Effect of seed source on fruit, seed characteristics and seed germination of *Prunus cerasoides* (D. Don)

Thesis
By

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CERTIFICATE- I

This is to certify that the thesis entitled **"Effect of seed source on fruit, seed characteristics and seed germination of *Prunus cerasoides* (D. Don)"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Forestry** in the discipline of **Tree Improvement** of VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, Pauri Garhwal, Uttarakhand is a bonafide research work carried out by **Miss. Shweta Dhiman, I.D. No. 19353** 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 investigation have been fully acknowledged.

Place: Ranichauri
Date 10/10/22

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CERTIFICATE-II

This is to certify that the thesis titled, "**Effect of seed source on fruit, seed characteristics and seed germination of *Prunus cerasoides* (D.Don).**" **submitted by Ms. Shweta Dhiman, I.D. No. UUHF/19353** to VCSG Uttarakhand University of Horticulture & Forestry, Bharsar, Pauri Garhwal, Uttarakhand, India in partial fulfilment 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 13th July, 2022 (4.00PM).**

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ABSTRACT

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Title: Effect of seed sources on fruit, seed characteristics and seed germination of *Prunus cerasoides* (D. Don).

Prunus cerasoides is indigenous multipurpose tree species of the Himalayan regions and is also used for religious purpose, edible fruit, seed and gum as well as different medical applications, lumber, dyestuff and tannins. The present investigation was carried out to estimation the variability in fruit, seed characteristics and seed germination of *P. cerasoides* from different sources of Garhwal regions of Uttarakhand. The experiment consisted of six seed sources and fifteen different pre-sowing treatments, the data regarding on fruit and seed morphology were analyzed for Randomized Block Design, while seed germination and seedling growth data were analyzed for Completely Randomized Design. Among the seed sources, Silyara, Kuteti and Sadargaun seed source were showed superiority with respect to fruit and seed morphology. For seed germination and growth attributes, the highest (72.86%) germination percent was recorded in Silyara seed source followed by Sadargaun (69.00%), Kuteti (66.66%), Develgaun (64.4%), Chaurangikhal (63.06%) and Ranichauri (55.00%). In pre-sowing treatments, Gibberellic acid and hot water for 100°C at 24 hours was showed maximum germination percent and total seedling growth as compared to other treatments. The maximum heritability, genetic advance and genetic gain were found in seed length and seed weight. These two characters might be considered for the improvement in *P. cerasoides*. Correlation coefficient among various geographical, edaphic and climatic factors of seed sources with different fruit and seed characteristics were showed significant interrelationship between fruit and seed parameters. The overall study indicated that Silyara, Kuteti and Sadargaun seed sources are superior with respect to fruit, seed, seedling morphology and germination attributes as compared to Develgaun, Chaurangikhal and Ranichauri seed sources. The application of treatment GA_3 solution and hot water for 100°C at 24 hours are better for seed germination and seedling growth in case of *P. cerasoides*.

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सारांश

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शीर्षक: "प्रूनस सेरासोइड्स के फल, बीज विशेषताओं और बीज अंकुरण पर बीज स्रोतों का प्रभाव।"

प्रूनस सेरासोइड्स हिमालयी क्षेत्रों की स्वदेशी बहुडेशीय वृक्ष प्रजाति है और इसका उपयोग धार्मिक उश्य, खाद्य फल, बीज और गोंद के साथ-साथ विभिन्न चिकित्सा अनुप्रयोगों, लकड़ी, डाईस्टफ, टैनिन के लिए भी किया जाता है। वर्तमान अध्ययन उत्तराखंड के गढ़वाल क्षेत्रों के विभिन्न स्रोतों से प्रूनस सेरासाइड्स के फल, बीज विशेषताओं और बीज अंकुरण में परिवर्तनशीलता का आकलन करने के लिए किया गया है। प्रयोगों में छह बीज स्रोतों से बीज एकत्र किए गए तथा बुवाई से पूर्व पंक विभिन्न ट्रीटमेंट द्वारा बीजों को उपचारित किया गया जिसके फलस्वरूप बीज आकारिकी का विश्लेषण आर.बी. डी. विधि द्वारा किया गया, एवं बीज अंकुरण और अंकुर वृद्धि का विश्लेषण सी.आर.डी. विधि द्वारा कियागया। बीज स्रोतों में सिल्यारा, कुटेटी और सदरगाँव बीज स्रोत के फल एवं बीज आकार में श्रेष्ठता पाई गई और बीज अंकुरण और वृद्धि विशेषताओं के लिए सिल्यारा बीज स्रोत में उच्चतम अंकुरण प्रतिशत (72. 86%) पाया गया, इसके बाद सदरगांव (69.00%), कुटेती (66.66%), देवेलगाँव (64.4%), चौरंगीखाल (63.06%) और रानीचौरी (55.00%) का स्थान रहा। बुवाई पूर्व उपचार में जिबरेलिक एसिड और गर्म पानी (24 घंटे) के लिए 100 डीग्री सेल्सियस पर) में अन्य ट्रीटमेंटों की तुलना में अधिककतम अंकुरण प्रतिशत और कुल अंकुर की लम्बाई देखी गई। बीज की लंबाई और बीज के वजन में अधिकतम परिवर्तनशलता आनुवंशिक लाभ, आनुवंशिक प्रगति पाई गई। प्रूनस सेरासोइड्स में सुधार के लिए इन दो वर्ण विशेषताओं पर विचार किया जा सकता है। विभिन्न फल और बीज विशेषताओं के साथ बीज स्रोतों के विभिन्न भौगोलिक, मृदीय और जलवायु कारकों के बीच सहसम्बन्ध गुणांक को फल और बीज मानकों के बीच सार्थक अंर्तसम्बन्ध देखा गया। समग्र अध्ययन से यह संकेत मिलता है कि देवलगाँव, चौरंगीखाल और रानीचौरी बीज स्रोतों की तुलना में सिल्यारा, कुटेटी और सदरगाँव बीज स्रोतों के फल, बीज आकारिकी और अंकुरण गुणों के मामले में बेहतर है। प्रूनस सेरासोइड्स के मामले में बीज के अंकुरण और अंकुर वृद्धि के लिए जिबरेलिक एसिड (वृद्धि हारमोन) का विलयन और गर्म पानी (24 घंटे के लिए 100 डिग्री सेल्सियस पर) ट्रीटमेंट का उपयोग बेहतर है।

(डा०सी.एस.धनाई)
सलाहकार

(श्वेता धीमान)
लेखक

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ABBREVIATIONS

Particulars	Full name
%	Percent
et al.	Etalia (co-worker)
cm	Centimetre
/	Per
ºC	Degree Celsius
No.	Number
masl	Mean above sea level
mm	Mili meter
Sp.	species
SD	Standard deviation
NO.	Number
MGT	Mean germination time
GI	Germination index
gm	Gram
CV	Coefficient of variance
CD	Critical difference

CHAPTER-1 INTRODUCTION

The geographic place where seeds are gathered or discovered is referred to as the seed source. The use of proper seed sources is essential for the development and productivity of the forest (Zobel and Talbert, 1984). Provenance testing is used to assess the chance of discovering better populations for at least one attribute that can be used to boost planting programme productivity for future references. Provenance trials are established from seed obtained from several geographical locations and established at one or more sites to discover the optimal provenance in terms of growth performance and desired attributes in a specific location. Provenance trials serve as a source of high-quality seeds as well as a basis for choosing a candidate plus tree for seed orchards and breeding programmes (Kumar *et al.*, 2016).

Seed, which is utilised to conserve genetic variety, transfer and propagate flora, makes up the majority of natural resources. A shortage of high-quality tree seeds has hampered efforts to restore land through afforestation, reforestation and agroforestry. As a result, a number of countries developed tree seed programmes to address the paucity of tree seeds (Graudal and Lilleso, 2007). Variability study is required for increased productivity and future breeding activities. Tree improvement programmes have been reported as benefiting from morphological heterogeneity in seed traits among a speciesseed sources (Singh *et al.*, 2010; Fredrick *et al.*, 2015). Forest tree seed source studies are particularly useful since they assist in finding the best and most adaptable provenance. The initial phase in the forest tree enhancement programme is to find a seed source capable of generating the best-adapted trees (Fornah *et al.*, 2017).Forest tree improvement program starts with the study of available variations in the entire range of species (Suri, 1984). Knowledge of variability within a species is a prerequisite for developing effective tree improvement or breeding strategies. The genetic gain can be realized by making seed collections from phenotypically and genotypically superior trees or stands (Vakshaya *et al.,* 1992).

