations in fruit and seed morphological traits among the studied populations. Ruaha population had significantly higher fruit length (19.31 ± 0.1 cm), width (7.71 ± 0.12 cm) and number of seeds per fruit (22 ± 0.48) than Kigwe (15.65 ± 0.14 cm, 4.85 ± 0.17 cm, 20 ± 0.45), and Tarangire (16.84 ± 0.1 cm, 5.40 ± 0.12 cm, 20 ± 0.37) populations. Ruaha (62.46 ± 1.37 g) and Tarangire (60.71 ± 1.12 g) had significantly heavier fruits than Kigwe (56.53 ± 1.28 g). Kigwe population had significantly higher seed width (1.80 ± 0.01 cm) and weight (0.83 ± 0.01 g) than Ruaha

(1.75 ± 0.01 cm, 0.75 ± 0.01 g) and Tarangire (1.65 ± 0.01 cm, 0.77 ± 0.01 g) populations. Among the populations Tarangire had higher seed length (9.60 ± 0.06 cm) than the rest.

2. Effect of seed source on genetic components.

Sachan *et al.*, (2006) studied altitudinal variations in cone and seed characteristics of *Pinus kesiya*. They reported that highest genotypic variance (83.22), genotypic coefficient of variation (83.54), phenotypic coefficient of variation (92.45) and heritability (90.36) recorded for number of grooves. Minimum genotypic variance (0.06), genotypic coefficient of variation (0.10), phenotypic coefficient of variation (0.13), and heritability (75.00) recorded germination at 30^0C. Maximum (51.55) genetic advance recorded for seed thickness and minimum (0.72) for germination at 30^0C. Lowest genotypic variance (0.06) also recorded for 100 seed weight and heritability (75.00) for germination at field.

Loha *et al.* (2008) experimented on *Millettia ferruginea* (Hochst.) Baker a potential agroforestry species endemic to Ethiopia. No documented information exists about genetic variation in this species, thus baseline information is needed to initiate improvement program. They quantified variations in seed size, germination and seedling growth at nursery stage based on seeds collected from six sites across the natural range of distribution of the species in Ethiopia. All seed- and seedling-related traits exhibited highly significant differences among seed sources (P \0.01), and the magnitude of genetic variation was substantially higher (77–99%) than the environmental variation. The genetic advance as percent of the mean was higher for germination capacity (69.4%) and seed weight (31.7%) than that of other traits, suggesting that the population means for these traits may be changed considerably by selecting the superior 5% of the genotypes. There were strong phenotypic (rp = 0.81) and genotypic (rg = 0.89) correlations between seed width and seed weight, so also between seedling height and root collar diameter (rp = 0.95 and rg = 1.00). They concluded that the existence of substantial genetic variation, which can be utilized to initiate tree improvement program of the species and for gene conservation in seed banks.

Aslam *et al.*, (2010) investigated variability in cone and seed charterers of *Pinus wallichiana*. They reported that genotype correlation in all traits was greater than the phenotypic correlation and they revealed that cone weight, seed per cone, seed length are

important character because of the direct effect on 100 seed weight. These trait given to priority while selecting genotype character.

Divakara *et al.* (2010) experimented screening of twenty-four candidate plus trees from naturally available *Pongamia pinnata* genetic resources was carried out to elucidate the genetic variation and relationship of pod and seed traits on germination capacity to select the best planting material for higher productivity. The experiment conducted at Forest Research Centre, Institute of Forest Productivity Mandar, Ranchi during 2005- 2006. Variability studies reveled that, genotype CPT-19 recorded maximum values for six traits viz. pod length (65.64 mm), 100-pod weight (542.35 g), 2D surface area (351.18 mm2), seed length (27.93 mm), 100-seed weight (202.89 g) and total oil content (44.33%). However, maximum pod thickness (12.72 mm), seed length (17.49 mm), pod-seed ratio (2.89) germination capacity (94.67%) was recorded by the genotype CPT-6. The phenotypic and genotypic coefficients of variations were also close to each other for all traits, but 100-pod weight and 100-seed weight exhibited higher phenotypic coefficients of variation and genotypic coefficients of variation than the other traits. Estimates of broad sense heritability ranged from 0.82 (for seed length) to 0.98 (for 100-pod weight), genetic advance as percent of the mean ranged between 12.30% and 46.04% with seed length giving the lowest value and 100-pod weight giving the highest value. Germination capacity exhibited positive significant correlation with pod width, 100-pod weight, 2D surface area and seed width at both genotypic and phenotypic level. However, pod length, pod thickness and 100-seed weight expressed positive significant correlation only at genotypic level. Path analysis of pod and seed traits revealed that, the 100-pod weight (0.909) is the most pronounced character contributing directly to germination capacity followed by seed length (0.785) and pod length (0.324).

Singh and Thapliyal (2012) investigated variation in cone and seed characters in *Pinus wallichiana* across natural distribution in western Himalayas. They reported that wide range of genetic variation observed in this study. Highest heritability (0.87) and genetic gain (34.23) recorded in seed weight. Cone fresh weight showed maximum genotypic variance (259.64) and phenotypic variance (717.13) while minimum (0.02) genotypic variance recorded in seed width and minimum (0.37) phenotypic variance recorded in seed length.

Singh *et al.* (2015) investigated variability in cone, seed and seedling characteristics of *Pinus kesiya* Royle ex. Gordon. They reported that, seeds per cone showed highest genotypic variance (299.47), phenotypic variance (322.57), heritability

(0.93) and genetic advance (34.40). Lowest genotypic variance (0.04) and phenotypic variance (0.07) recorded for seed diameter. Maximum genotypic coefficient of variation (34.69) and phenotypic coefficient of variation (36.64) noticed in seedling diameter while lowest in seed germination (4.94 and 8.50 respectively). Minimum (0.34) heritability recorded for seed germination. Seedling diameter exhibit maximum (67.66) genetic gain and minimum (5.93) genetic gain was reported in seed germination.

Sudrajat (2015) studied white jabon (*Anthocephalus cadamba* [Roxb.] Miq.), at the population level. Eleven natural populations were examined for variations in fruit, seed, and seedling morphophysiological characteristics. Analysis of variance revealed significant differences among populations for all the characteristics studied, except the radicle length. Genotypic variance and genotypic coefficient of variance for all fruit, seed, and seedling characteristics were found to be higher than corresponding environment variance and environment coefficient of variance, indicating that the genotype explained most of the variance for these characteristics. In particular, high heritability values coupled with high genetic gain were found for fruit weight, seedling height, root collar diameter, sturdiness index, leaf number, leaf length, and leaf width. Principal component analysis and hierarchical clustering of various characteristics of fruit, seed, and seedling revealed that most of the geographically distant populations are genetically close. Since these characteristics appear to be under strong genetic control, considerable scope exists for exploitation of heritable additive genetic components for future breeding and improvement in white jabon.

Ravi *et al.* (2021) reported *Moringa oleifera* Lam. (common name: drum stick, horseradish tree) belongs to the monogeneric family, Moringaceae. Immature pods, fresh leaves and flowers of *M. oleifera* are used for culinary purposes. The leaves and young pods are a rich source of minerals and vitamins. In the present study, 23 genotypes of drumstick, which were selected based on superiority of yield/tree from 120 genotypes surveyed in South India were subjected to analysis morphology, yield and quality attributes and found they are substantially varying thus necessitate further analysis. Diversity analysis based on the coefficient of variation (CV), genotypic coefficient of variation (GCV), environmental coefficient of variation (ECV), phenotypic coefficient of variation (PCV) and heritability were determined. Quantitative fruit traits such as fruit length (30.56–127.57 cm), fruit weight (72.22–163.27 g), fruit breadth (3–8 cm), number of fruits/tree (NF/T) (320–1000), and number of seeds/ fruit (NS/F) (11–29) varied among the genotypes. Correlation studies revealed that the fruit yield had a significant,

positive correlation with the number of fruits per tree, length of fruit and single fruit weight. The estimate of PCV was slightly higher than the GCV for all characters studied, indicating that the apparent variation is not only genetic but also influenced by the growing environment in the expression of the traits. Heritability was greater than 90% for all characters studied. The overall analysis outcome of the study emphasizes that selection of high yielding genotypes should give due weightage to the number of fruits per tree and single fruit weight.

Chen *et al.* (2022) experimente on four Chinese provenance of *Xanthoceras sorbifolium* Bunge evaluated at the population level. Seed samples were collected from four provenances in China and examined for variations in morphometric traits, chemical components, and seedling growth in the nursery stage. There were significant differences in the seed length, width, dry weight, 1000-seed weight, oil concentration, Mg and Cu concentrations, root biomass, and root–stem biomass ratio. The largest seed in terms of size and weight was from Ongniud Banner, Inner Mongolia (OB), but these seeds also had the lowest seed oil concentration. At the end of the first growing season in the nursery, seedlings stopped growing one month earlier in height than in diameter. The provenance difference in height was significant at the first 2 months after sowing but disappeared later. Genotypic variance (Vg) was found to be higher than corresponding environmental (Ve) variance for seed length, seed width, seed dry weight, 1000-seed weight, diameter, and root biomass, indicating that these parameters were strongly inherited and there was ample scope for improvement. Moreover, correlations between seed and seedling traits and climatic and geographical factors were assessed. Some significant intercharacter correlations were found, such as between seed length, width and seed weight, between oil concentration and seed size, and between seedling height, diameter, and root biomass.

3. Effect of pre-treatment on seed germination and growth parameter

Sharma and Graves, (2004) studied the germination of seeds collected from several disjunct populations of *L. floridana* in 2002 and 2003. In 2002, ≤ 5% germination occurred when ripe drupes from Missouri and Florida were sown soon after collection. Effect of GA_3 (750 mg. L^{-1} for 24 hours) were assessed on stored drupes leached with water and on seeds excised from stored drupes. Germination percentage were 21 and 32 for leached drupes and excised seeds from Florida, respectively, but ≤ 5% germination occurred among germplasm from Missouri and among untreated

drupes from both provenances. Viability of ungerminated seeds among treatments ranged from 0% to 7%. In 2003, fleshy, apparently unripe drupes from Texas, which were scarified with H_2SO_4 and then treated with 1000 mg. L^{-1} GA_3 showed 48% germination (germination value = 3.9). Up to 29% germination (germination value =2.7) occurred when seeds were excised from unripe drupes from Arkansas and Missouri and then were treated for 24 hours with 750 or 1000 mg. L^{-1} GA_3.

Zare *et al.* (2011) investigated at improving seed germination of *Prosopis koelziana* and *Prosopis juliflora*, different treatments of seeds were conducted, including scarification with sulfuric acid 98% for 10 and 15 min, sandy paper, hot water for 5 and 10 min, potasium nitrate 0.1%, gibberellic acid at 250 mg·L-1 and 500 mg·L-1 and combinational treatment of scarification with gibberellic acid of 250 mg·L-1 and 500 mg·L-1. The results show that scarifications with sandy paper and sulfuric acids 98% were the most effective treatments on breaking seed dormancy and seed germination induction. Scarification with sulfuric acid 98% for 15 min was the best treatment. According to the positive effect of scarification and lack of reaction of seeds against KNO3 and gibberellic acid, the kind of seed dormancy was determined as exogenous.

Nosrati *et al*., (2013) found that the seed dormancy is an obstacle to revegetation and reclamation efforts, particularly in arid and semiarid environments. Therefore, the objective of this study was to determine the most effective germination pretreatment for *Haloxylon persicum*, a tall desert shrub or small tree. The experiment employed a completely randomized block design. Dormancy breaking treatments included scarification with 98% sulfuric acid for 10, 20, 30, and 60 minutes; debracting seeds; debracting + piercing seeds; stratification for 1, 2, 3 and 4 weeks; and leaching seeds in flowing water for 1, 2, 3, and 4 days. Results demonstrated that scarification with 98% sulfuric acid for 10 min was the most effective treatment which increased germination from 23.3% (control) to >82.6%.

Maku *et al.* (2014) assessed the effect of plant growth hormones viz: indole acetic acid (IAA), indole butyric acid (IBA), naphthalene acetic acid (NAA) and gibberellic acid (GA3), on seed germination and seedling growth of *Tetrapleura tetraptera* (Thaub). Seeds were collected from Akungba Akoko, Western Nigeria (Lat. 70 27’ N and 50 44’ E). Nine hundred and forty-five seeds (945) of T. tetraptera were

sown in germination trays containing washed-sterilized river sand in the screen house. Before sowing, seeds were treated with different plant growth hormones (IAA, IBA, NAA and GA3) at different rates (0.005g/ml, 0.01g/ml, 0.015g/ml, 0.02g/ml and 0.03g/ml). Germination count was taken daily and seedlings were later transferred to open nursery at two leaf stage and watered daily. Growth parameters such as height of the plant, collar diameter and number of leaves were taken fortnightly. The effect of different hormone concentrations were highly significant ($P \leq 0.05$) on mean height growth of T. tetraptera seedlings, seedlings collar diameter and number of leaves. Different growth hormone concentration had no significant ($P \geq 0.05$) effect on leaf dry weight, stem dry weight, root dry weight and total dry weight. However, IAA, IBA and NAA at low concentrations enhanced the growth of *T. tetraptera* seedlings. They,concluded that, IAA, IBA and NAA could be used for rapid regeneration of *T. tetraptera* in natural forest and GA3 should be excluded in the pre-treatment procedure of *T. tetraptera* prior sowing.

Aslam *et al.*, (2017) studied seed germination of *Pinus wallichiana.* The outstanding seed germination behaviour and growth characteristics observed in Lidder forest division. The highest mean germination value (4.81) and mean seed germination percent (81.50%) recorded in seeds treated with GA_3.

Asgari *et al.*, (2018) evaluated different methods of seed dormancy breaking for Chinese lantern (*Physalis alkekengi L.*), two experiments were conducted at laboratory and greenhouse conditions. The laboratory treatments were 22 different physical and chemical methods such as washing, stratification, scarification (sandy paper), sulfuric acid, gibberellic acid, potassium nitrate and the combination of both physical and chemical treatments. Eight of the best breaking seed dormancy treatments at the laboratory study were assessed at the greenhouse study. The results of the first experiment showed that all the treatments had significant effects on the measured traits. The highest germination percentage was shown in the combinational treatments (washing + gibberellic acid, sulfuric acid + potassium nitrate, scarification + gibberellic acid and scarification + potassium nitrate). These treatments led to 100% germination. The minimum mean germination time (MGT) was found in the washing + gibberellic acid (3.89 days), washing + potassium nitrate (4.42 days) and stratification + gibberellic acid (4.79 days) treatments. Sulfuric acid + potassium nitrate, washing + gibberellic acid, washing + potassium nitrate and stratification + potassium nitrate led to the

highest seed vigor. The results of the second experiment revealed that the best treatments in terms of emergence percentage (EP) in the greenhouse were sulfuric acid + potassium nitrate (92%) and sulfuric acid + gibberellic acid (89%). Also, the minimum mean emergence time (MET) was obtained in washing + gibberellic acid (10 days). The highest seed vigor was found in washing + potassium nitrate and sulfuric acid + gibberellic acid. Totally, washing + gibberellic acid, washing + potassium nitrate, sulfuric acid + gibberellic acid and sulfuric acid + potassium nitrate were the best treatments to break Chinese lantern seed dormancy regarding germination percentage, mean emergence time (MET) and seed vigor.

Bhat *et al.*, (2018) investigated cone, seed and seedling characteristics in silver fir. They noticed that stratification and altitude significantly influenced the germination percent, germination value and mean germination time. Altitude A_3 showed highest germination percent and germination value with minimum mean germination time among all the selected altitudes.

Mahdi *et al*., (2019) reported that seed germination and regeneration ecology of tree seeds are different because of the process of evolution and the influence of some environmental factors. Thus, determining factors of the germination rate and seedling emergence timing are understandable. Mainly they showed the impact of the pre-sowing treatments on the germination and seedling emergence timing of *Celtis tournefortii*, the native tree species in the Kurdistan region. Pretreatment included untreated seeds (control), fruit seed with exocarp, chemical scarification 5, 10 and 15 minutes, mechanical scarification, hot water soaking for 5, 10 and 15 minutes, cold stratification for 1, 2 and 3 months, Gibberellic acid with concentrations of 500, 1000 and 2000ppm for five minutes soaking, and water soaking for 1, 2 and 3 days. In their finding the best germination of seeds 46% was achieved from Stratification for 3 months, Mechanical scarification, and seed treated with concentration 500ppm of gibberellic acid). Whereas some treatments are reduced the seed germination of this tree species while soaking the seeds for 10 and 15minutes in H2SO4, normal water 1 and 2 days, and soaking in Hot water for 10 and 15minutes respectively. Moreover, the result showed that the seedling emergence are related to the seed sowing date where the suitable sowing date for this species was in winter and early spring season. Their findings showed important implication, particularly for the managers of the plant

nurseries, for developing a timetable for the suitable sowing time of the tree species seeds.

In one of the studies **Chaiyarat (2020)** found that germination rates were the same in both topsoil under the bamboo forest and fine sandy loam mixed with bamboo roots ($p = 0.134$). However, growth of seedlings was greater in topsoil under the bamboo forest than both fine sandy loam mixed with bamboo roots and pure sand ($p = 0.001$). The treatment of monastery bamboo seeds with potassium nitrate (KNO_3) 0.1%, smoking, gibberellic acid (GA_3) at 250 mg/L, 90% sulfuric acid (H_2SO_4) and untreated control showed that the germination, survival and growth of monastery bamboo was greater in KNO_3 and smoked, but H_2SO_4 killed all seeds after 15 mins with appropriate temperature of 4 - 5°C.

MATERIALS AND METHODS

The present study entitled **"Effect of provenance and pre-sowing treatment on seed germination of *Celtis australis* under laboratory condition in Garhwal Himalaya"** conducted in Forestry Laboratory of College of Forestry, Ranichauri, Tehri Garhwal, during 2022. The experimental details and procedures followed during the course of study have described under the following heads.

3.1. Description of experimental site

3.1.1 Location of experimental site

The experimental site, Forestry Laboratory, College of Forestry, Ranichauri Campus located 6 km away from Chamba-Rishikesh Road at an altitude of about 1850 m above mean sea level, lying between the latitude of $30^0$15" N and longitude of $78^0$30" E under mid hill zones in Garhwal Himalaya.

3.1.2 Laboratory conditions of experiment

The experiment was conducted under controlled conditions in Forestry laboratory, College of Forestry, Ranichauri. The seed germinator was used to conduct the test**.** During experiment, the temperature of the germinator was 25^0C.

3.2 Description of seed provenance

Seed source refers to the place from where the fruits (drupe) collected for the study. Seed source plays a vital role because it determines the phenotypic and genotypic quality of the seeds.

3.2.1 Location of seed source

During the course of study, ten seed sources selected from Chamoli, Pauri Garhwal, Tehri Garhwal, Rudraprayag and Uttarkashi districts of Uttarakhand**. (Table 2.1)**.

3.2.2 Time and season for fruit collection

Fruits were collected in the month of November and December (2021).

3.2.3 Collection of fruit

The fruit (drupe) of *Celtis australis* was collected from ten different provenances of Garhwal Himalaya, Uttarakhand.

Table 2.1: Description of seed source of *Celtis australis* in Garhwal Himalaya.

S. No.	Provenance	District	Altitude (m asl)	Latitude (N)	Longitude (E)	pH	EC (dS m^{-1})
1	Srinagar	Pauri Garhwal	592	$30^0$13’00	$78^0$47’57	7.45	0.173
2	Tilwara	Rudraprayag	784	$30^0$20’39	$78^0$58’36	6.64	0.283
3	Nainbagh	Tehri Garhwal	898	$30^0$34’14	$78^0$00’22	7.96	0.304
4	Narainbagar	Chamoli	1067	$30^0$07’48	$78^0$23’14	6.67	0.34
5	Barkot	Uttarakashi	1343	$30^0$48’21	$78^0$12’32	5.83	0.506
6	Kot	Pauri Garhwal	1415	$30^0$08’52	$78^0$42’07	6.67	0.27
7	Devikhet	Pauri Garhwal	1560	$29^0$54’36	$78^0$33’19	7.27	0.24
8	Maun Gaon	Tehri Garhwal	1584	$30^0$18’12	$78^0$23’32	5.73	0.186±
9	Sonprayag	Rudraprayag	1753	$30^0$37’43	$78^0$59’50	6.37	0.137
10	Bhatwari	Tehri Garhwal	1787	$30^0$36’50	$78^0$07’47	7.19	0.168

3.2.4 De-pulping

Mature fruit (drupes) of *Celtis australis* were allowed to dry in the sun for 24 hrs. Thereafter, seeds were soaked in hot water overnight, macerated on a wire mesh and rinsed with water to remove the pulp. Seeds tended sink to the bottom while the soft pulp material tended to float. The seeds were dried in the sun for 24 hrs.

3.3 Morphological characteristics of fruit

3.3.1 Fruit length

Each of provenance having 5 replications containing 20 fruits each and their length was measured with the help of vernier caliper.

3.3.2 Fruit width

Fruit width of 20 fruits in 5 replications from each seed source was measured with using vernier caliper.

3.3.3 Fruit thickness

Thickness of fruit collected from 10 different sources was measured with vernier caliper. 20 fruits in 5 replications were measured.

3.3.4 Fruit length/fruit width ratio

Length/width ratio was obtained by dividing the fruit length with fruit width and fruit width by fruit thickness.

3.3.5 Fruit weight

Fruit weight was determined with using electrical balance. 100 fruits in 5 replications from each seed source was recorded.

3.4 Morphological characteristics of seeds

3.4.1 Seed length

Each of provenance having 5 replications containing 20 seeds each and their length was measured with the help of vernier caliper.

3.4.2 Seed width

Seed width was measured with vernier caliper. 20 seeds in 5 replications from each seed source was measured.

3.4.3 Seed thickness

Seed thickness of 20 seed in 5 replications from each seed source was measured with vernier caliper.

3.4.4 Seed length / seed width ratio

Length/width was attained by dividing the seed length by seed width.

3.4.5 Seed weight

Seed weight per 100 seeds was recorded with help of electronic weighing machine.

3.5 Moisture content (%)

Fresh weight (M1) of the seed was recorded with help of electronic wing machine. Seed was oven dry for 17 hours at 107^0 C till constant weight. This weight of seed was recorded as oven dry weight (M2).

The moisture percent of the seed was calculated by using the formula-

$$\text{Moisture content (\%)} = \frac{M1-M2}{M1} \times 100$$

3.6 Study on phenotypic, genotypic and environmental coefficient of variation and estimation of genetic components.

3.6.1 Variances estimation

Genotypic, phenotypic and environmental variances was calculated using the following equations of **Burton and Devane (1953).**

$$\textbf{Genotypic variaance (Vg)} = \frac{Mt-Me}{r}$$

Phenotypic variance (Vp) = Vg + Ve

Environmental variance (Ve) = Me

Where, Mt = Mean sum of square due to treatment or family

Me = Mean sum of square due to error

r = Number of replications

3.6.2 Phenotypic coefficient of variance (PCV):

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

$$\textbf{PCV} = \frac{\sqrt{Vp}}{\bar{X}} \times 100$$

Where, Vp = Phenotypic variance

$\bar{X}$ = Mean of the character

3.6.3 Genotypic coefficient of variance (GCV)

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

$$\mathbf{GCV}(\%) = \frac{\sqrt{\mathrm{Vg}}}{\bar{\mathrm{X}}} \times 100$$

Where, Vg = Genotypic variance

$\bar{X}$ = Mean of the character

3.6.4 Environmental coefficient of variance (ECV)

It is the measure of environmental variation existing in a particular character, expressed in percentage, and was calculated as suggested by **Burton and Devane (1953).**

$$\mathbf{ECV} = \frac{\sqrt{\mathrm{Ve}}}{\bar{\mathrm{X}}} \times 100$$

Where, Ve = Environmental variance

$\bar{X}$ = Mean of the character

3.6.5 Broad sense heritability (h^2)

Broad sense of heritability is the ratio of genetic variance to the phenotypic variance and was estimated as suggested by **Burton and Devane (1953)** and **Johnson *et al.* (1955).**

$$\mathbf{h^2} = \frac{\mathrm{Vg}}{\mathrm{Vp}} \times 100$$

Where, h^2 = Broad sense heritability of character

Vg = Genotypic variance

Vp = Phenotypic variance

3.6.6 Genetic advance (GA)

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

$$\mathbf{GA} = \frac{\mathrm{Vg}}{\mathrm{Vp}} \times \sqrt{\mathrm{Vp}}$$

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

Vg = Genotypic variance,

Vp = Phenotypic variance.