Variations due to nature are responsible for creating provenances, clones, races and ecotypes (Zobel and Talbert, 1984). Nature variations are important source for a tree breeder to improve a species. Variations can be successfully used for adaptability of a species such as; drought resistance and selection of a suitable genotype for fruit quality

etc. (Sundaram *et al.,* 2003). Considerable variation exists in traits of tress as an undisturbed pool of high natural variability has developed over the years (Perry, 1978). Generally, forest trees maintain high level of genetic variation within populations as a tree being long/ lived plants have high fecundity, an out crossing mode of reproduction and wind pollination (Yeh and Arnot, 1986). The natural variation existing in nature can be broadly divided into those variations from tree to tree in same site, variation in certain characters of trees between localities and variations in tree due to geographical locations. The regions attribute for the variations may be difference in enlivenment, due to variation in temperature, rainfall, moisture, soil, latitude, altitude and other external factors (Padmini and Banerjee, 1986; Mathur *et al.,* 1984). The variation is also described for large number of tree species due to environmental and edaphic factors of seed source (Vasudeva *et al.,* 1999).

Prunus cerasoides (D. Don) is a sacred plant in Hindu mythology which belongs to the Rosaceae family (Tiwari *et al.,* 2010).It is also known as; Padmakastha, Puddum, Phaya, Padmakha, Pajia, Paya, Phaja in Hindi, Padmakathi, Padmaka nu lakadu, Padmakashtha, Padmak in Gujrati, Padmakastha, Padmaka, Padmakasta in Marathi, Paja, Chabheearee, Amalguckr, Chamiari, Puddum in Punjabi (Tiwari *et al.*, 2016). The genus has approximately 430 species (divided across five sub-genera: Padus, Amygdalis, Cerasus, Prunophora, and Laurocerasus) that grow primarily in temperate regions of the Northern hemisphere (Ghora and Panigrahi, 1984).

Prunus is a vast genus of trees and shrubs ranked fifth among the temperate fruit that includes almonds, apricots, cherries, peaches, plums, wild Himalayan cherries and nectarines (Das *et al.*2011). In India, over 36 Prunus species have been identified in the Himalayan regions with 18 of them being useful for cultivation for various reasons (Ghora *et al.*, 1995; Pandey *et al.*, 2008 and Joseph *et al.*, 2018). *Prunus cerasoides* is found in the temperate Himalayan regions from Kashmir to the Khasi hills of Assam and Manipur. It is found in the Western Himalaya on open village lands on the outskirts of villages. *Prunus cerasoides* is one of the 31 multipurpose tree species of the Himalayan region and distributed form between 1,200 and 2,400 m on sloping land and reaches a height of 10–11 m (Samant *et al.*, 1998 and Tewari *et al.*, 2010). It's also grown as a

decorative plant at rest areas along the highway and in public parks and gardens (Joshi, 2004).

Prunus cerasoides is a medium sized deciduous tree species and has a smooth red brown bark that peels away in tiny horizontal stripes. The leaves have a short stem are glossy, long and pointed, toothed and have an elliptic blade 5–8 cm long with a slender petiole. Flowers are bisexual and occur in rose red colour faded to virtually white with time. Flowers are borne at the ends of leafless branches and the petals are 1.5 cm long, obovate and extend outward. The fruit of *Prunus cerasoides* is fleshy, yellow and red in colour with one stony seeded nut that is oval in shape about 1.3–1.6 cm long (Tiwari *et al,* 2010 and Joshi, 2004).

Prunus cerasoides is traditionally used for edible fruit, seed and gum as well as different medical applications, lumber, dyestuff, tannins and beads. Ripe fruits are edible but because of their acidic and astringent taste, they are rarely eaten raw. Instead, they are cooked and used to make sauces and cherry brandy (Tanaka and Nakao, 1976). Gum ejected from the trunk and branches are chewed and can be used in place of gum tragacanth. The tree wood is moderately hard, robust, resilient and scented; thus, it is employed in a variety of rituals by the locals. Buildings and ornamental furniture are occasionally made from heartwood that has aged well. Walking sticks and umbrella crooks can be made from the wood, branches and root suckers. Young twigs are used as toothbrushes and leaves are used as fodder (Singh and Nautiyal, 1991). The leaves of *Prunus cerasoides* is used to make green dye, fruitsare used to make a dark grey to green dye and tannins are obtained from the bark (Joseph, 2018).

Prunus cerasoides is mainly used as rootstock for cultivation of cherries and is also used in rituals by the local inhabitants, especially in Garhwal Himalaya. The plant has immense apicultural importance, flowers are pinkish-white in colour are rich source of nectar and pollenand useful source ofbee-forage. All of the four species of *Apis* present in India namely *Apiscerana indica*, *Apisdorsata, Apis florae and Apis mellifera* visit the flowers of *Prunus cerasoides* for its rich nectar and pollen (Gaur, 1999 and Awasthi *et al.,* 2015).

Many *Prunus* species produce seeds that are dormant in one of two ways: internal or embryo dormancy and external or endocarp dormancy (Ghayyad *et al.*, 2010; Gomez

and Dicenta, 2001; Mehanna and Martin, 1985). Scientists have used a variety of pre-treatments to break the dormancy of *Prunus* seeds with stratification being the most popular. To overcome the seed dormancy of most *Prunus* species, prolonged cold or warm plus cold stratification is required. The impact of warm and cold stratification pre-treatment on germination differs amongst *Prunus* species (Dirr, 1987 and Grisez *et al.*, 2008).

Seed germination is referred to a seed ability to produce normal seedlings under ideal conditions (Samarah, 2005). The effect of environment on seed germination is very complex because of interaction of external and internal factors which modify the rate and magnitude of germination (Rao, 1984). Germination occurs only when mature, viable seeds are given enough moisture and an appropriate temperature, which varies by species. In addition to moisture and temperature, certain species require light and pre-treatments. The four factors viz; moisture, temperature, light and pre- treatment are therefore regarded as essential factors that control the seed germination (Justce, 1972; Tamta and Tewari, 2018).

Prunus cerasoides trees produce a large number of seeds with hard seed coat and the regeneration of this species is very poor in its natural habitat (Tewari *et al.,* 2010). To fulfil the demands of modern life, forests have been overused. It is critical to plant large-scale plantations of fast-growing indigenous and foreign tree species to safeguard the future generation (Ekhuemelo *et al.*, 2016). Evaluation of germplasm, collection and maintenance are the essential pre-requisites for saving any endangered species from extinction under tree improvement programmes (Kedarnath, 1982). Keeping in view of the above mention fact, the present study was carried out in **"Effect of seed source on fruit, seed characteristics and seed germination of *Prunus cerasoides* (D. Don)"** with the following objective:

1. To study the effect of seed source variation on seeds and fruits of *Prunus cerasoides* from different seed sources.
2. To study the effect of pre-treatment on seed germination of *Prunus cerasoides* from different seed sources.
3. Estimation of genetic variability among the different *Prunus cerasoides* seed sources.

CHAPTER-2 REVIEW OF LITERATURE

The review of literature on research is an essential part of any kind of scientific research. The review of literature here is based on the objective of the study, which gives an idea about the work done in past and also provide the basis for interpretation and discussion of new findings. For the present investigation, the available literature on seed source variability into the seed/ fruit characteristics, germination and effect of pre-treatments on seed germination is being reviewed under the title "**Effect of seed source on fruit, seed characteristics and seed germination in *Prunus cerasoides* (D. Don)"** described below with appropriate headings:

2.1 Seed and fruit morphology

Seed size and seed weight are important characteristics of plant species which depends on a different factor such as; seed source, genetic makeup and geographical environment where it is growing **(Carvers and Steel, 1984).**

Bisht *et al.* (2002) observed the variation in seed characteristics of *Azadirachta indica* from different locations in Madhya Pradesh. The seed length was varied from 0.97 to 1.36 cm, the maximum seed length was observed in Phulbani provenance while the seed width varied from 0.56 to 0.68 cm with the maximum in Phulbani and Bolangir provenance. Weight of 1000 seeds varied from 181 to 231.21 g with the maximum seed weight was recorded in Phulbani provenance.

Kumar *et al.* (2003) assessed the variation in seed morphological characteristics of *Prosopis cineraria* on 30 provenances in Rajasthan and Haryana. They concluded that the average maximum seed weight (72.0 g/seed) was recorded in Mukam village (I) provenance with Mukam village (V) provenance (39.6 mg/seed) being least. The average seed length varied between 5.39 mm in Jodhpur city (1) to 7.42 mm in Nandri village (II) while the average seed breadth was minimum (3.82mm) in Mukam village (V) and maximum (4.89mm) in Rewari city provenance. The variation in seed characters attributed to mother tree differences and these are as a result of large variation in climatic

conditions in areas of its natural condition. The variation expected since it is a cross pollination species.

Dhanai *et al.* (2003) observed the seed source variation in pod and seed characteristics of *Albezia chinensis* wherein they collected the seeds from various regions in Himachal Pradesh. They have reported that seed length varied from 5.60 mm to 6.53 mm in Kund and Manan seed source, respectively. Seed width varied between 4.19 mm to 5.08 mm in Kund and Manan seed source, respectively.