3.6.7 Genetic gain

Genetic gain is expressed in percentage and was calculated using the formula given by **Johnson *et al.* (1955).**

$$\mathbf{Genetic\ gain} = \frac{\mathrm{GA}}{\bar{X}} \times 100$$

Where, GA = Genetic advance

$\bar{X}$ = Mean of the character

3.6.8 Correlation coefficient

Correlations were worked out by using SPSS (Statistics is a statistical software suite**).**

3.7 Treatments given:-

3.7.1 Control: Double distilled water.

3.7.2 Gibberellic Acid

3.8 Making of different concentration Gibberellic Acid (GA_3)

GA_3 500 ppm:- It was made by adding 0.5 gram of Gibberellic acid (GA_3) in 1 liter of water.

GA_3 750 ppm:- It was made by adding 0.75 gram of Gibberellic acid (GA_3) in 1 liter of water.

GA_3 1000 ppm:- It was made by adding 1 gram of Gibberellic acid (GA_3) in 1 liter of water.

GA_3 1250 ppm:- It was made by adding 1.25 gram of Gibberellic acid (GA_3) in 1 liter of water.

GA_3 1500 ppm:- It was made by adding 1.50 gram of Gibberellic acid (GA_3) in 1 liter of water.

3.9 Gibberellic Acid (GA_3) Treatment: 30 seeds per provenance was treated with Gibberellic acid of different concentration for 24 hours.

3.10 Determination of seed germination

3.10.1 Seed germination percent

The physiological process is the first stage of growth of seed. In seed germination, resumption of active growth in the embryo of a seed is demonstrated by the protrusion of the radical. In seed testing (ISTA definition), resumption of active growth in an embryo, which results in its emergence from the seed and development of those structures essential to normal plant development. It was percent of sown seed germinated at the completion of test period, i.e., 28 days after sowing (ISTA, 1999).

Germination percent was calculated by the formula:

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

3.10.2 Germination value

With the help of Czabator 1962 rules, germination value of seeds was determined by using the following formula

Germination value = MDG$\times$ *PV*

Where, MDG = Mean Daily Germination,

PV = Peak Value.

3.10.3 Peak Value (PV)

It was calculated by using the following formula given by **Czabator, (1962)**

$$\text{Peak value} = \frac{\text{Highest number of seed germinated on a single day}}{\text{Number of days (after start of experiment) on which the above recorded}}$$

3.10.4 Mean daily germination (MDG)

It was calculated by using the following formula given by **Czabator, (1962)**

$$\text{Mean daily germination} = \frac{\text{Total number of germinated seeds}}{\text{Total number of days}}$$

3.10.5 Mean Germination Time (MGT)

The Mean Germination Time (MGT) was calculated by following formulae given by **Ellis and Roberts (1981)** as:

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

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

3.10.6 Germination speed

It was calculated by using the following formula given by **Czabator, (1962)**

Germination speed = n1/d1+n2/d2+n3/d3+----------

Where,

n= number of germinated seed

d = number of days

3.11 Growth parameters

3.11.1 Plumule length (cm)

In each treatment, germinated seeds were selected from three replications for the measurement of plumule length. The plumule length will be measured with the help of measuring scale.

3.11.2 Radicle length (cm)

Each treatment, germinated seeds was selected from three replication for the measuring of radicle length. The radicle length was measured with the help of measuring scale.

3.11.3 Plumule - radicle ratio

Plumule - radicle ratio was obtained by dividing the plumule length by radicle length.

3.11 Soil Parameters

3.11.1 Collection of Soil samples

Soil sample from the study site was collected.

3.9.2 Soil reaction (pH)

The method adopted for soil reaction (pH) is Soil water suspension 1:2 ratio given by **Jackson (1973).**

3.9.3 Electrical conductivity

Electrical conductivity of soil was determined in 1:2 soil water suspensions by using Digital conductivity meter **Jackson (1973).**

3.12 STATISTICAL ANALYSIS

The data obtained during the course of this investigation was analyzed by applying Analysis of variance (ANOVA) using the OPSTAT. For morphological study, CRD (Completely Randomized Design) was used which was developed by O.P. Sheoran programmer, computer section, CCS HAU, Hisar. To compare the mean and standard deviation, critical difference (1 % and 5% level of significance) was calculated. Test for significance was determined by applying Analysis of variance (ANOVA). The genetic variation analyzed by RStudio and correlation analyzed by SPSS (Statistics is a statistical software suite) developed by IBM for data management.

RESULTS

The results of the study entitled **"Effect of provenances and pre-sowing treatment on seed germination of *Celtis australis* under laboratory condition in Garhwal Himalaya"** have been described in this chapter under different objectives as stated earlier.

4.1. Morphological variation in fruit and seeds of *Celtis australis* collected from different provenances.

4.2 Estimate the genetic variation in fruit and seed characters of *Celtis australis.*

4.3 Effect of pre-treatment on seed germination and growth of *Celtis australis* under laboratory conditions.

4.1 Morphological variation in fruit and seeds of *Celtis australis* collected from different provenances.

4.1.1. Morphological variation of fruit

4.1.1.1 Fruit Length (mm)

The fruit length showed significant difference among all the provenances (Table 4.1). Maximum (7.42 mm) fruit length was recorded in Tilwara succeeded by Kot and Barkot with values of (7.41 mm) and (7.15 mm), respectively. The minimum (6.68 mm) fruit length was recorded in Bhatwari preceded by Srinagar and Nainbagh with the values of (6.81 mm) and (6.89 mm), respectively.

4.1.1.2 Fruit width (mm)

Assessment of fruit width recorded highly significant variation among various provenances (Table 4.1). Highest (7.06 mm) fruit width was recorded in Kot followed by Tilwara and Devikhet with the values of (6.99 mm) and (6.983 mm). The lowest (6.39 mm) was observed for Bhatwari followed by Srinagar and Nainbagh with the values of (6.65 mm) and (6.67 mm), respectively.

4.1.1.3 Fruit thickness (mm)

Among all provenances fruit thickness showed significant variation (Table 4.1). Maximum fruit thickness was, observed in Tilwara (7.44 mm) succeeded by Kot and

Devikhet with values of (7.42 mm) and (7.26 mm), respectively. The minimum (6.67 mm) value was recorded in Bhatwari preceded by Srinagar and Nainbagh with the values of (6.76 mm) and (6.89 mm), respectively.

4.1.1.4 Fruit length/fruit width ratio

The data revealed in table 4.1 significant difference for fruit length / fruit width ratio among all seed sources. The range of length/width ratio among the seed sources recorded between (1.01) to (1.06) with an average value (1.04). The maximum (1.06) length/width ratio was recorded in Tilwara followed by Kot with the value of (1.05). Minimum (1.01) value was observed in Devikhet followed by Srinagar with the value of (1.02).

4.1.1.5 Fruit weight (g)

The weight of 100 fruits were recorded ranged from (15.42gm) to (22.73gm). The maximum (22.73 gm) seed weight was recorded in Tilwara provenances. However, minimum (15.42 gm) fruit weight was recorded and value in Bhatwari followed by Srinagar with the value of (16.30 gm) **(Table 4.1).**

4.1.1.6 Fruit moisture per cent (%)

There was non-significant difference recorded for fruit moisture per cent among the seed source. (Table 4.1). Fruit moisture per cent varied from (10.77) to (15.26 %) among the seed sources with an average value (13.33%). Highest (15.26 %) fruit moisture percent recorded in Bhatwari and lowest (10.77%) fruit moisture was observed in Kot.

4.1.2. Morphological variation of seed

4.1.2.1 Seed length (mm)

The perusal data in table 4.2 revealed highly significant difference in seed length. Maximum (5.92 mm) seed length was measured in Tilwara succeeded by Kot and Barkot with values of (5.91 mm) and (5.65 mm), respectively. The minimum (5.18 mm) value was recorded in Bhatwari preceded by Srinagar and Nainbagh with the values of (5.29mm) and (5.39mm), respectively.

4.1.2.2 Seed width (mm)

The appraisal of table 4.2 illustrated highly significant variation in seed width. Highest (5.56 mm) seed width was observed in Kot followed by Tilwara and Devikhet with the values of (5.487 mm) and (5.483 mm). The lowest (4.89 mm) was recorded in Bhatwari followed by Srinagar and Narainbagar with the values of (5.15mm) and (5.17 mm), respectively.

4.1.2.3 Seed thickness (mm)

The perusal data in table 4.2 showed highly significant difference in seed thickness. Maximum (5.94 mm) seed thickness was recorded in Tilwara succeeded by Kot and Devikhet with values of (5.92mm) and (5.76mm), respectively. The minimum (5.17mm) value was recorded in Bhatwari preceded by Srinagar and Nainbagh with the values of (5.26mm) and (5.39mm), respectively.

4.1.2.4 Seed length/seed width ratio

The data in table 4.2 showed highly significant difference in seed length/seed width ratio among all seed sources. The range of length/width ratio among the seed sources recorded between (1.01) to (1.08) with an average value (1.05). The maximum (1.08) seed length/seed width ratio was recorded in Tilwara. Minimum (1.01) value was observed in Devikhet.

4.1.2.5 Seed weight (g)

The 100 seed weight was found highly significant among different provenances and ranged from (6.30gm) to (9.27 gm). The maximum (9.27gm) seed weight was recorded in Sonprayag with value of. However, minimum seed weight 6.30 gm was recorded in Bhatwari. **(Table 4.2)**

4.1.2.6 Seed moisture per cent (%)

There was non-significant difference for seed moisture percent among the seed source (Table 4.2). Seed moisture per cent varied from (10.97%) to (16.37 %) among the seed sources with an average value 13.31%. Highest (16.37%) seed moisture per cent was recorded in Bhatwari and lowest (10.97%) seed moisture per cent was recorded in Kot.

Table no. 4.1: Variation on fruit characteristics (Mean±S.D.) influenced by provenances

S. No.	Provenances	Altitude (m asl)	Fruit length (mm)	Fruit width (mm)	Fruit thickness (mm)	Fruit weight (g)	Moisture percent (%)	Fruit length/ fruit width ratio
1	**Srinagar**	592	6.80±0.08	6.65±0.19	6.76±0.04	16.30±0.74	13.73±0.35	1.02±0.018
2	**Tilwara**	784	7.42±0.06	6.98±0.14	7.44±0.08	22.73±0.30	12.89±2.31	1.06±0.015
3	**Nainbagh**	898	6.89±0.06	6.67±0.06	6.89±0.06	18.51±0.23	15.18±3.19	1.03±0.003
4	**Narainbagar**	1067	6.98±0.24	6.76±0.15	6.97±0.24	19.86±1.29	12.55±1.03	1.04±0.013
5	**Barkot**	1343	7.15±0.04	6.97±0.08	7.23±0.00	21.60±1.09	14.23±0.35	1.03±0.015
6	**Kot**	1415	7.41±0.27	7.06±0.17	7.42±0.27	21.98±0.42	10.78±0.16	1.05±0.013
7	**Devikhet**	1560	7.04±0.04	6.98±0.02	7.26±0.10	21.25±1.06	13.15±1.66	1.01±0.009
8	**Maun Gaon**	1584	6.98±0.05	6.70±0.05	6.97±0.06	19.87±0.73	12.70±0.98	1.04±0.001
9	**Sonprayag**	1753	7.03±0.11	6.79±0.13	7.03±0.11	21.55±0.70	12.87±1.55	1.03±0.003
10	**Bhatwari**	1787	6.68±0.18	6.39±0.21	6.67±0.18	15.42±0.15	15.26±1.30	1.04±0.013
	C.D.		0.293	0.286	0.299	1.612	NS	0.026
	SE(m)		0.098	0.096	0.101	0.543	1.109	0.009

S.D± Standard deviation. Mean followed by same letter are not significantly ($p<0.05$) different**.**

Table 4.2: Variation on seed characteristics (Mean±S.D.) influenced by provenances

S. No.	Provenances	Altitude (m asl)	Seed length (mm)	Seed width (mm)	Seed thickness(mm)	Seed weight	Moisture %	Seed length/seed width ratio
1	**Srinagar**	592	5.29±0.07	5.15±0.19	5.26±0.04	7.84±0.60	12.42±0.69	1.03±0.027
2	**Tilwara**	784	5.92±0.06	5.48±0.14	5.94±0.08	8.19±0.32	13.35±2.25	1.08±0.019
3	**Nainbagh**	898	5.39±0.06	5.20±0.05	5.39±0.06	8.84±0.83	14.29±2.01	1.04±0.018
4	**Narainbagar**	1067	5.48±0.24	5.17±0.06	5.47±0.24	9.20±0.59	12.74±1.36	1.06±0.033
5	**Barkot**	1343	5.65±0.04	5.47±0.08	5.73±0.00	8.94±0.93	13.51±1.49	1.03±0.019
6	**Kot**	1415	5.91±0.27	5.56±0.17	5.92±0.27	6.69±0.13	10.97±0.74	1.06±0.016
7	**Devikhet**	1560	5.54±0.04	5.48±0.02	5.76±0.10	6.52±0.24	13.49±1.77	1.01±0.012
8	**Maun Gaon**	1584	5.48±0.05	5.29±0.12	5.47±0.06	7.58±0.32	13.60±0.72	1.03±0.025
9	**Sonprayag**	1753	5.53±0.11	5.29±0.13	5.53±0.11	9.27±1.08	12.40±1.80	1.04±0.005
10	**Bhatwari**	1787	5.18±0.18	4.89±0.21	5.17±0.18	6.30±0.05	16.36±1.67	1.06±0.018
	C.D.		0.291	0.279	0.299	1.282	NS	N/A
	SE(m)		0.098	0.094	0.101	0.431	1.094	0.014

S.D± Standard deviation. Mean followed by same letter are not significantly ($p<0.05$) different**.**

4.2. Estimate the genetic variation in fruit and seed characters of *Celtis australis.*

4.2.1 Variability and genetic studies in morphological traits of fruit and seeds

The variability and genetic studies in morphological traits of fruit and seeds were shown in Table 4.3. The fruit moisture per cent showed maximum (3.6551) environmental variance (Ve) and minimum (0.0225) in fruit thickness and seed thickness. Maximum (5.7552) genotypic variance (Vg) recorded in fruit weight and minimum (0.0336) in fruit width and seed width. Highest (6.7247) phenotypic variance (Vp) recorded in fruit weight and lowest (0.0592) in seed width. With respect to the coefficient of variance, maximum (13.9637) environmental coefficient of variance (ECV) recorded in seed moisture per cent and minimum (2.1262) in fruit thickness. Highest (13.4264) genotypic coefficient variance (GCV) recorded in seed weight and lowest (2.6970) in fruit width. Maximum (15.9440) phenotypic coefficient of variance (PCV) was recorded in seed weight and minimum (3.5859) in fruit width. Genetic parameter on morphological traits were worked out with regard to estimates of heritability per cent, genetic advance and genetic gain per cent. Maximum (0.8558) heritability recoded in fruit weight and minimum (0.1347) in fruit moisture per cent. Maximum (5.3617) genetic advance (GA) recorded in fruit length and minimum (0.2840) in fruit width. Highest (76.1605) genetic gain (GG) recorded in fruit length and lowest (4.1765) in fruit width.

4.3 Correlation of morphological characteristics of *Celtis australis*

4.3.1 Fruit length

The fruit length was recorded to have highly significant positive correlation with fruit width (0.880**), fruit thickness (0.963**), fruit weight (0.764**), seed length (1.000**), seed width (0.834**) and seed thickness (0.963**). The significant negative correlation in fruit length with fruit moisture per cent (-0.407*) and seed moisture per cent (-0.397*) was found significant. The fruit length with seed weight (-0.011) recorded non-significant negative correlation **(Table 4.4).**

4.3.2 Fruit width

The fruit width was recorded to have highly significant positive correlation with fruit thickness (0.907**), fruit weight (0.717**), seed length (0.875**), seed width (0.951**) and seed thickness (0.907**). The negative correlation of fruit width with fruit moisture per cent (-0.440*) and seed moisture per cent (-0.449*) was recorded significant and non-significant correlation with seed weight **(Table 4.4).**

4.3.3 Fruit thickness

The fruit thickness was exhibited highly significant positive correlation with fruit weight (0.795**), seed length (0.965**), seed width (0.866**), seed thickness (1**) and significant negative correlation with fruit moisture per cent (-0.380*), seed moisture per cent (-0.368*). The non-significant negative correlation was found in fruit thickness with seed weight (-0.080) **(Table 4.4).**

4.3.4 Fruit weight

Fruit weight was founded highly significant positive correlated with seed length (0.770**), seed width (0.691**), seed thickness (0.795**) and significant negative correlation with fruit moisture percent (-0.392*), seed moisture (-0.392*) and non-significant correlation with seed weight (0.229) **(Table 4.4).**

4.3.5 Fruit moisture per cent (%)

The fruit moisture per cent exhibited highly significant positive correlated with seed moisture (0.749**) and highly significant negative correlation with seed width (-0.494**). The fruit moisture per cent found significant negative correlation with seed length (-0.408*), seed thickness (-0.380*) and non-significant negative correlation with seed weight (-0.024) **(Table 4.4).**

4.3.6 Seed length

The seed length was recorded highly significant positive correlated with seed width (0.829**) and seed thickness (0.965**) and significant negative correlation with seed moisture (-0.396*). The non-significant negative correlation was recorded of seed length with seed weight (-0.010) **(Table 4.4).**

4.3.7 Seed width

The seed width was highly significant positive correlated with seed thickness (0.866**) and significant negative correlation with seed moisture per cent (-0.460*). The non-significant negative correlation was found of seed width with seed weight (-0.021) **(Table 4.4).**

4.3.8 Seed thickness

Seed thickness was recorded significant negative correlated with seed moisture per cent (-0.368*) and non-significant negative correlation with seed weight (-0.080) **(Table 4.4).**

Table 4.3: Variance and coefficient of variability for morphological traits of fruit and seed

Trait	Mean	Range	Variance			Coefficient of variance			Heritability %	Genetic advance	Genetic gain (%)
			Environmental (Ve)	Genotypic (Vg)	Phenotypic (Vp)	Environmental (ECV)	Genotypic (GCV)	Phenotypic (PCV)			
Fruit length	7.0407±0.27	6.430-7.780	0.0229	0.0492	0.0721	2.1498	3.1504	3.8138	68.24	5.3617	76.1605
Fruit width	6.7967±0.24	6.100-7.300	0.0258	0.0336	0.0594	2.3633	2.6970	3.5859	56.57	0.2840	4.1765
Fruit thickness	7.0625±0.29	6.425-7.775	0.0225	0.0627	0.0852	2.1262	3.5455	4.1330	73.59	0.4425	6.2677
Fruit weight	19.9071±2.50	15.304- 23.101	0.9695	5.7552	6.7247	4.9461	12.0510	13.0265	85.58	4.5718	22.9623
Fruit moisture %	13.3340±2.05	10.6-19.67	3.6551	0.5691	4.2242	3.6551	5.6576	15.4139	13.47	0.5704	4.2791
Seed length	5.5393±0.27	4.930-6.280	0.0226	0.0500	0.0726	2.7123	4.0367	4.8642	68.87	0.3823	6.9007
Seed width	5.2997±0.24	4.60-5.80	0.0256	0.0336	0.0592	3.0207	3.4588	4.5911	56.76	0.2845	5.3679
Seed thickness	5.5625±0.29	4.925-6.275	0.0225	0.0627	0.0852	2.6995	4.5016	5.2475	73.59	0.4425	7.9586
Seed weight	7.9377±1.26	6.210-10.800	0.4659	1.1358	1.6017	8.5995	13.4264	15.9440	70.91	1.8488	23.2846
Seed moisture %	13.3140±2.08	10.13-18.61	3.4563	0.8272	4.2835	13.9637	6.8312	15.5450	19.31	0.8233	6.1856

Table 4.4: Correlation of morphological characteristics of *Celtis australis*

	Fruit width	**Fruit thickness**	**Fruit weight**	**Fruit moisture %**	**Seed length**	**Seed width**	**Seed thickness**	**Seed weight**	**Seed moisture %**
Fruit length	0.880**	0.963**	0.764**	-0.407*	1.000**	0.834**	0.963**	-0.011	-0.397*
Fruit width		0.907**	0.717**	-0.440*	0.875**	0.951**	0.907**	0.021	-0.449*
Fruit thickness			0.795**	-0.380*	0.965**	0.866**	1.000**	-0.080	-0.368*
Fruit weight				-0.392*	0.770**	0.691**	0.795**	0.229	-0.392*
Fruit moisture %					-0.408*	-0.494**	-0.380*	-0.024	0.749**
Seed length						0.829**	0.965**	-0.010	-0.396*
Seed width							0.866**	-0.021	-0.460*
Seed thickness								-0.080	-0.368*
Seed weight									-0.089

* significant at < 0.05, ** significant at < 0.01

4.3.9 Seed weight

The seed weight was found to be non-significantly negatively correlated with seed moisture (-0.089) **(Table 4.4).**

4.4 Effect of pre-treatment on seed germination and growth of *Celtis australis* under laboratory conditions.

4.4.1 Seed germination per cent

The data of seed germination per cent of *Celtis australis* had been presented in Table 4.5 The non-significant different were recorded for seed germination per cent with among different provenances. The data showed that the germination percentage ranged from (30%) to (83.33%). Maximum (83.33%) seed germination was recorded in Srinagar with GA_3 treatment T5 (1250 ppm). Minimum (30%) germination per cent was observed in Barkot, Kot and Maun gaon with treatment in T1 (control) **(Table 4.5).**

4.4.2 Germination value

Germination value differed high significantly ($p \leq 0.01$) variation among all the provenances. The mean germination value ranged between (0.003) to (0.105). The highest (0.105) germination value was observed in Srinagar with GA_3 treatment in T5 (1250 ppm). The lowest (0.003) germination value was recorded in Sonprayag with treatment in T1 (control) **(Table 4.6).**

4.4.3 Peak value

Peak value differed high significantly variation ($p \leq 0.01$) among all the provenances. The mean peak value varied from (0.030) to (0.380). Maximum (0.380) peak value was recorded in Srinagar with GA_3 treatment T5 (1250ppm). Minimum (0.080) peak value was recorded in Sonprayag with treatment in T1 (control) **(Table 4.7).**

4.4.4 Mean daily germination (MDG)

The difference in mean daily germination among all the seed source recorded non-significant variation. The data showed that the mean daily germination varied from (0.10) to (0.28). Maximum mean daily germination (0.28) was observed in Srinagar with GA_3 treatment T5 (1250ppm). The minimum (0.10) mean daily germination was recorded in Barkot, Kot and Maun Gaon with treatment T1 (control). **(Table 4.8).**

4.4.5 Mean germination time (MGT)

The data showed highly significant ($p \leq 0.01$) difference for mean germination time among all the provenances. The mean germination time ranged from (17.39) to (25.78) days. Maximum (25.78) mean germination time was recorded in Kot with treatment T1 (control). The minimum mean germination time was observed 17.39 in Srinagar with GA_3 treatment T5 (1250ppm) (Table 4.6) **(Table 4.9).**

4.4.6 Germination speed

Germination speed recorded non-significant variation among all the provenances. The germination speed ranged from (0.117) to (0.512). The highest (0.512) germination speed was recorded in Srinagar with GA_3 treatment in T5 (1250ppm). The lowest (0.117) germination speed in Kot with treatment T1 (control) **(Table 4.10).**

4.5 Growth parameters

4.5.1. Plumule length (cm)

The plumule length differed non-significant been measured by measuring scale. The range of plumule length among the provenances varied from (2.42cm) to (6.39cm). Maximum length 6.39cm was recorded in Srinagar with GA_3 treatment in T5 (1250ppm). The minimum (2.42cm) was measured in Maun gaon with treatment in T1 (control). **(Table 4.11).**

4.5.2. Radicle length (cm)

The radicle length recorded highly significant variation ($p \leq 0.01$) among all provenances ranged from 1.36 to 3.83cm. The maximum (3.83cm) radicle length was recorded in Bhatwari with GA_3 treatment T5 (1250ppm). Minimum (1.36cm) radicle length in Nainbagh with treatment in T1 (control). **(Table 4.12).**

4.5.3. Plumule/radicle length ratio

The data showed significant ($p \leq 0.05$) difference for plumule/radicle ratio among all provenances. The range of plumule/radicle ratio among the provenances recorded between (1.15) to (2.28). The Maximum (2.28) plumule/radicle length was recorded in Nainbagh with treatment in T1 (control) whereas, minimum (1.15) value was recorded in Srinagar with GA_3 treatment in T6 (1500 ppm). **(Table 4. 13).**

Table 4.5: Variation in germination percent (Mean±S.D.) influenced by different concentration of GA_3 and provenances.