Kumar *et al.* (2004) observed the seed source variation in seed characteristics between thirteen seed sources of *Acacia catechu* in Dehradun, Uttarakhand. They concluded that maximum seed length (7.33 mm) was recorded in darpur seed source with Mahondrowal seed source (6.45 mm) being minimum, while the highest seed width (6.16 mm) was recorded from Mahondrowal seed source with Satyal seed source (5.25 mm) being least. Highest seed weight (39.97 g) was recorded in Rampur seed source while the lowest (25.99 g) in Basoli seed source. They also reported that variation in seed source with respect to their morphological characters could be due to the fact this species grows over wide range of rainfall, temperature and soil types.

Kumar and Siddiqui (2008) studied on provenance variation in seed characteristics of *Pongamia pinnata* and the seed were collected from different states of India in Tamil Nadu, Kerala, Karnataka, Bihar and Jharkhand. They reported that maximum seed length (2.28cm) was observed in Tumkur (Karnataka) provenance, while minimum seed length (1.44cm) was recorded in Patna (Bihar) provenance. The highest seed width (1.81cm) was recorded in Trissur (Kerala) provenance with Patna (Bihar) provenance (1.23cm) being least. The maximum seed weight was found (2.25g) in Trissur and least was (1.42g) form wayanad (Kerala). The seed characteristics of *Pongamia pinnata* from Tumkur (Karnataka) provenance have showed superiority as compared to other provenance because of bigger seed size.

Kumar *et al.* (2008) studied on variation for seed traits in *Pongamia pinnata* L. of different agro-climatic zones of southern Karnataka. They reported that seed length, seed width and test weight of seeds varied from seed source ranged between (18.52-23.13 mm), (12.92-19.80 mm) and (176.99-255.13 gm) respectively.

Tewari *et al.* (2010) observed the variation in fruit parameters of *Prunus cerasoides* in Nainital, Kumaoun Himalaya. They concluded that all *Prunus cerasoides* fruit parameters showed significant variation between seed source and date of seed collections. The average maximum fruit length was recorded in (13.55±0.16 mm), fruit width (10.25±0.13 mm), weight of 100 fruits 87.75±2.36 gm and fruit moisture content between (46.57 ± 0.45%).

Singh *et al.* (2010) investigated the provenance variation in seed and seedling characteristics of *Quercus glauca* Thunb, in Garhwal Himalaya, India. They observed that significant variation in seed length, breadth and weight between 8 seed sources. Seed length ranged between 1.03 to 2.30 cm with lowest to Nauty and Kakragad seed source while seed breadth ranged between 1.04 at Nauty to 1.39 at Kulsari seed source. The maximum seed wight of 100 seed (183.33g) was found in Harmani seed source with minimum (106.66g) being Nauty seed source. Seed length and weight showed significant inverse correlation with altitudinal range of seed source.

Raut *et al.* (2011) studied on variation in fruits and seeds characters *Pongamia pinnata* in Konkan region of Maharashtra and they reported that the KKVPP-13 and KKVPP-19 seed source showed highest seed weight (3.18 gm) and seed length (27.75 mm).

Lekha and Lalji (2011) studied on variation in seed characters of *Jatropha curcas* L. with various zones and provenances. The highest seed length (19.06 mm) was recorded in Nainpur provenance, while Udaipur provenance showed the lowest seed length of (16.40 mm).

Anita and Vidya (2012) assessed seed source variation in fruit, seed and seedling traits of *Hippophae salicifolia* and the seeds were collected from various 12 seed sources of Uttarakhand. They found that maximum fruit length (7.15 mm), fruit width (6.25mm), seed length (5.20 mm), seed width (2.83 mm) and weight of 100 seed (2.83 g) were observed in S9 seed source of Chamoli district of Uttarakhand.

Parthiban *et al.* (2013) studied seed source variation and biochemical characterizations of ten *Pongamia pinnata* genetic resources at Forest College and Research Institute, Mettupalayam. The studies revealed that among the selected seed sources, Karamadai seed source was showed superiority over others in terms of seed

length (24.45 cm), seed breadth (15.46 cm), seed length/breadth ratio (1.90 cm), weight of 100 seeds (144.30 g) and oil content (24.56%).

Renuka (2013) studied on the provenance variation in *Cassia fistula* and the pods collected from five different provenance. The highest pod length and weight (68.90 cm and 73.90 gm) was recorded in Hilly zone.

Jaisankar *et al.* (2014) assessed the variability in pod, seed traits and oil content of 24 accessions of *Pongamia pinnata* and seeds collected from different parts of the Andaman and Nicobar Islands, India. It is revealed that, the accession CPT-6 collected from New Wandoor in South Andaman was showed the maximum values for pod length (75.51 mm), pod width (34.62 mm), pod thickness (17.55 mm), weight of 100 pod (770.33 g), seed width (21.23 mm), weight of 100 seed (377.00 g) and oil content (43.92%). Maximum seed length (2646 mm) was recorded in from CPT 2 and the maximum pod-seed ratio was obtained from CPT 13 and CPT 4 (2.50 and 2.44, respectively).

Ajeesh *et al.* (2014) examined the impact of seed weight on germination parameters of *Caloplyllum inophyllum* L. from coastal region. Number of fruits per kg was 116.0, 166.7 and 262.0 and thousand seed weight was 8.55, 6.60 and 5.07 kg, respectively in seed grade classes such as; 8-11 g, 5-8 g and 2-5 g. With regards to individual seed characters, seeds belonging to 8- 11 g class recorded a higher weight (8.62 g), length (3.24 cm), breadth (2.99 cm) and volume (0.12 cm) as compared to other classes.

Rakesh and Shivanna (2015) studied on variation in important traits of Jamun (*Syzygium cumini* Skeels). They concluded that the maximum test weight (32.85 gm), maximum seed width (8.42 mm) and seed length (15.20 mm) were recorded in Mundgod seed source. Lower seed length and diameter was recorded in the Sirsi seed source (12.16 and 7.51 mm) respectively.

Nagar (2016) studied seed source variation in pod, seed and seedling characteristics of *Bauhinia variegata* lin. and the seeds were collected from 10 different seed source of Uttarakhand. They found that the maximum pod length (22.38cm), pod breath (2.41), pod thickness (0.63cm) and weight of 100 seed (50.70 g) were recorded in khadi seed source of Uttarakhand.

Tewari and Tewari (2016) assessed the exact maturity time and suitable temperature for seed germination of *Prunus cerasoides* in Central Himalayan region of

Uttarakhand, India. The average seed length ranged between (7.46±0.1 mm) to (12.87 ± 0.29 mm), seed width between (4.31 ± 0.09 mm) to (8.91 ± 0.08 mm), and the weight of 100 seeds ranged between (20.37 ± 0.18 g) to (48.08 ± 0.68 g). The seed and fruit (length, width and weight) were varied significantly across sites and dates of collection.

Tamta and Tewari (2018) assessed the exact time of seed maturation and germination of wild apricot (*Prunus armenica*) at four sites of Nainital district of Uttarakhand and study was conducted in two years 2015-16. They found that the fruit (length × width) ranged from 436.73 ± 3.17 mm^2 to 1269.61 ± 3.34 mm^2 and seed (length × width) was 223.19 ± 3.16 mm^2 to 465.66 ± 3.09 mm^2 in first year. In second year, fruit (length × width) ranged from 440.30 ± 3.18 mm^2 to 1295.09 ± 2.30 mm^2 and seed (length × width) 232.49 ± 2.12 mm^2 to 591.49 ± 2.97 mm^2. The weight of 100 fruits ranged from 639.84 ± 5.84g to 1610.30 ± 6.49g and weight of 100 seeds 119.13 ± 4.13g to 274.75 ± 3.43g in first year. In second year, the weight of 100 fruits ranged from 641.27 ± 5.96g to 1633.24 ± 12.67g and weight of 100 seeds 120.61 ± 2.42g to 305.65 ± 6.48g.

2.2 Effect of pre-treatments in seed germination

Universitesi *et al.* (1999) investigated the effects of seed coat removal, GA_3, H_2SO_4, preserved in cold and hot water and stratification (20-24°C and 2-4°C) in seed germination of *Prunus mahaleb*. They reported that after removal of seed coats and soaking for 24 hours, the highest mean germination was recorded in a solution of GA_3 at 1000 ppm + cold stratification for twelve weeks 2-4°C, while the seeds preserved at 20-24ºC or 2-4ºC with seed coats were not showed germination and the removal of seed coats + soaking 200, 500 or 1000 ppm GA_3 showed germination beginning of stratification, but the seeds with seed coat started to germinate after 56 days of stratification in sand + perlite.

Esen *et al.* (2009) assessed the effects of 0.1% Citric acid (CA) or deionized water (DW) soaking in combination with various pre-treatments on the germination of *Prunus avium* seeds from northern Turkey. They found that pre-soaking seeds in deionized water for two days increased germination more than pre-soaking in 0.1% citric acid solution. Citric acid and deionized water both pre-soaking treatments significantly affected seed germination. A 15days warm period followed by a four-month cold period, warm + cold periods and three-month cold periodwere found the best pre-treatments for seed germination

Tewari *et al.* (2010) observed the effect of pre-treatment on seed germination of *Prunus cerasoides* in Kumaoun Himalaya. They concluded that hot water and sulphuric acid treatment not showed germination and mechanical removal of seed coat was increased germination percent rapidly (70-100%) in comparison to control (5.83 ± 0.83 to 31.68 ± 25.02%).