S. No.	Provenances	Altitude (m asl)	Germination per cent						
			Control (T1)	500ppm (T2)	750ppm (T3)	1000ppm (T4)	1250ppm (T5)	1500ppm (T6)	Mean P
1	Srinagar	592	40.00±8.16	50.00±8.16	66.67±4.71	73.33±4.71	83.33±4.71	46.67±4.71	60.00±15.52
2	Tilwara	784	36.67±4.71	46.67±4.71	63.33±4.71	70.00±0.00	80.00±0.00	43.33±4.71	56.67±15.52
3	Nainbagh	898	36.67±4.71	43.33±4.71	60.00±8.16	66.67±4.71	76.67±4.71	36.67±4.71	53.33±15.40
4	Narainbagar	1067	33.33±4.71	40.00±8.16	60.00±0.00	63.33±9.43	76.67±4.71	36.67±4.71	51.67±15.96
5	Barkot	1343	30.00±0.00	40.00±0.00	50.00±8.16	63.33±4.71	66.67±4.71	36.67±4.71	47.78±13.56
6	Kot	1415	30.00±0.00	46.67±4.71	50.00±8.16	63.33±4.71	80.00±0.00	36.67±4.71	51.11±16.63
7	Devikhet	1560	33.33±4.71	43.33±4.71	53.33±4.71	66.67±4.71	73.33±4.71	40.00±8.16	51.67±14.37
8	Maun Gaon	1584	30.00±0.00	33.33±4.71	56.67±4.71	66.67±9.43	73.33±4.71	33.33±4.71	48.89±17.39
9	Sonprayag	1753	33.33±4.71	40.00±8.16	56.67±4.71	60.00±8.16	70.00±8.16	36.67±4.71	49.44±13.53
10	Bhatwari	1787	33.33±4.71	40.00±8.16	46.67±12.47	66.67±4.71	76.67±4.71	40.00±8.16	50.56±15.68
	Mean T		33.67±3.14	42.33±4.48	56.33±6.05	66.00±3.59	75.67±4.73	38.67±3.71	

	P	T	P×T
C.D.	4.620	3.579	NS
SE(m)	1.648	1.277	4.037

S.D± Standard deviation. Mean followed by same letter are not significantly ($p<0.05$) different**.**

Table 4.6: Variation in germination value (Mean±S.D.) influenced by different concentration of GA_3 and provenances.

S. No.	Provenances	Altitude (m asl)	Germination value						
			Control (T1)	500ppm (T2)	750ppm (T3)	1000ppm (T4)	1250ppm (T5)	1500ppm (T6)	Mean P
1	Srinagar	592	0.014±0.002	0.025±0.005	0.033±0.003	0.059±0.002	0.105±0.004	0.020±0.002	0.043±0.031
2	Tilwara	784	0.009±0.002	0.013±0.004	0.017±0.003	0.026±0.002	0.040±0.002	0.006±0.001	0.018±0.012
3	Nainbagh	898	0.005±0.002	0.013±0.001	0.016±0.005	0.029±0.004	0.054±0.003	0.010±0.001	0.021±0.016
4	Narainbagar	1067	0.004±0.000	0.009±0.001	0.026±0.002	0.015±0.003	0.056±0.002	0.006±0.001	0.019±0.018
5	Barkot	1343	0.004±0.001	0.007±0.001	0.062±0.063	0.021±0.001	0.035±0.001	0.006±0.002	0.022±0.021
6	Kot	1415	0.007±0.001	0.012±0.001	0.020±0.003	0.034±0.002	0.072±0.004	0.006±0.001	0.025±0.023
7	Devikhet	1560	0.007±0.002	0.019±0.001	0.021±0.001	0.033±0.003	0.066±0.003	0.011±0.002	0.026±0.020
8	Maun Gaon	1584	0.005±0.000	0.020±0.021	0.013±0.001	0.019±0.001	0.042±0.005	0.005±0.001	0.017±0.013
9	Sonprayag	1753	0.003±0.001	0.005±0.002	0.013±0.001	0.028±0.005	0.035±0.003	0.006±0.002	0.015±0.012
10	Bhatwari	1787	0.006±0.002	0.006±0.000	0.023±0.007	0.038±0.002	0.036±0.004	0.010±0.003	0.020±0.013
	Mean T		0.006±0.003	0.013±0.006	0.025±0.014	0.030±0.012	0.054±0.021	0.009±0.004	

	P	T	P×T
C.D.	0.007	0.006	0.018
SE(d)	0.004	0.003	0.009

S.D± Standard deviation.

Table 4.7: Variation in peak value (Mean±S.D.) influenced by different concentration of GA_3 and provenances.

S. No.	Provenances	Altitude (m asl)	Peak value						
			Control (T1)	500ppm (T2)	750ppm (T3)	1000ppm (T4)	1250ppm (T5)	1500ppm (T6)	Mean P
1	Srinagar	592	0.110±0.008	0.150±0.008	0.150±0.008	0.240±0.008	0.380±0.008	0.130±0.008	0.193±0.093
2	Tilwara	784	0.070±0.016	0.080±0.016	0.080±0.008	0.110±0.008	0.150±0.008	0.040±0.008	0.088±0.034
3	Nainbagh	898	0.040±0.016	0.090±0.016	0.080±0.016	0.130±0.024	0.213±0.021	0.080±0.000	0.106±0.055
4	Narainbagar	1067	0.040±0.008	0.070±0.008	0.130±0.008	0.070±0.008	0.220±0.008	0.050±0.008	0.097±0.062
5	Barkot	1343	0.040±0.008	0.050±0.008	0.370±0.375	0.100±0.008	0.160±0.008	0.050±0.016	0.128±0.116
6	Kot	1415	0.070±0.008	0.080±0.008	0.120±0.016	0.160±0.016	0.270±0.016	0.050±0.008	0.125±0.074
7	Devikhet	1560	0.060±0.008	0.130±0.008	0.120±0.008	0.150±0.008	0.270±00008	0.080±0.008	0.135±0.068
8	Maun Gaon	1584	0.050±0.000	0.200±0.212	0.070±0.008	0.100±0.008	0.170±0.016	0.050±0.016	0.107±0.058
9	Sonprayag	1753	0.030±0.008	0.040±0.008	0.070±0.008	0.140±0.008	0.150±0.008	0.050±0.008	0.080±0.048
10	Bhatwari	1787	0.050±0.008	0.050±0.008	0.150±0.008	0.170±0.008	0.140±0.008	0.070±0.008	0.105±0.050
	Mean T		0.056±0.022	0.094±0.048	0.134±0.084	0.137±0.045	0.212±.072	0.065±0.025	

	P	T	P×T
C.D.	0.040	0.031	0.098
SE(d)	0.020	0.016	0.050

S.D± Standard deviation.

Table 4.8: Variation in mean daily germination (Mean±S.D.) influenced by different concentration of GA_3 and provenances.

S. No.	Provenances	Altitude (m asl)	Mean daily germination						
			Control (T1)	500ppm (T2)	750ppm (T3)	1000ppm (T4)	1250ppm (T5)	1500ppm (T6)	Mean P
1	Srinagar	592	0.133±0.027	0.167±0.027	0.222±0.016	0.244±0.016	0.278±0.016	0.156±0.016	0.200±0.052
2	Tilwara	784	0.122±0.016	0.156±0.016	0.211±0.016	0.233±0.000	0.267±0.000	0.144±0.016	0.188±0.053
3	Nainbagh	898	0.122±0.016	0.144±0.016	0.200±0.027	0.222±0.016	0.256±0.016	0.122±0.016	0.177±0.052
4	Narainbagar	1067	0.111±0.016	0.133±0.027	0.200±0.000	0.211±0.031	0.256±0.016	0.122±0.016	0.172±0.054
5	Barkot	1343	0.100±0.000	0.133±0.000	0.167±0.027	0.211±0.016	0.222±0.016	0.122±0.016	0.158±0.045
6	Kot	1415	0.100±0.000	0.156±0.016	0.167±0.027	0.211±0.016	0.267±0.000	0.122±0.016	0.171±0.057
7	Devikhet	1560	0.111±0.016	0.144±0.016	0.178±0.016	0.222±0.016	0.244±0.016	0.133±0.027	0.172±0.048
8	Maun Gaon	1584	0.100±0.000	0.111±0.016	0.189±0.016	0.189±0.016	0.244±0.016	0.111±0.016	0.157±0.054
9	Sonprayag	1753	0.111±0.016	0.133±0.016	0.189±0.016	0.200±0.027	0.233±0.027	0.122±0.016	0.164±0.046
10	Bhatwari	1787	0.111±0.016	0.133±0.027	0.156±0.042	0.222±0.016	0.256±0.016	0.133±0.027	0.168±0.053
	Mean T		0.111±0.010	0.141±0.016	0.188±0.019	0.215±0.014	0.253±0.017	0.128±0.013	

	P	T	P×T
C.D.	0.015	0.012	NS
SE(d)	0.008	0.006	0.019

S.D± Standard deviation.

Table 4.9: Variation in mean germination time (Mean±S.D.) influenced by different concentration of GA_3 and provenances.

S. No.	Provenances	Altitude (m asl)	Mean germination time						
			Control (T1)	500ppm (T2)	750ppm (T3)	1000ppm (T4)	1250ppm (T5)	1500ppm (T6)	Mean P
1	Srinagar	592	21.91±0.64	22.5±0.71	20.76±0.89	19.53±0.85	17.39±1.38	20.47±0.75	20.43±1.67
2	Tilwara	784	25±1.41	23.77±1.35	22.08±0.45	21.14±1.35	19.04±1.73	21.42±2.06	22.07±1.91
3	Nainbagh	898	23.78±1.26	24.5±1.08	20.38±0.13	19.44±0.40	20±0.82	24.36±0.89	22.08±2.17
4	Narainbagar	1067	24.36±0.31	24.34±1.52	21.11±0.39	22.44±0.31	20.64±0.52	22.94±0.27	22.64±1.43
5	Barkot	1343	24.34±0.47	21.75±0.41	20.64±0.51	18.8±0.18	18.36±1.23	23.39±0.99	21.21±2.20
6	Kot	1415	25.78±0.16	23.32±0.13	21.47±0.93	21.65±0.97	20.17±0.59	24.19±0.81	22.76±1.87
7	Devikhet	1560	25±0.27	23.65±0.64	21.08±0.68	19.13±0.37	18.86±1.00	24.4±0.85	22.02±2.47
8	Maun Gaon	1584	22.78±0.31	21.03±1.45	20.29±0.28	21.22±1.10	20.49±0.53	22.47±1.08	21.38±0.94
9	Sonprayag	1753	21±0.54	23.98±0.99	21.42±0.13	22.25±0.58	19.15±0.81	23.42±0.42	21.86±1.60
10	Bhatwari	1787	23.13±0.59	22.53±0.34	21.78±0.42	20.74±0.69	18.11±0.79	25.4±1.18	21.95±2.23
	Mean T		23.71±1.42	23.14±1.09	21.1±0.56	20.64±1.26	19.22±1.03	23.25±1.41	

	P	T	P×T
C.D.	0.699	0.541	1.712
SE(d)	0.353	0.273	0.864

S.D± Standard deviation.

Table 4.10: Variation in germination speed (Mean±S.D.) influenced by different concentration of GA_3 and provenances.