Azad *et al.* (2010) investigated the pre-sowing treatments on seeds of *Melia azedarach* in Bangladesh and five pre-sowing treatments control, immersion in cold water, immersion in hot water, scarification with sand paper and H_2SO_4 were used on seed germination. They concluded that the germination rates of pre-sowing treated seeds were significantly increased compared to those in control, except for cold water treatment. The maximum germination rate (80 %) was found in scarification with sand paper followed by immersion in sulphuric acid (74 %) and hot water treatment (69 %).

Ghayyad *et al.* (2010) examined the effect of endocarp removal, Gibberellin, stratification and Sulfuric acid on germination of *Prunus mahaleb* L. Seeds. Thry reported that alternate (cold-warm) stratification for 10 weeks is more effective for germination of *Prunus mahaleb* seeds. The highest germination (70 %) was found in by removing the endocarp then soaking the seed for 24 hours at 1250 PPM Gibberellic acid, while soaking seeds in Gibberellic acid at 1250 PPM then alternate stratification showed (58 %) germination. Sulfuric acid showed minimum germination percent (16.66%) with seeds treated for 10 minutes then alternate stratification for 6 weeks. They also reported that before stratification removing the endocarp of seeds is more effective than immersion in sulfuric acid.

Moreira *et al.* (2012) investigated the suitable conditions for seed germination of *Prunus azorica*. After removal of the outer layers of the fruit bydetermining the effect of stones or seeds, stratification regime (six treatments and a control), incubation temperature (four alternating temperature regimes) and gibberellic acid concentration (three levels) were used for seed germination. They found that incubation temperature, stratification regime and growth regulator concentration showed significant effect of both stones and seeds. Effect of endocarp removal showed 49% germination with seeds and 15% with stones. In stratification process, germination occurred for only endocarp

removal seeds, the highest germination percentage was recorded in cold stratification followed by warm stratification (80% to 75%) and cold stratification alone (77%).

Mello *et al.* (2009) examined the effect of Gibberellic acid (GA_3) on seed germination of *Penstemon digitalis.* Three experiments were evaluated to determine the germination percent, GA_3 concentrations used were 0, 10, 50, 100, 200 and 500 mg/L^{-1} in first experiment, in second experiment 0, 500, 1000 and 1500 mg/L^{-1} and 0, 500 and 1000 mg/L^{-1} in third experiment. They reported that GA_3 increased the germination percentage and rate of seed germination, the treatment 1000 mg/L^{-1} GA^3 was found best for seed germination in all three experiments.

Das (2014) assessed the effect of seed sources variation and pre-sowing treatments on seed germination of *Acacia catechu* and *Elaeocarpus floribundus* in Bangladesh. The seeds were collected from 4 different regions in Bangladesh and seeds treated with six pre-sowing methods. He concluded that significant variation was observed in among the pre-sowing treatments for both species. The highest germination percent was found to be 91.26% in hot water (80°C for 10 min) treatment in *Acacia catechu* and the highest germination percent (89.81%) of *Elaeocarpus floribundus* was found in H_2SO_4 treatment followed by 86.35% and 78.42% in treatments with hot water (100∘ C for 12 min) and scarification. The investigation revealed that the interactions of seed source variation and pre-sowing treatments was significantly effect in seed germination percentages.

Bhandari (2017) studied the effect of pre-treatment on seed germination and seedling growth of three *Albizia* species. They reported that the highest mean germination percentage (39.31%) was observed in *Albizia julibrissin* and minimum in *Albizia odoratissima* (34.58%) among three *Albizia* species. In *Albizia oxioratissima*, the maximum germination (71.66%) was found in hot water 20 minutes and minimum (15%) in coldwater 12hrs and 48hrs. In *Albizia procera*, the maximum germination (46.67%) was found H_2SO_4 for 5 minutes and minimum (28%) in coldwater and nicking. In *Albizia julibrissin*, the maximum germination (60%) was found in hot water for 20 minutes and minimum (11.67%) in cold water 24 hours. Lowest germination percentage *Albizia odoratissima* shows that the seed coat of *A. odoratissima* is the hardiest among the three species.

Chukwu *et al.* (2020) examined the effect of Pre-sowing treatments on the germination of *Prosopis Africana* seeds. The result revealed that seeds treated with tetraoxosulphate (VI) acid for 30 min (T3) was showed highest germination percentage (83.3%) followed by the seeds treated with hot water for 6 hours (T4) and 12 hours (T5) (33.3% and 13.3%, respectively). However, seeds treated with cold water for 3 days (T7), 7 days (T9) and control were not showed any germination.

Thapliyal *et al.* (2021) examined the seed germination response of *Pyrus pashia,* seeds were collected from two sites S1-Champawat and S2-Pithoragarh from Uttarakhand and gibberellic acid treatment, cold storage. They reported that the highest GP (94 %) was observed in the seeds pre-treated with GA_3 500 ppm followed by the ones treated with 300 ppm (93 %), 700 ppm (92 %) and 100 ppm (86 %). Seeds pre-treated with GA_3 at 100 ppm resulted in highest GP (31 %) in Source 2 followed by 700 ppm (29 %), 300 ppm (25 %) and 500 ppm (23 %). After one year of storage, germination percent of seed was 55% which increased to 64.5% after second year and further to 82.5 % in third year while in case of seeds of other source (S2), GP was 12.25 %, 17.33 % after first and second year respectively, that doubled to 34.75 % after three years of storage.

2.3 Effect of seed source variation in seed germination

Nayak *et al.* (2004) assessed seed source variation of *Albezia lebbeck* in Karnataka, India and reported that between five provenances, mean daily germination ranges varied from 0.728 (Chickmagalur) to 1.382 (Mandya). The highest germination value (2.806) observed in Mandya provenance with Dharwad provenance (1.37) being least. They also reported that variation in germination may be attributed by dormancy of seed caused by im-permeability of hard seed coat or may be dormancy in embryo.

Singh *et al.* (2005) studied on seed sources variation in seed and seedling traits of *Saraca asoca* (Roxb.) De Wilde in Kerala and seeds were collected from six different seed source. They found that significant variation between the seed sources with respect to seed and seedling traits. The germination percent varies from 63% to 93%, where the Oorakam seed source found to be superior with respect to seed and seedling traits.

Mahto *et al* (2006) observed the seed source variation in germination percent of *Azadiractha indica* in Jharkhand. They concluded that maximum germination percentage

(72%) was observed in Ranchi seed source and minimum (36%) in Girdh seed source. The germination energy was also high (38) in Ranchi provenance which reflects that seedling should be raised from Ranchi provenance.

Sridhar (2006) studied on effect of variations in *Jatropha curcus* and he reported that germination percent was varied from 49.30 to 86.10 %. The germination percent varied from 61.90% to 95.23% in heavy and large seed followed by medium seed 47.61% to 91.47% and small seed 39.09% to 71.42%.

Reddy *et al.* (2007) observed the seed source variation in *Pongamia pinnata* for seed and seedling traits in Karnataka. They concluded that germination percent and their attributes showed significant variation between seed sources. The highest germination percent 94.87% was recorded in Kolar seed source with Mandya seed source 42.70% being least. Kolar seed source has recorded significantly maximum germination vigour (12.65) with owing higher mean daily germination (3.30) and peak value of germination (3.82).

Nawahbahar (2008) observed the seed source variation of *Albezia lebbeck* and the seeds were collected from different locations of Uttarakhand, India. They found that significant variation in germination percent and vigour index between the seed sources. Seed germination percent varied between 62.80% (Chandra Nagar) to 96.36% (Dehradun). Highest vigour index (2022) was recorded in Nahan seed source with Chinglepet seed source (1177) being least. They also reported that heavy and large seed contains more food reserve than smaller ones, which helpful in germination by providing more energy.

Hembrom *et al.* (2010) studied on germination and germination speed in *Terminalia arjuna* and *Terminalia tomentosa*. The seeds were collected from different provenances of Jharkhand state and the maximum seed germination (83.33 %) was recorded in the seeds of *Terminalia arjuna* from Bahargoda seed source while the maximum seed germination (23.3 %) was recorded in *Terminalia tomentosa* from Pipariya seed source.

Kumar and Siddiqui (2008) studied on the seed characteristics and seed germination of *Pongamia pinnata* from different 12 provenances of India that from Tamil

Nadu, Kerala, Karnataka, Bihar, Jharkhand. The maximum germination percent (64.33%) was recorded from Ranchi (Jharkhand) provenance and minimum (30.67%) was found in Mettupalayum provenance. Significant superiority of Ranchi provenances in inferred over other in respect to physiological characteristics.

Tewari *et al.* (2010) studied the various physical attributes of fruits/seeds of *Prunus cerasoides* and enhance seed germination by giving various chemical and mechanical pre-treatments to the seeds. The fruits/seeds were collected from two different elevations: high elevation sites and low elevation sites in Nainital Kumaun Himalaya, Uttarakhand. They reported that highest germination (58.0±8.6%) was occurred in high elevation site at third collection. They also reported that germination on the seed does not occur when the moisture content of the seed is high.

Anita and Vidya (2012) assessed seed source variation in fruit, seed and seedling traits of *Hippophae salicifolia* and the seeds were collected from various 12 seed sources of Uttarakhand. They reported that the maximum germination percent (96.25%), length of radicle (2.30 cm) and length of plumule (4.43 cm) was recorded in S9 seed source of Chamoli district of Uttarakhand.

Oyebade *et al.* (2012) studied on seed source variation in *Chrysophyllum albidum* (G. Don) from six sites in river state, Nigeria. They reported that the highest germination percent (53 %) was recorded in Bori seed source with Bonny seed source (21 %) being least.

Lekha and Lalji (2011) studied on variation in seed and seedling characters of *Jatropha curcas* L. with various zones and provenances. They observed that germination percent varied from 34.00% to 86.50% in different provenances within the various zones.

Reddy *et al.* (2014) observed the seed source variation in germination behaviour of *Vateria indica* Linn. and the seed of *Vateria indica* were collected from three locations in Karnataka. They reported that results not showed significant variation for speed of germination and time taken for complete germination. On other hand, tree-to-tree variations in all three seed sources showed significant variation for all the parameters except for speed of germination.

Ajeesh *et al.* (2014) studied the effect of seed size on seed germination of *Calophyllum inophyllum* L. and they observed that the highest germination percentage in medium sized seeds (68.00 % +3.00) followed by large seeds (68.00 % +2.00).

Palanikumaran *et al.* (2015) assessed the different populations of South India for seed germination in Undi (*Calophyllum inophyllum* L.). They reported that significant variation was recorded in seed germination between various populations and it ranged varied from 46.67 to 78%. The maximum germination percent (78.00%), mean daily germination (1.79 days), germination value (5.11) and peak value of germination (3.06) was recorded in Honnavar seed source.

Palanikumaran *et al.* (2016) assessed variation in seed and seedling traits of *Pongamia pinnata* in Mettupalayam, Tamil Nadu and seeds were collected from different agro-climatic zones of Tamil Nadu. They reported that significant variation was observed in all the germination attributes. Maximum germination percent was recorded in Hosur seed source (85.33%) followed by Krishnagiri seed source (85.33 %) and Theni seed source (81.67 %), whereas, Dharapuram seed source showed minimum germination percent (61.00 %).

Tiwari and Tiwari (2016) assessed the exact maturity time and optimum temperature for reaching the maximum germination in the seeds of *Prunus cerasoides* in Central Himalyan region of Uttarakhand, India. The fruits were collected from six various sites with altitudinal range of 1350 to 1810 m and the seeds were placed in two conditions: above paper (AP) and between papers (BP). They found that average germination precent in all site seeds were placed on AP and BP ranged between 6.66±2.66 to 53.33±13.33% and 0±0 to 7.49±4.16% respectively. The higher germination was found at a temperature of 25°C, when seeds were placed on above the paper.

Tamta and Tewari (2018) assessed the exact time of seed maturation and germination of wild apricot (*Prunus armenica*) at four sites of Nainital district of Uttarakhand and study was conducted in two years 2015-16. They concluded that the highest germination in stored seeds was 62.67 ± 5.81% when moisture content of the stored seeds was 22.18 ± 1.36%.

Renuka (2013) observed the provenance variation in *Cassia fistula* and they reported that significant variation was observed in germination percent between the five different provenances. The maximum germination (64.85 %) was found in Hilly zone with North eastern dry zone (54.44%) being least.

2.4 Phenotypic, Genotypic and Environmental Coefficient of Variation

Singh and Bhat (2008) studied on provenance variation in morphology traits of *Dalbergia sissoo* Roxb. from Central Himalaya, India. Between 19 different altitudinal sources with respect to seed length, seed breadth, seed thickness, seed weight and seed germination which revealed considerable genetic variability. They found that Rishikesh provenance showed highest coefficient of variance for seed length (16.05 %), seed breadth (17.78 %) and seed thickness (12.75 9%) while Haripur provenance showed highest coefficient of variance of (9.59 %) for seed weight. Germination among provenances varied between 93.33 to 100%.

Singh and Bhatt (2008) observed variability in seed and seedling traits of *Celtis australis* Linn. in the Central Himalaya, India. They found that highest phenotypic variance (357.85) and environmental variance (253.63) were noticed in seedling survival percentage, while the highest genotypic variance (165.32) was noticed in shoot length. Shoot weight had the highest phenotypic coefficient of variance (46.03) and genotypic coefficient of variance (36.99) while nursery germination percent (41.17) had the highest environmental coefficient of variance (21.99) genetic advance was noticed in shoot length and the lowest (0.070) in root shoot ratio. Shoot weight showed maximum (61.08%) genetic gain, followed by seedling weight (46.11%) and number of branches per plant (42.03%).

Rawat and Bhakshi (2011) studied the seed source variation for seed characteristics of *Pinus wallichiana* between 20 locations in Himachal Pradesh and Uttarakhand with respect to seed length, seed width, seed thickness, seed weight, seed volume and seed germination attributes. They reported that the maximum coefficient of variance was observed in seed weight (14.95 %) followed by seed volume (11.85 %), seed thickness (9.97 %), seed length (8.37 %) and seed width showed least coefficient of variance (7.81 %). The highest amount of variation was recorded in germination energy varied between 10.14 to 78.25 % (CV 58.61%), followed germination percent 16.00 to

80.67 % (CV 36.36%), germination value 1.41- 40.97 % (CV 30.31 %) germination energy 5.80-74.80 % (CV 24.04 %) and germination period showed least variations 13.30 - 19.30 % (CV 7.50 %).

Shankar and Synrem (2012) studied the variation in morphology traits of fruits and seeds of *Prunus nepaulensis* and the seeds were collected from three provenances (Nongostoin, Mawlao and Kshaid) on the Shillong plateau in Meghalaya, India. They reported that seed weight showed the highest coefficient of variation (29.79), followed by seed diameter (7.98) and seed length showed least coefficient of variation (7.86).

Uniyal *et al.* (2014) assessed the effect of seed source variation on seed and seedling characteristics of *Grewia oppositifolia* Roxb. and the seeds were collected from 22 sources. Variance estimates between the seed germination, root collar diameter, root and shoot lengths and root/shoot ratios did not exhibit any significant differences. Maximum phenotypic (109.1) and genotypic (87.5) variance was recorded for root length, germination percent that showed the highest (37.07) environmental variance. Root to shoot ratios showed the lowest values for phenotypic (0.17), genotypic (0.11) and environmental (0.06) variances.

Kumar and Kaushik (2015) assessed of 23 progenies of *Pongamia pinnata* for estimation of genetic parameters for seed oil content and different growth characters for improvement of the species for higher oil yield. They observed that the highest phenotypic coefficient of variation (49.33) and genotypic coefficient of variation (28.56) was recorded for the germination percentage followed by height of the first branch. Number of leaves (0.5551), inter-nodal length (0.5580) and number of branches (0.6182) showed positive correlation with the seed oil content. The genotypic coefficients of variation were less as compared to the phenotypic coefficients of variation for all the characters.

Palanikumaran *et al.* (2016) assessed variation in seed and seedling traits of *Pongamia pinnata* in Mettupalayam, Tamil Nadu and seeds were collected from different agro-climatic zones of Tamil Nadu. They reported that highest genotypic coefficient of variation (GCV) 1.559 was observed in seed weight, while the highest phenotypic coefficient of variation (PCV) 0.084 was observed in root vigour index. The highest significant and positive correlation observed between mean daily germination (0.149)

followed by germination percent (0.141), peak value (0.140), root vigour index (0.084) and shoot vigour index (0.066).

CHAPTER-3 MATERIALS AND METHODS

The present investigation entitled on "**Effect of seed source on fruit, seed characteristics and seed germination of *Prunus cerasoides* (D. Don)"** was carried out in college of forestry Ranichauri, Tehri Garhwal, VCSG Uttarakhand University of Horticulture and Forestry Bharsar, Pauri Garhwal, Uttarakhand. The experimental details relaying to site description, seed source, materials used and course of action followed during the study was described here under following.

3.1 Experimental site

3.1.1 Location

The experimental site College of Forestry, Ranichauri campus is located 10 km from Chamba (Rishikesh Gangotri Road) at an altitude of about 1700 to 1750 masl. The experimental site lies between latitude $30^0$18'654" to $30^0$19'562" N and longitudes $78^0$24'570" to $78^0$24'521" E under mid-hill zones of Uttarakhand.