S. No.	Provenances	Altitude (m asl)	Germination speed						
			Control (T1)	500ppm (T2)	750ppm (T3)	1000ppm (T4)	1250ppm (T5)	1500ppm (T6)	Mean P
1	Srinagar	592	0.186±0.037	0.226±0.031	0.328±0.029	0.393±0.045	0.512±0.027	0.233±0.030	0.313±0.113
2	Tilwara	784	0.149±0.026	0.201±0.0311	0.293±0.029	0.342±0.024	0.44±0.040	0.193±0.019	0.27±0.100
3	Nainbagh	898	0.157±0.027	0.196±0.039	0.299±0.039	0.349±0.022	0.396±0.037	0.152±0.015	0.258±0.095
4	Narainbagar	1067	0.138±0.018	0.17±0.046	0.289±0.004	0.288±0.047	0.383±0.017	0.163±0.023	0.238±0.088
5	Barkot	1343	0.124±0.003	0.187±0.003	0.249±0.043	0.345±0.043	0.381±0.043	0.16±0.027	0.241±0.095
6	Kot	1415	0.117±0.001	0.188±0.021	0.238±0.049	0.3±0.35	0.406±0.015	0.156±0.026	0.234±0.096
7	Devikhet	1560	0.135±0.019	0.185±0.017	0.259±0.026	0.357±0.023	0.37±0.075	0.168±0.041	0.246±0.091
8	Maun Gaon	1584	0.133±0.003	0.161±0.021	0.287±0.024	0.321±0.041	0.37±0.029	0.152±0.026	0.238±0.092
9	Sonprayag	1753	0.163±0.024	0.172±0.040	0.269±0.024	0.275±0.035	0.378±0.038	0.16±0.023	0.236±0.080
10	Bhatwari	1787	0.147±0.018	0.18±0.033	0.215±0.059	0.33±0.032	0.443±0.038	0.16±0.037	0.246±0.107
	Mean T		0.145±0.019	0.187±0.017	0.273±0.032	0.33±0.033	0.408±0.043	0.17±0.024	

	P	T	P×T
C.D.	0.026	0.020	N/A
SE(d)	0.013	0.010	0.023

S.D± Standard deviation.

Table 4.11: Variation in plumule length (Mean±S.D.) influenced by different concentration of GA_3 and provenances.

S. No.	Provenances	Altitude (m asl)	Plumule length						
			Control (T1)	500ppm (T2)	750ppm (T3)	1000ppm (T4)	1250ppm (T5)	1500ppm (T6)	Mean P
1	Srinagar	592	3.48±0.38	4.46±0.76	5.32±0.21	5.87±0.24	6.39±0.34	3.99±0.48	4.92±1.03
2	Tilwara	784	2.82±0.27	4.07±0.21	4.97±0.10	5.78±0.43	6.10±0.32	3.24±0.21	4.10±1.22
3	Nainbagh	898	2.88±0.47	3.70±0.26	4.68±0.41	5.65±0.32	5.94±0.52	3.23±0.37	4.35±1.17
4	Narainbagar	1067	2.65±0.39	3.64±0.41	4.56±0.63	5.34±0.44	5.52±0.38	3.18±0.00	4.15±1.07
5	Barkot	1343	2.60±0.22	3.35±0.11	4.39±0.25	5.17±0.04	5.95±0.03	2.99±0.11	4.07±1.20
6	Kot	1415	3.23±0.31	3.93±0.68	5.14±0.80	5.49±0.25	5.68±0.09	3.80±0.24	4.55±0.98
7	Devikhet	1560	2.90±0.36	3.76±0.18	4.52±0.33	5.03±0.36	5.24±0.37	3.23±0.33	4.11±0.88
8	Maun Gaon	1584	2.42±0.24	3.31±0.38	4.74±0.28	5.36±0.28	5.66±0.30	2.95±0.19	4.07±1.24
9	Sonprayag	1753	2.66±0.15	3.76±0.15	4.68±0.47	5.42±0.34	5.75±0.47	3.01±0.15	4.21±1.16
10	Bhatwari	1787	2.90±0.16	3.80±0.39	4.89±0.43	5.05±0.18	5.65±0.27	3.22±0.08	4.25±1.01
	Mean T		2.85±0.30	3.78±0.32	4.79±0.28	5.42±0.27	5.79±0.30	3.29±0.33	

	P	T	P×T
C.D.	0.247	0.191	N/A
SE(m)	0.088	0.068	0.216

S.D± Standard deviation.

Table 4.12: Variation in radicle length (Mean±S.D.) influenced by different concentration of GA_3 and provenances.

S. No.	Provenances	Altitude (m asl)	Radicle length						
			Control (T1)	500ppm (T2)	750ppm (T3)	1000ppm (T4)	1250ppm (T5)	1500ppm (T6)	Mean P
1	Srinagar	592	1.77±0.19	1.973±0.06	2.62±0.17	3.27±0.17	3.66±0.38	3.02±0.08	2.72±0.68
2	Tilwara	784	1.7±0.14	2.29±0.10	2.44±0.04	3.17±0.04	3.47±0.30	1.98±0.22	2.51±0.62
3	Nainbagh	898	1.36±0.05	2.02±0.07	2.653±0.03	3.04±0.12	3.44±0.29	1.71±0.13	2.37±0.74
4	Narainbagar	1067	1.57±0.12	1.99±0.23	2.34±0.03	3.33±0.24	3.65±0.31	1.89±0.17	2.46±0.77
5	Barkot	1343	1.57±0.14	1.98±0.01	2.74±0.02	3.02±0.62	3.59±0.19	1.68±0.05	2.43±0.74
6	Kot	1415	1.9±0.14	2.2±0.08	2.59±0.23	3.27±0.44	3.83±0.22	2.29±0.24	2.68±0.67
7	Devikhet	1560	1.47±0.21	2.09±0.15	2.44±0.11	3.15±0.42	3.79±0.06	1.98±0.13	2.49±0.77
8	Maun Gaon	1584	1.52±0.09	1.93±0.14	2.15±0.02	2.65±0.38	3.70±0.35	1.78±0.10	2.29±0.72
9	Sonprayag	1753	1.58±0.13	1.93±0.18	2.82±0.02	2.98±0.21	3.64±0.27	1.76±0.15	2.45±0.75
10	Bhatwari	1787	1.53±0.05	2.13±0.22	2.503±0.05	3.49±0.29	3.83±0.08	1.93±0.22	2.57±0.83
	Mean T		1.60±0.15	2.05±0.12	2.53±0.19	3.14±0.22	3.66±0.13	2.00±0.38	

	P	T	P×T
C.D.	0.167	0.130	0.410
SE(m)	0.060	0.046	0.146

S.D± Standard deviation.

Table 4.13: Variation in plumule length/radicle length ratio (Mean±S.D.) influenced by different concentration of GA_3 and provenances.

S. No.	Provenances	Plumule length/radicle length ratio							
		Altitude (m asl)	Control (T1)	500ppm (T2)	750ppm (T3)	1000ppm (T4)	1250ppm (T5)	1500ppm (T6)	Mean P
1	Srinagar	592	1.75±0.36	1.92±0.42	2.03±0.08	1.80±0.12	1.77±0.27	1.15±0.19	1.74±0.28
2	Tilwara	784	1.66±0.05	1.76±0.12	2.03±0.07	1.83±0.15	1.85±0.23	1.69±0.18	1.80±0.12
3	Nainbagh	898	2.28±0.42	1.84±0.06	1.76±0.14	1.86±0.09	1.84±0.24	2.00±0.12	1.93±0.17
4	Narainbagar	1067	1.66±0.14	1.81±0.01	1.95±0.28	1.64±0.02	1.53±0.12	1.66±0.15	1.71±0.13
5	Barkot	1343	1.65±0.01	1.69±0.07	1.60±0.08	1.80±0.43	1.66±0.08	1.78±0.11	1.70±0.07
6	Kot	1415	1.63±0.27	1.57±0.32	1.63±0.35	1.47±0.18	1.31±0.10	1.45±0.22	1.51±0.11
7	Devikhet	1560	2.02±0.34	1.79±0.05	1.86±0.23	1.63±0.25	1.38±0.12	1.60±0.09	1.71±0.20
8	Maun Gaon	1584	1.60±0.21	1.71±0.07	2.20±0.13	2.05±0.21	1.55±0.22	1.61±0.05	1.79±0.25
9	Sonprayag	1753	1.69±0.13	1.97±0.17	1.66±0.15	1.71±0.05	1.53±0.18	1.69±0.06	1.71±0.13
10	Bhatwari	1787	1.89±0.12	1.90±0.04	1.89±0.13	1.48±0.18	1.45±0.10	1.70±0.21	1.72±0.19
	Mean T		1.78±0.21	1.80±0.11	1.86±0.19	1.73±0.17	1.59±0.18	1.63±0.21	

	P	T	P×T
C.D.	0.156	0.121	0.383
SE(d)	0.079	0.061	0.193

S.D± Standard deviation.

DISCUSSION

The results of the study entitled **"Effect of provenance and pre-sowing treatment on seed germination of *Celtis australis* under laboratory condition in Garhwal Himalaya"** have been discussed in this chapter under different objectives as stated earlier.

5.1. Morphological variation in fruit and seeds of *Celtis australis* collected from different provenance.

5.2 Estimate the genetic variation in fruit and seed characters of Celtis australis.

5.3 Effect of pre-treatment on seed germination and growth of *Celtis australis* under laboratory conditions.

5.1 Morphological variation in fruit and seeds of *Celtis australis* collected from different provenance.

5.1.1. Morphological parameters of fruit

5.1.1.1 Fruit length

The ten provenances showed significant variation in fruit length. The highest (7.42 mm) and lowest (6.67 mm) fruit length were recorded in Tilwara and Bhatwari seed sources respectively. It might not be related to only genetic resources, but also to the conditions determined by the environment. Similarly, **Dar and Agnihotri (2017)** investigated an experiment on *Terminalia chebula* and reported that the maximum fruit length (4.71 cm) was recorded from provenance Timli Forest Range collected from Uttarakhand, whereas minimum (3.33 cm) was recorded in provenance Sirmour collected from Himachal.

5.1.1.2 Fruit width

Data presented in the Table 4.1 revealed that provenance showed significant variation in fruit width, maximum (7.06mm) fruit width was observed in Kot and minimum (6.39 mm) fruit width was recorded in Bhatwari. Comparably, **de Melo *et al.* (2016)** revealed that *Acacia farnesiana* L. and observed fruit width ranged from 9.82 -14.98 mm.

5.1.1.3. Fruit thickness

The data presented in Table 4.1 revealed that ten provenances showed a significant difference in fruit thickness, the highest (7.44 mm) fruit thickness was recorded in Tilwara and the lowest (6.39 mm) fruit thickness was recorded in Bhatwari. The differences observed might be related due to genetic resources, and also to the conditions determined by the environment. Similarly, **de Melo *et al.* (2016)** reported that the fruit thickness of *Acacia farnesiana* L ranged from 8.49- 14.70 mm.

5.1.1.4 Fruit weight

Significant variation of ten provenances showed, that maximum (22.73 gm) fruit weight was found in Tilwara and minimum (15.42 gm) in Bhatwari. This might have been caused by differences in the place of fruit collection and/or different periods of fruit collection. Similarly, **Malhotra *et al.* (2012)** investigated an experiment on *Jatropha curcas* and found the maximum (2.47gm) fruit weight at Belkhet and minimum (2.15 gm) at Bamoth.

5.1.2. Morphological parameters of Seed

5.1.2.1 Seed length

Significant variation was observed in seed length within the ten provenances, seed source Tilwara reported highest (5.92 mm) seed length and lowest (5.18 mm) value was reported at Bhatwari. The reason for this might be due to the temperature regime within the distributional range of this species. Similarly, **Singh *et al.* (2004**) investigated an experiment on *Celtis australis* and found that the seed length ranged from 4.46-6.31 mm.

5.1.2.2 Seed width

Data revealed that the provenance taken in the study showed significant variation in seed width. The highest (5.56 mm) and the lowest (4.89) mm seed width was recorded for Kot and Bhatwari, respectively. Comparably, **Singh *et al.* (2004)** experimented that the seed width of *Celtis australis* ranged from 4.01- 4.70 mm and the highest was at Jakholi and lowest at Koshiand.

5.1.2.3 Seed thickness

It is evident from the data presented in Table 4.2, that provenances showed a significant difference in seed thickness. The maximum (5.56 mm) and minimum (5.16 mm) seed thickness were reported in Kot and Bhatwari respectively. The difference might be

due to different genetic patterns of seeds collected from different provenances. **de Melo *et al.* (2016)** also investigated an experiment on *Acacia farnesiana L*. and observed that seed thickness ranged from 2.90-4.50 mm.