3.1.2 Climate

Climate and weather condition of the experimental site is generally humid temperate characterized by chilling winters. Normally, January and February months are the coldest, while May and June are the hottest. The mean annual rainfall is 1200 – 1500 mm, most of which is received from June to September. The average annual maximum and minimum temperature of experimental site ranged between 8.9ºC to 23.5ºC and 0.6ºC to 14.1º C.

3.2 Description of the seed source

Seed source refers to the place from which the seeds were collected for the study. The source of the seeds plays a vital role because it determines the phenotypic and genotypic quality of the seeds.

Table 1: Description of seed source of *Prunus cerasoides* in Garhwal (Himalaya).

S.No.	Seed source (village)	Block	Elevation (m.asl)	Latitude (N)	Longitude (E)	Temperature (°C)	Rainfall (mm)	pH
1.	Silyara	Ghansali	965	30º45'54"	78º63'84"	25	53.87	5.73
2.	Develgaun	Ghansali	996	30º37'06"	78º58'58"	23	55.30	5.46
3	Kuteti	Uttarkashi	1,654	30º82'42"	78º62'76"	21	76.62	5.60
4.	Ranichauri	Chamba	1,863	30º31'20"	78º40'98"	18	83.72	5.98
5.	Sadargaun	Pratapnagar	1,981	30º57'45"	78º45'79"	21	67.63	6.12
6.	Chaurangikhal	Uttarkashi	2,305	30º64'44"	78º48'84"	16	89.41	5.89

3.2.1 Seed source selection criteria

A survey was carried out in Tehri Garhwal and Uttarkashi district of Uttarakhand. Sites were selected where *Prunus cerasoides* mostly occurs. The selection of seed source was done by based on their geographical record such as altitude, latitude, longitude and horizontal distance.

3.2.2 Collection of fruit

One kg completely ripened fruits of *Prunus cerasoides* were collected from ten trees in each seed source. Average 100 gm ripened fruits were collected from each tree in each seed source.

3.3 Extraction of seed

The ripened fruits of *Prunus cerasoides* were dipped in water for 24 hours, and then the pulp of fruits removed manually by hand. The seeds were collected and dried for 1-2 days with the under sun light, thereafter, seeds were stored for further experiment in refrigerator.

3.4 Observation recorded

3.4.1 Studies on fruit morphology

3.4.1.1 Fruit length (cm)

The fruit lengths of 20 fruits (five replication) from each seed source were measured with the help of a vernier calliper in cm.

3.4.1.2 Fruit width (mm)

The fruit widths of 20 fruits (five replication) from each seed source were measured with the help of a vernier calliper in cm.

3.4.1.3 Fruit length/width ratio

The fruit length/width ratio was calculated by dividing the fruit length by the fruit diameter in cm.

3.4.1.4 Fruit thickness (mm)

The fruit thicknesses of 20 fruits (five replication) from each seed source were measured with the help of a vernier calliper in mm.

3.4.1.5 Fruit weight (gm)

Weight of 100 fruits (five replication) from each seed source weredetermined by weighing electronic balance (Citizon).

3.4.1.6 Fruit moisture (%)

The moisture content was determined in accordance with ISTA Rule 1999.

Moisture content (%) =Fresh fruit weight- seed weight / Fresh fruit weight ×100

3.4.2 Studies on seed morphology

3.4.2.1 Seed length (cm)

The seed lengths of 20 seeds (five replication) from each seed source were measured with the help of a vernier calliper in cm.

3.4.2.2 Seed width (mm)

The seed widths of 20 seeds (five replication) from each seed source were measured with the help of a vernier calliper in cm.

3.4.2.3 Seed thickness (mm)

The seed thickness of 20 seeds (five replication) from each seed source were measured with the help of a vernier calliper in cm.

3.4.2.4 Seed length/width ratio

The seed length/seed width ratio was calculated by dividing the seed length by the seed diameter in cm.

3.4.2.5 Seed weight (gm)

Weights of 100 seeds (five replication) from each seed source were determined by weighing electronic balance (Citizon).

3.4.2.6 Moisture content (%)

The moisture content was determined in accordance with ISTA Rule 1999.

Moisture content (%) =Seed weight- dry seed weight / seed weight ×100

3.4.2.7 Peel thickness (mm)

Peel thickness were calculated by the formula (Fruit width-Seed width /2)

3.4.3 Pre-treatment details

T1: Seed with seed coat + cold water for 24 hours

T2: Seed without seed coat + cold water for 24 hours

T3: Seed nicking + cold water for 24 hours

T4: Seed with seed coat + hot water for 24 hours at a temperature 100ºC

T5: Seed without seed coat + hot water for 24 hours at a temperature 100ºC

T6: Seed nicking + hot water for 24 hours at a temperature 100ºC

T7: Seed with seed coat +cold stratification for 15 days

T8: Cold stratification for 15 days + seed nicking

T9: Seed with seed coat +cold stratification for 15 days + hot water for24hoursat 100º C

T10: Seed with seed coat + cold stratification for 15 days +$GA_3$1000 ppm

T11: Seed with seed coat + cold stratification for 15 days +$GA_3$1500 ppm

T12: Cold stratification for 45 days + seed nicking

T13: Seed with seed coat +cold stratification for 45 days + hot water for 24 hours

T14: Seed with seed coat + cold stratification for 45 days +$GA_3$1000 ppm

T15: Seed with seed coat + cold stratification for 45 days +$GA_3$1500 ppm

3.4.4 Study on seed germination

3.4.4.1 Germination method

Following observation on seed germination was recorded by following the procedures as given below.

For the germination, 20 seeds (5 replicate) from each seed source were placed in Petri dish (9.5 cm) after pre- treatment mention earlier and cover with Whatman filter paper. The moisture in the Petri dish was maintained by adding 2 ml distilled water these Petri dishes were kept under germinator pre-fixed at 20ºC temperature. Daily germination was checked till complete the germination for 28 days.

3.4.4.2 Germination percent (GP)

The seeds were counted as germinated when the radical emerges by about 1 cm. Total germination was calculated by the following formula.

Germination percent (%) =Total numbers of germination seeds/Total numbers of seeds X 100

3.4.4.3 Mean germination time (MGT)

Mean germination time (MGT) was calculated by the following formula given by Ellis and Roberts (1981).

MGT = Dn/n

Where n= number of seeds germinated on day and D= representing the number of days since the sowing of seeds.

3.4.4.4 **Germination index (GI)**

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

GI= Total germination % /time taken for 50% germination in hours.

3.4.5 Study of seedling growth characteristics

3.4.5.1 Plumule length (cm)

The length of the plumule was measured from the cut base to the plumule tip. The plumule length was calculated with the help of measuring scale for six randomly selected seedlings from each replicate on the end of 28 days.

3.4.5.2 Radicle length (cm)

The length of the radicle was measured with the help of using measuring scale from the cut base to the root tip of the seedling 6 randomly selected seedlings from each replicate on the final count after 28 days in each replication from each seed sources.

3.4.5.3 Radicle and Plumule length ratio

The radicle length was divided by the plumule length of the same seedling to determine the radicle/plumule length ratio.

3.4.5.4 Total seedling length (cm)

The total length of seedling was measured by adding radicle and plumule length from each replication from each seed source.

3.4.5.5 Seed vigour index

The seed vigour index will be calculated by given formula (Abdul-Baki and Anderson, 1973) seedling vigour index was used to determine the germination percentage and seedling length of the same seed lot.

3.5 Computation of variability parameters

Genotypic, phenotypic and environment variances was calculated using the following equations, suggested by Burton and Devane (1953).

Genotypic variance (Vg) =Mt-Me/R

Phenotypic variance (Vp) = Vg + Ve

Environmental variance (Ve) =Me

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

3.5.1 Phenotypic coefficient of variance (PCV)

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

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

Where, = Mean of the character and Vp = Phenotypic variance

3.5.2 Genotypic coefficient of variance (GCV)

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

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

Where, = Mean of the character and Vg = Genotypic variance

3.5.3 Environmental coefficient of variance (ECV)

It was measure of environmental variation existing in a character and it was calculatedusing the following formula as suggested by Burton and Devane (1953): -

ECV (%) $= \frac{\sqrt{Ve}}{\bar{X}} \times 100$

Where, = Mean of the character and Ve = Environmental variance

3.5.4 Heritability in broad sense (h^2)

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

h^2 (%) $= \frac{Vg}{Vp} \times 100$

Where h^2 = Broad sense heritability in per cent, Vg = Genetic variance and Vp = Phenotypic variance

3.7.5 Genetic advance

Genetic advance is the expected increase in the magnitude of a character when a selection pressure of chosen intensity is applied. Itwas calculate during the following formula as per Johnson *et al.* (1955): -

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

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

Vp = Phenotypic variance andh^2= Broad sense heritability (%).

3.7.6 Genetic gain

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

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

Where, GA = Genetic advance and = Mean of the character.

3.8 STATISTICAL ANALYSIS

The data obtained during the course of this investigation was analysed by applying Analysis of variance (ANOVA) using the WASP software with version 1.0. For

morphological study, RBD (Randomized Block Design) and for germination study, CRD (Completely Randomized Design) was used which was developed by Ashok Kumar Jangam and Pranjali Ninad 32 Wadekar at ICAR Research Complex, Goa. 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).

CHAPTER-4 RESULTS

The results of the study entitled "**Effect of seed sources on fruit, seed characteristics and seed germination of *Prunus cerasoides* (D. Don**)" have been described in this chapter under different objectives as stated earlier.

4.1 To study the effect of seed source variation on fruit, seed and seedling morphology in *Prunus cerasoides.*

4.2 Effect of pre-treatments on seed germination of *Prunus cerasoides* from different seed sources.

4.3 Estimation of genetic variability among the different *Prunus cerasoides*seed sources.

4.1 To study the effect of seed source variation on fruit, seed and seedling morphology in *Prunus cerasoides.*

4.1.1 Morphological variation of fruit in *Prunus cerasoides*

Morphological studies on fruits of *Prunus cerasoides* from different seed sources were under taken and the results of various fruit morphological parameters are presented under following heads:

4.1.1.1 Fruit length

The fruit length of *P. cerasoides* from different seed sources was measured and the observations are presented in table 4.1. Results revealed that significant ($p \leq 0.05$) variations were recorded for fruit length among the seed source. The ranged of fruit length among the seed source was varied from 1.06 to 1.53cm with an average value 1.31cm. The maximum fruit length (1.53cm) was recorded in Silyara seed source while the minimum (1.06cm) was recorded in Chaurangikhal seed source.

4.1.1.2 Fruit width

Result presented in table 4.1 indicates that significant ($p \leq 0.05$) variations were observed for fruit width between the seed source. The fruit width was varied from 0.75 to 1.02mm with an average value 0.87mm. The maximum fruit width (1.02mm) was recorded in Develgaun seed source with Sadargaun seed source being least (0.75mm).

4.1.1.3 Fruit thickness

The observations regarding on fruit thickness of *P.cerasoides* with various seed sources are presented in table 4.1. Result indicated that fruit thickness was not showed significant variations between the seed source. Among the seed source fruit thickness ranged from 0.91-1.02mm with an average value 0.96mm. The maximum fruit thickness (1.02mm) was found in Develgaun seed source and minimum (0.91mm) was found in Chaurnagikhal seed source.

4.1.1.4 Fruit length/width ratio

The fruit length/width ratio was showed significant ($p \leq 0.05$) variations between all the seed sources of *P. cerasoides*. Results presented in table 4.1 indicate that fruit length/width ratio was varied from (1.33 to 1.97) with a mean value (1.63), while the Silyara seed source was showed the maximum (1.97) fruit length/width ratio and Develgaun seed source being least (1.33).

4.1.1.5 Fruit weight

The observations regarding on weight of fruits are presented in table 4.1 was showed that significant ($p \leq 0.05$) variations between all the seed sources. Result indicated that the weights of 100 fruit were varied from 82.93gm to 116.72gm with an average value 108.63 gm. The maximum (116.72 gm) fruit weight was found in Silyara seed source with Develgaun seed source being minimum (82.93 gm).

4.1.1.6 Fruit moisture

Results presented in table 4.1 indicates that the fruit moisture content was showed significant ($p \leq 0.05$) difference between the seed source. The fruits moisture content was varied from 45.08 to 75.65% with a mean value 64.83%. The highest (75.65%) fruit moisture content was found in Sadargaun seed source while the lowest (45.08%) was found in Develgaun seed source.

Table 4.1: Variation on fruit characteristics (Mean±S.D.) influenced by seed sources

S. No.	Seed Source	Elevation (m.asl)	Fruit Length (cm)	Fruit width(mm)	Fruit thickness(mm)	Fruit Length/width ratio	Fruit weight (gm)	Moisture (%)
1.	Silyara	965	1.53±0.08^{b}	0.77±0.07^{c}	1.00±0.05	1.97±0.10^{a}	116.72±1.26^{a}	71.24±3.09^{ab}
2.	Develgaun	996	1.35±0.08^{c}	1.02±0.10^{a}	1.02±0.04	1.33±0.19^{b}	82.93±2.05^{b}	45.08±12.48^{c}
3.	Kuteti	1654	1.42±0.09^{a}	0.97±0.09^{bc}	0.93±0.09	1.47±0.14^{a}	115.56±10.10^{a}	66.85±14.12^{ab}
4.	Ranichauri	1863	1.13±0.15^{d}	0.78±0.11^{c}	0.93±0.08	1.46±0.18^{b}	114.54±9.91^{a}	71.48±9.01^{ab}
5.	Sadargaun	1981	1.39±0.12^{c}	0.75±0.12^{c}	0.93±0.08	1.79±0.31^{a}	108.71±11.21^{a}	75.65±13.10^{a}
6.	Chaurangikhal	2305	1.06±0.17^{bc}	0.90±0.02^{b}	0.91±0.09	1.78±0.19^{b}	113.34±6.06^{a}	58.67±9.92^{b}
	Mean		1.31	0.87	0.96	1.63	108.63	64.83
	CV		5.73	11.60	9.83	12.35	8.360	15.75

CV= Coefficient of Variation, S. D.= Standard Deviation . Mean followed by same latter are not significantly ($p \leq 0.05$) different.

4.1.2 Morphological variation of seeds in *Prunus cerasoides*

Morphological studies on seeds of *P. cerasoides* from different seed sources were undertaken and the results of various seed morphological parameters are described below with proper headings:

4.1.2.1 Seed length

The observations regarding on seed length of *P. cerasoides* with different seed sources were measured and the data are presented in table 4.2. Results revealed that seed length was showed significant ($p \leq 0.05$) variations between the seed source. The seed length was varied from 0.43 to 0.97 cm with an average value 0.82 cm. The maximum (0.97 cm) seed length recorded in Silayra seed source with Ranichauri seed source being minimum (0.43cm).

4.1.2.2 Seed width

Results indicated that seed width was showed significant ($p \leq 0.05$) difference among the seed source. Results presented in table 4.2 showed that seed width was varied from 0.58 to 0.69 cm with in average value 0.64cm. The maximum (0.69 cm) seed width was found in Silyara seed source and minimum (0.58cm) seed width was recorded in Kuteti seed source.

4.1.2.3 Seed thickness

A result presented in table 4.2 indicates that seed thickness of *Prunus cerasoides* was not showed significant variations between the seed source. Among the seed source seed thickness ranged was from 0.48 to 0.61mm with an average value 0.52mm. The maximum seed thickness (0.61mm) was found in Sadargaun seed source with Kuteti seed source being minimum (0.48mm).

4.1.2.4 Seed length /width ratio

Results revealed that significant ($p \leq 0.05$) differences were observed among the seed source with respect to seed length and seed width ratio. Result presented in table 4.2 indicates that seed length/width ratio was varied from (1.19 to 2.46) with an average value 1.63. The maximum (2.64) seed length/width ratio was observed in Silyara seed source and Ranichauri seed source being minimum (1.11).

4.1.2.5 Seed moisture

A result presented in table 4.2 showed that significant ($p \leq 0.05$) variations were observed in seed moisture percent between the seed source. The seed moisture percent was varied from 4.79 to 8.17 % among the seed sources with an average value 6.77%. The highest (8.17%) seed moisture percent was recorded in Sadargaun seed source while the lowest (4.79%) seed moisture percent was found in Develgaun seed source.

4.1.2.6 Peel thickness

Results presented in table 4.2 indicate that among the seed source peel thickness was not showed significant variations. Peel thickness ranged from (0.32 to 0.52mm) was recorded in between the seed source with an average value (0.44mm). The maximum (0.52mm) peel thickness was recorded in Develgaun seed source while the minimum (0.32) peel thickness was recorded in Sadargaun seed source.

4.1.2.7 Seed weight

The observations regarding on seed weight are presented in table 4.1 was showed that significant ($p \leq 0.05$) variations among the seed sources. Result indicated that the weights of 100 seeds were varied from 22.59 to 31.00 gm with an average value 27.54gm. The highest weight of seeds (31.00 gm) was found in Develgaun seed source with Ranichauri seed source being least (22.59 gm).

4.2 Effect of pre-treatments on seed germination of *Prunus cerasoides* from different seed sources.

4.2.1 Seed germination percent

Effects of various pre-treatments on seed germination of *P.cerasoides* were studied and the observations regarding on seed germination percent are presented in table 4.3.

In seed germination, seeds were collected from six different locations and fifteen different pre-sowing treatments were used to observe their effects on seed germination. Seeds of *P. cerasoides* treated with three types; seed with seed coat (T-1), seed without seed coat (T-2) and seed nicking (T-3) in cold water for 24 hours at room temperature.