5.1.2.4 Seed length/width ratio

Data presented in table 4.2 revealed that the provenances showed a significant difference in length-width ratio. The maximum (1.08) length/width ratio was observed in Tilwara and the minimum (1.01) ratio was observed in Devikhet. This difference might be due to genotypic (heritable) factors and due to environmental (non-heritable) effects. A similar finding was reported by **Singh *et al.* (2006)** in *Celtis australis* which observed that the seed length-width ratio, had a maximum value of 1.24.

5.1.2.5 Seed weight

It is obvious from the data presented in table 4.2 that seed weight varied significantly, highest (9.27 gm) and lowest (6.30 gm) seed weight was reported in Sonprayag and Bhatwari respectively. The reason for this might be due to exhibited high heritability and genetic variation that may exist between seed sources. **Singh *et al.* (2004)** investigated an experiment on *Celtis australis* seed weight ranging from 55.50-83.09 gm/1000 seed and maximum weight at Badiyargaon and lowest at Khandahsrikot.

5.1.2.6 Seed moisture percent (%)

It is apparent from the data presented in the table that provenance showed significant variation in seed moisture percent. The highest (16.37%) seed moisture percent was recorded in Bhatwari, whereas the lowest (10.97%) one found in Kot. Similarly, **Kotoky *et al.* (2015)** studied *Jatropha curcas* L. and reported the highest (11.32%) and lowest (6.06 %.) seed moisture percentages in Lakhimpur and Lambding seed sources, respectively.

5.2 Estimate the genetic variation in fruit and seed characters of *Celtis australis*.

5.2.1 Variability and genetic studies in morphological traits of fruit and seeds:

A significant variation was observed for variance, variability, and genetic components in morphological traits. Fruit weight showed the highest genotypic and phenotypic variance, whereas fruit moisture percent showed maximum value for environmental variances. In the coefficient of variance, the value for seed weight showed the highest genotypic and phenotypic coefficient of variance. Maximum environmental coefficient of variance in seed moisture percent. This is might be due to different genetic architectures developed as a result of adaptation to diverse environmental conditions prevailing throughout their distributional range. Similarly, **Roy (2004)** also reported in *Pinus roxburghii* the highest phenotypic and genotypic variance in No. of seed/cone. Highest environmental variance in cone fresh weight (g). The maximum value of the phenotypic and genotypic coefficient of variance in laboratory germination value and highest environmental variance in shoot length. Trait showed the highest heritability in fruit weight and maximum value of genetic advance and genetic gain in fruit length. Similarly, **Meena *et al.* (2015)** investigated an experiment on *Tecomella undulata* and found the highest heritability in pot length and genetic advance in seed weight. **Roy (2004)** investigated an experiment on *Pinus roxburghii* and found the highest genetic gain in laboratory germination value.

5.3 Correlation coefficient for various characteristics of *Celtis australis*

Among the different parameters being studied of genotypic correlation, various parameters showed highly significant positive correlation at $p \leq 0.01$ and a positive significant correlation at $p \leq 0.05$. A highly significant positive correlation was found between, fruit length: fruit width, fruit length: fruit thickness, fruit length: fruit weight, fruit length: seed length, fruit length: seed width, fruit length: seed thickness, fruit width: fruit thickness, fruit width: fruit weight, fruit width: seed length, fruit width: seed width, fruit width: seed thickness, fruit thickness: fruit weight, fruit thickness: seed length, fruit thickness: seed width, fruit thickness: seed thickness, fruit weight: seed length, fruit weight: seed width, fruit weight: seed thickness, fruit moisture percent – seed moisture, seed length: seed width, seed length: seed thickness, seed width: seed thickness. A significant negative correlation was found between, fruit length: fruit moisture percent, fruit length: seed moisture percent, fruit width: fruit moisture percent, fruit width: seed moisture percent, fruit thickness: fruit moisture percent, fruit thickness: seed moisture percent, fruit weight: fruit moisture percent, fruit weight: seed moisture percent, fruit moisture percent: seed length, fruit moisture percent: seed thickness, seed length: seed moisture percent, seed

width: seed moisture percent, seed thickness: seed moisture percent. Similarly, **Gawali *et al.* (2015)** investigated an experiment on *Pongamia pinnata* (L.) and found phenotypic correlation of variation were found a highly significant positive correlation ($p \leq 0.01$) found between 100-pod weight – pod length, 100-pod weight – pod thickness, seed length – pod length, seed length – pod thickness, seed length - 100-pod weight, seed breadth – pod width, seed breadth – 100-pod weight, seed breadth- seed length, aspect ratio - seed breadth, 100 seed weight – pod length, 100-seed weight – 100-pod weight, 100-seed weight – seed length, 100-seed weight – seed breadth, pod-seed ratio –pod thickness, pod-seed ratio – 100-pod weight, pod-seed ratio – seed length, pod-seed ratio - seed breadth, plant height – 100-pod weight, plant height – seed length, plant height – aspect ratio, plant height – pod-seed ratio, collar diameter – 100-pod weight, collar diameter – pod-seed ratio, volume index – 100-pod weight, volume index – pod-seed ratio, volume index – collar diameter. Also, **Bhat *et al.* (2018)** investigated an experiment on *Grewia optiva* and found similar results.

5.2 Seed germination testing of *Celtis australis* under laboratory conditions at 25^0C.

5.2.1 Seed germination percentage (%)

The data of seed germination percentage varied significantly, the maximum (83.33%) seed germination percentage was found in Srinagar with treatment T5 (1250 ppm), whereas minimum (30 %) in Barkot, Kot, and Maun gaon of each with treatment T1 (control). It is might be due to the genetic character of the source and the impact of the mother plant environment. Similarly, **Singh *et al.* (2006)** experimented on *Celtis australis* and found that the highest seed germination percentage value was 48% at 25^0C, whereas the lowest 15.50% was recorded at 15^0C. **Datt *et al.* (2017)** experienced *Zanthoxylum armatum* DC and found the gibberellic acid 200 ppm with kinetin 100 ppm-soaked seed for 48 hrs. highest value of 72.50% in T5 (GA3 200ppm) and lowest value of 12.25% in T1 (control) 33.66%.

5.2.2 Germination value

Germination value varied significantly with the highest value (0.105) in Srinagar with treatment T5 (1250 ppm). Lowest value (0.003) was found in Sonprayag with treatment T1 (control). The reason might be due to variation in growth related traits of several tree species indicating that some portion of the total variation might be under strong genetic control, which is of adaptive importance and leads to the differentiation into distinct

populations. Similarly, **Ghildiyal *et al.* (2009)** studied an experiment on *Pinus roxburghii* and found the germination value range from (2.84) to (28.9). The highest value (28.9) in Ashtavakra and the lowest (2.84) in Badiyargarh.

5.2.3 Peak value

The data significant variation was observed in peak value. Highest (0.380) peak value found in Srinagar with treatment T5 (1250 ppm). Minimum value (0.080) in Sonprayag with treatment T1 (control). It is might be due to elevation, geographic location, and some abiotic conditions of the seed source. Similar results were reported by **Gairola *et al.* (2011)** on *Jatropha curcas* and also, **Rout *et al.* (2021)** on *Saracaasoca (Roxb.) De Wilde*.

5.2.4 Mean Daily Germination

Mean Daily Germination showed non-significant effect with the highest value (0.28) in Srinagar with treatment T5 (1250ppm). The lowest value (0.157) was recorded in Barkot, Kot, and Maun Gaon of each with treatment in T1 (control). The reason might be due to different genetic factors of different provenances. Our result were in accordance with the finding of **Gairola *et al.* (2011)** and **Rout *et al.* (2021**)

5.2.5 Mean germination time

Mean germination time was recorded maximum (25.78 days) in Kot with treatment T1 (control) and minimum (17.39 days) mean germination time was found in Srinagar with treatment in T5 (1250ppm). It is might be due to different altitudes, geographic locations and some abiotic conditions of the seed source Similar finding on *Pinus roxburghii* Sarg was reported by **Roy *et al.* (2004)**. Also reported by **Saxena *et al.* (2020)** in an experiment on *Stereospermum suaveolens* and found the maximum mean germination time in T1 (Cocopeat+GA3) and the lowest in T17 (sand+hot water).

5.2.6 Germination Speed

The data presented in Table 4.10 showed the highest value (0.512) germination speed was found in Srinagar with treatment in T5 (1250ppm) and minimum (0.117) in Kot with treatment in T1 (control). Similarly, **Uniyal *et al.* (2003)** reported the germination speed of *Grewia oppositifolia* and found the highest germination speed in Cham 1.46 and lowest in Karanprayag 0.44.

5.3 Growth parameters

5.3.1 Plumule length

A significant differance was observed in the plumule length. The highest (6.39cm) plumule length was recorded in Srinagar with treatment in T5 (1250ppm). The lowest value (2.42 cm) was measured in Maun gown with treatment T1 (control). It might be attributed to the architectures developed as a result of adaptation to diverse environmental conditions prevailing throughout their distributional ranges. Similarly, **Singh and Thapliyal (2012)** reported an experiment on *Pinus wallichiana* and found the highest (6.67 cm) plumule length in Joshimath, and the lowest (4.32) one in Kufri.

5.3.2 Radicle length

Data revealed that ten provenances showed a significant difference in radicle length, the highest (3.83cm) radicle length was found in Bhatwari with treatment in T5 (1250ppm). Lowest (1.36 cm) in Maun gown with treatment in T1 (control). Similarly, **Singh and Thapliyal (2012)** investigated an experiment on *Pinus wallichiana* and found the maximum (5.70 cm) radicle length in Kufri and minimum (3.65 cm) in Nagar.

5.3.3 Plumule-Radical ratio

Significant differences were found in our investigation, maximum (2.28) plumule-radical length ratio was recorded in Nainbagh with treatment T1 (control) and minimum (1.15) in Srinagar with treatment T6 (1500 ppm). This might be due to adaptation to diverse environmental conditions prevailing throughout their distributional ranges.

SUMMARY AND CONCLUSION

The present investigation entitled **"Effect of provenance and pre-sowing treatment on seed germination of *Celtis australis* under laboratory condition in Garhwal Himalaya"** were carried out with the following objectives:

6.1 Morphological variation in fruit and seeds of *Celtis australis* collected from different provenance.

6.2 Estimate the genetic variation in fruit and seed characters of *Celtis australis.*

6.3 Effect of pre-treatment on seed germination and growth of *Celtis australis* under laboratory conditions.

The experiment was conducted in Laboratory, Department of Forestry, College of Forestry, Ranichauri, during 2021-22.

In this study, fruits (drupe) were collected from 10 different seed sources. The experimental site lies in the Garhwal Himalayan region of Uttarakhand.

The current study showed effect of seed source variation in fruit and seed morphology, genetic variation, germination characteristics of *Celtic australis.* The data obtained during the course of investigation were analyzed according to the procedure of analysis of variance for Complete Randomized Design. However, under laboratory conditions, data were analyzed according to the procedure of analysis of variance for Complete Randomized Design. The main finding of the study are summarized below.

6.1 Morphological variation in fruit and seeds of *Celtis australis* collected from different provenance.

6.1.1 Morphological parameters of fruit

It is seen that maximum fruit length was reported in Tilwara, fruit width in Kot, fruit thickness in Tilwara, fruit length and fruit width ratio in Tilwara, fruit weight in Tilwara and fruit moisture percent in Bhatwari. Minimum value of fruit length, fruit width, fruit thickness, fruit weight was recorded in Bhatwari, fruit length/fruit width ratio in Devikhet and fruit moisture percent in Kot respectively.

6.1.2 Morphological parameters of Seed

It was observed that maximum seed length was recorded in Tilwara, seed width in Kot, seed thickness in Tilwara, seed length and seed width ratio in Tilwara seed weight in Sonprayag and seed moisture percent in Bhatwari. Minimum value of seed length, seed width, seed thickness, seed weight was recorded in Bhatwari. The maximum seed length and seed width ratio was observed in Devikhet and seed moisture was recorded in P3 (Kot).

6.2 Variability and genetic studies for fruit and seed traits

6.2.1 Variability and genetic studies in morphological traits of fruit and seeds

Among the morphology maximum genotypic and phenotypic variation was recorded in fruit weight and highest environmental variation in fruit moisture. Maximum genotypic and phenotypic coefficient of variance was observed in seed weight and highest environmental coefficient of variance was seen in case of seed moisture percent. Maximum values of genetic advance and genetic gain were recorded in fruit length whereas maximum heritability was reported in fruit weight.

6.3. Effect of pre- treatment on seed germination and growth of *Celtis australis* under laboratory conditions.

Among the provenances, maximum germination percent, germination value, peak value, mean daily germination, germination speed was recorded in Srinagar with T5 (1250 ppm GA_3 concentration) and mean germination time in Kot with T1 (Control).

6.4 Growth parameters

Regarding the growth parameters, maximum plumule and radicle length was recorded in Srinagar with T5 (1250 ppm GA_3 concentration) and Bhatwari with T5 (1250 ppm GA_3 concentration) respectively. The plumule length/radicle length ratio was observed to be maximum in Nainbagh provenance with T1 (control).

CONCLUSION

Flow the present investigation, it could be concluded that Tilwara seed source proved to be the best regarding morphological characteristics among all seed sources. Srinagar seed source with 1250 ppm concentration showed best results in the relation to seed germination and growth parameters.

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PHOTO PLATE

Plate-1 Fruit (drupe) collection of *Celtis australis* from different seed sources

Plate-2 Measuring of fruit and seed parameters in the laboratory

Plate-3 De-pulping of fruit for the extraction of seeds

Plate-4 Preparation of different concentrations of Gibberellic Acid (GA_3)

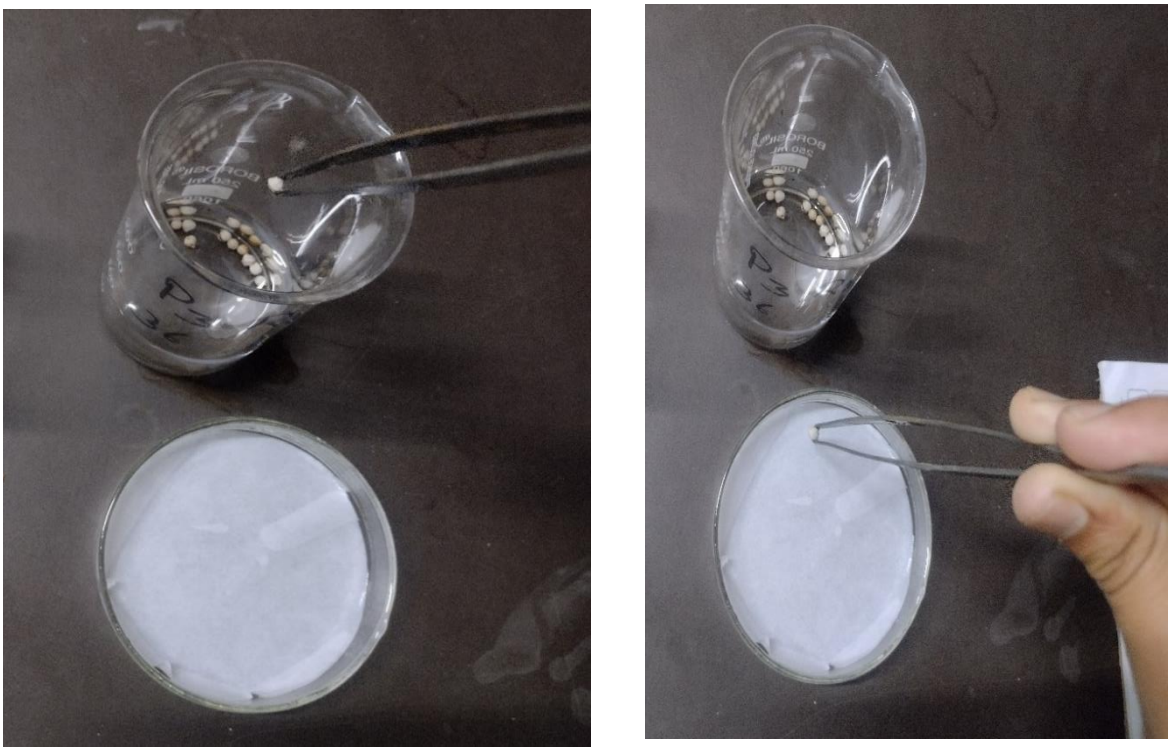

Plate – 5 Arrangement of seeds in the petridishs for the assessment of germination parameters

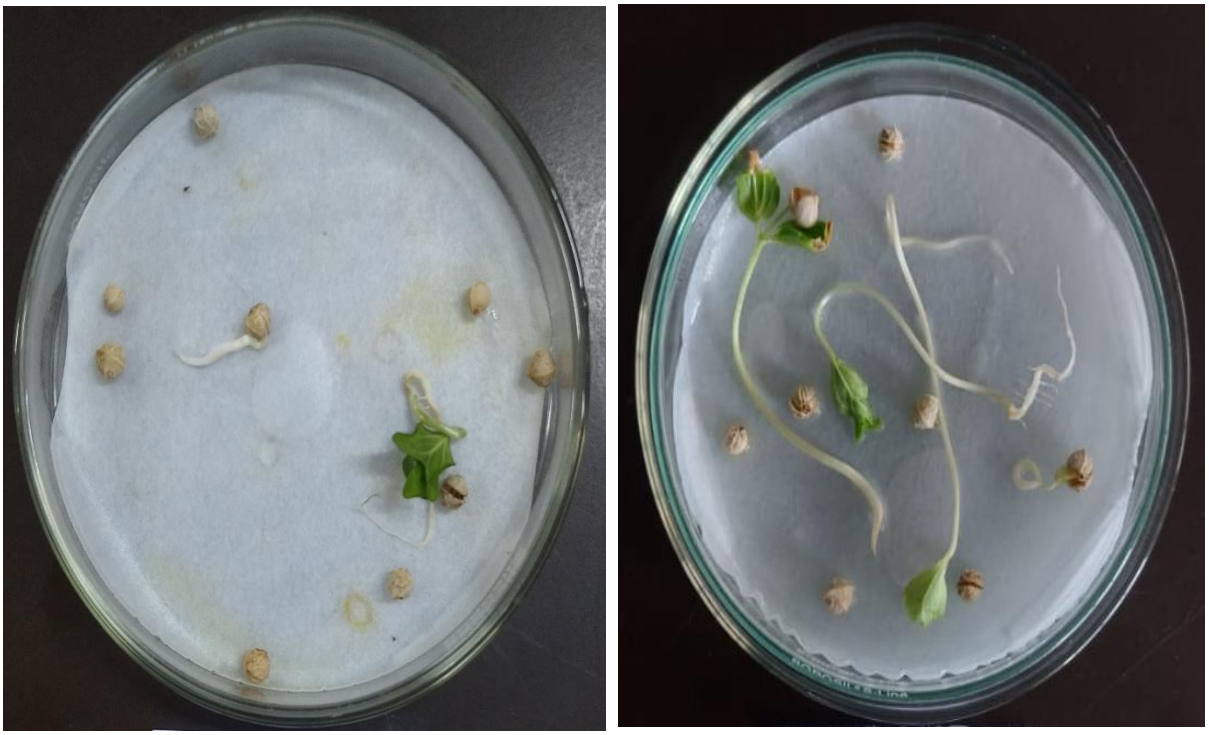

Plate-6 Effect of different treatments on seed germination of *Celtis australis*

APPENDICES

Appendix I: ANOVA for fruit length

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Treatment	9	1.535	0.171	0.00050
Error	20	0.582	0.029	
Total	29	2.117		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix II: ANOVA for fruit width

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Treatment	9	1.140	0.127	0.00231
Error	20	0.557	0.028	
Total	29	1.698		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix III: ANOVA for fruit thickness

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Treatment	9	1.894	0.210	0.00016
Error	20	0.606	0.030	
Total	29	2.501		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix IV: ANOVA for fruit length/fruit width ratio

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Treatment	9	0.006	0.001	2.923
Error	20	0.004	0.000	
Total	29	0.010		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix V: ANOVA for fruit weight

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Treatment	9	164.159	18.240	0.00000
Error	20	17.668	0.883	
Total	29	181.827		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix VI: ANOVA for fruit moisture percent (%)

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Treatment	9	48.262	5.362	0.23216
Error	20	73.842	3.692	
Total	29	122.104		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix VII: ANOVA for seed length

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Treatment	9	1.554	0.173	0.00043
Error	20	0.576	0.029	
Total	29	2.130		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix VIII: ANOVA for seed width

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Treatment	9	1.137	0.126	0.00178
Error	20	0.531	0.027	
Total	29	1.667		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix IX: ANOVA for seed thickness

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Treatment	9	1.895	0.211	0.00016
Error	20	0.606	0.030	
Total	29	2.501		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix X: ANOVA for seed length/seed width ratio

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated
Treatment	9	0.010	0.001	1.848
Error	20	0.012	0.001	
Total	29	0.022		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XI: ANOVA for seed weight

Source of Variation	DF	Sum of Squares	F-Calculated	Significance
Treatment	9	34.860	6.936	0.00016
Error	20	11.169		
Total	29	46.029		

Appendix XII: ANOVA for seed moisture percent (%)

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Treatment	9	53.440	5.938	0.16649
Error	20	71.748	3.587	
Total	29	125.188		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XIII: ANOVA for germination percent (%)

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Factor A	9	2,242.222	249.136	0.00001
Factor B	5	41,464.444	8,292.889	-0.00000
Interaction P X T	45	1,224.444	27.210	0.98657
Error	120	5,866.667	48.889	
Total	179	50,797.778		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XIV: ANOVA for germination value

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Factor A	9	0.010	0.001	0.00000
Factor B	5	0.048	0.010	-0.00000
Interaction A X B	45	0.015	0.000	0.00000
Error	120	0.014	0.000	
Total	179	0.088		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XV: ANOVA for peak value

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Factor A	9	0.187	0.021	0.00000
Factor B	5	0.528	0.106	0.00000
Interaction A X B	45	0.313	0.007	0.00337
Error	120	0.442	0.004	
Total	179	1.469		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XVI: ANOVA for mean daily germination (MDG)

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Factor A	9	0.028	0.003	0.00000
Factor B	5	0.460	0.092	0.00000
Interaction A X B	45	0.014	0.000	0.98174
Error	120	0.064	0.001	
Total	179	0.566		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XVII: ANOVA for mean germination time (MGT)

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Factor A	9	76.568	8.508	0.00000
Factor B	5	480.239	96.048	0.00000
Interaction A X B	45	168.148	3.737	0.00000
Error	120	134.249	1.119	
Total	179	859.204		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XVIII: ANOVA for germination speed

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Factor A	9	0.094	0.010	0.00000
Factor B	5	1.600	0.320	-0.00000
Interaction A X B	45	0.061	0.001	0.67600
Error	120	0.184	0.002	
Total	179	1.939		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XIX: ANOVA for plumule length

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Factor A	9	8.758	0.973	0.00000
Factor B	5	215.053	43.011	-0.00000
Interaction A X B	45	7.676	0.171	0.59639
Error	120	21.958	0.183	
Total	179	253.445		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XX: ANOVA for radicle length

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Factor A	9	2.795	0.311	0.00002
Factor B	5	90.528	18.106	0.00000
Interaction A X B	45	5.588	0.124	0.00241
Error	120	7.697	0.064	
Total	179	106.608		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

Appendix XXI: ANOVA for plumule length/radicle length ratio

Source of Variation	DF	Sum of Squares	Mean Squares	Significance
Factor A	9	1.781	0.198	0.00064
Factor B	5	1.636	0.327	0.00007
Interaction A X B	45	4.082	0.091	0.02008
Error	120	6.713	0.056	
Total	179	14.211		

* significant at < 0.05, ** significant at < 0.01, NS- Non-significant

VITAE

The author Mr. Sachin Negi s/o Mr. Kamal Singh Negi and Mrs. Urmila Devi, was born on 2nd of August, 1999 at Distt. Tehri Garhwal, Uttarakhand. He passed High School from G.I.C Inter college, Thangdhar (T.G.) in 2014 and Intermediate from S.L.V. Intermediate college, Dehradun in 2016, respectively from U.K. board. He has completed his graduation in B.Sc. (Agriculture) from S.G.R.R. (P.G.) College, Dehradun, Uttarakhand in 2020. He joined V.C.S.G Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal in 2020 for M.Sc. (Forestry) degree programme in Tree Improvement.

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