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

S. No.	Seed Sources	Elevation (m.asl)	Seed length (cm)	Seed width(mm)	Seed thickness (mm)	Moisture%	Seed length/width ratio	Peel thickness (mm)	Seed weight (gm)
1.	Silyara	965	0.97±0.17^{a}	0.69±0.13^{b}	0.49±0.03	7.39±1.76^{a}	2.46±0.84^{a}	0.51±0.03	28.90±1.41^{b}
2.	Develgaun	996	0.90±0.08^{a}	0.66±0.19^{a}	0.51±0.12	4.79±0.29^{b}	1.43±0.32^{b}	0.52±0.14	31.00±1.23^{a}
3.	Kuteti	1654	0.88±0.14^{a}	0.58±0.08^{a}	0.48±0.12	6.72±1.99^{a}	1.52±0.05^{b}	0.49±0.15	29.83±0.99^{c}
4.	Ranicharui	1863	0.43±0.18^{c}	0.62±0.11^{b}	0.51±0.04	7.06±1.63^{ab}	1.19±0.78^{b}	0.44±0.08	22.59±1.44^{d}
5.	Sadargaun	1981	0.77±0.15^{b}	0.62±0.13^{ab}	0.61±0.15	8.17±1.56^{a}	1.64±0.56^{b}	0.32±0.15	26.59±1.70^{c}
6.	Chaurangik-hal	2305	0.96±0.12^{ab}	0.64±0.17^{ab}	0.53±0.09	6.46±1.18^{a}	1.56±0.33^{b}	0.38±0.10	26.32±1.55^{b}
	Mean		0.82	0.64	0.52	6.77	1.63	0.44	27.54
	cv		12.050	24.802	19.718	19.78	24.802	28.508	5.512

C.V= Coefficient of variation, S.D. ± Standard deviation

Table- 4.3 Variation on seed germination percent (%) of different pre-treatments with seed sources

Treatment	Seed sources (Mean±Sd)						Mean
	Silayara	Develgaun	Ranichauri	Sadargaun	Chaurangikhal	Kuteti	
T-1	55.00±5.28	46.00±5.73	52.00±5.47	45.00±5.54	44.00±5.26	56.00±5.23	49.50
T-2	72.00±6.80	56.00±5.73	52.00±5.45	68.00±6.70	72.00±6.75	68.00±6.30	64.66
T-3	64.00±6.60	72.00 ±6.80	60.00±4.73	56.00±5.84	56.00±5.82	64.00±6.20	62.00
T-4	82.00±8.14	82.00±8.14	65.00±6.59	72.00±6.80	64.00±6.35	84.00±7.86	74.66
T-5	60.00±6.14	56.00±5.73	48.00±4.73	58.00±5.73	68.00±6.35	64.00±6.12	59.00
T-6	68.00±6.75	68.00±6.70	52.00±5.42	76.00±6.86	64.00±5.75	60.00±6.03	64.66
T-7	56.00±5.94	64.00±6.20	48.00±4.70	72.00±5.42	60.00±6.12	76.00±6.21	62.66
T-8	74.00±6.83	58.00±5.73	56.00±5.73	76.00±6.73	72.00±5.62	64.00±6.31	66.00
T-9	72.00±5.95	56.00±5.73	52.00±4.39	72.00±9.88	60.00±6.10	52.00±4.32	60.66
T-10	80.00±7.14	60.00±6.28	52.00±4.23	60.00±6.30	64.00±6.21	64.00±5.97	63.33
T-11	80.00±7.14	64.00±6.60	52.00±4.45	64.00±6.78	60.00±6.13	68.00±6.45	64.66
T-12	82.00±7.50	72.00±5.75	56.00±5.84	60.00±5.97	62.00±6.10	58.00±4.85	65.33
T-13	76.00±5.98	80.00±7.31	56.00±5.80	68.00±6.65	64.00±6.03	56.00±8.94	66.66
T-14	92.00±5.94	76.00±5.98	72.00±6.01	76.00±6.54	76.00±5.41	86.00±8.54	79.66
T-15	80.00±7.95	56.00±4.26	52.00±5.42	52.00±5.40	60.00±6.01	80.00±7.31	63.33
Mean	72.86	64.4	55.00	69.00	63.06	66.66	64.19

T-1:Seed with seed coat +cold water for 24 hours, T-2:Seed without seed coat +cold water for 24 hours, T-3:Seed nicking +cold water for 24 hours, T-4:Seed with seed coat +hot waterfor100º C at 24 hours, T-5:Seed without seed coat + hot waterfor100ºC at 24 hours, T-6: Seed nicking + hot water for100º C at 24 hours, T-7: Seed with seed coat + cold stratification for 15 days, T-8: Cold stratification for 15 days+Seed nicking, T-9: Seed with seed coat + cold stratification for 15 days + hot water for100ºC at 24 hours, T-10: Seed with seed coat + cold stratification for 15 days+ GA_3 1000 ppm,T-11: Seed with seed coat + cold stratification for 15 days+$GA_3$1500ppm,T-12: Cold stratification for 45 days+Seed nicking, T-13: Seed with seed coat +cold stratification for 45 days + hot water for100ºC at 24 hours,T-14: Seed with seed coat + cold stratification for 45 days+$GA_3$1000 ppm,T-15: Seed with seed coat + cold stratification for 45 days+$GA_3$1500 ppm.

Results presented in table 4.3 indicates that the highest (56.00±5.23%) germination percent was recorded from Kuteti seed source with Chaurangikhal seed source being least (44.00±5.26%) in treatment (T-1) seed with seed coat + cold water. Treatment (T-2) seed without seed coat+ cold waterwas showed maximum (72.00±6.80%) germination in Silyara seed source and minimum (52.00±5.45%) germination was recorded in Ranichauri seed source. Treatment (T-3) seed nicking+ cold water was showed highest (72.00±6.80%) germination percent in Develgaun seed source while Chaurangikhal seed source showed lowest (56.00±5.82%) germination percent.

In hot water treatment, seeds treated with three types; seed with seed coat (T-4), seed without seed coat (T-5) and seed nicking (T-6) in hot water for 100ºC at 24 hours. Results presented in table 4.3 indicates that the highest (84.00±7.86%) germination percent was recorded from Kuteti seed source with chaurangikhal seed source being least (64.00±6.35%) in treatment (T-4) seed with seed coat+ hot water for 100ºC at 24 hours. Treatment (T-5) seed without seed coat+ hot water for 100ºC at 24 hours was showed maximum (68.00±6.35%) germination percent in Chaurangikhal seed source and minimum (48.00±4.73%) was recorded in Ranichauri seed source. Treatment (T-6) seed nicking+ hot water for 100ºC at 24 hours was showed highest (76.00±6.86%) germination percent in Sadargaun seed source while Ranichauri seed source showed lowest (52.00±5.42%) germination percent.

In cold stratification for 15 days, results presented in table 4.3 indicates that the highest (76.00±6.21%) germination percent was found in Kuteti seed source and Ranichauri seed source showed minimum (48.00±4.70%) in treatment (T-7) seed with seed coat+cold stratification for 15 days. Treatment (T-8) cold stratification for 15 days + seed nicking was showed highest (76.00±6.73%) germination percent in Sadargaun seed source with Ranichauri seed source being least (56.00±5.73%). Treatment (T-9) seed with seed coat+cold stratification for 15 days + hot water for 100ºC at 24 hours was showed maximum (72.00±9.88%) germination percent in Sadargaun seed source while Kuteti seed source minimum (52.00±4.32%).

Results presented in table 4.3 indicates that treatment (T-10) seed with seed coat+ cold stratification for 15 days +$GA_3$1000 ppm was showed highest (80.00±7.14%) germination percent in Silyara seed source whereas Ranichauri seed source being least(52.00±4.23%). In treatment(T-11), seed with seed coat+ cold stratification for 15 days +$GA_3$1500 ppm was showed maximum (80.00±7.14%) germination percent from Silyara seed source while minimum (52.00±4.45%) germination percent was recorded in Ranichauri seed source. Treatment (T-12) cold stratification for 45 days + seed nicking was showed highest (82.00±7.50%) germination percent in Silyara seed source and lowest (56.00±5.84%) was recorded in Kuteti seed source.

Results presented in table 4.3 indicates that treatment (T-13) seed with seed coat+cold stratification for 45 days + hot water for 100ºC at 24 hours was showed highest (80.00±7.31%) germination percentin Develgaun seed source while lowest (56.00±5.80%)

was found in Ranichauri seed source. In treatment(T-14), seed with seed coat+ cold stratification for 45 days+$GA_3$1000 ppm was showed maximum (92.00±5.50%) germination percent from Silayara seed source with Ranichauri seed source being minimum (72.00±6.01%). Treatment (T-15) seed with seed coat+ cold stratification for 45 days +$GA_3$1500 ppm was showed highest (80.00±7.95%) germination percent in Silyara seed source and Sadargaun seed source lowest (52.00±5.40%).

4.2.2 Mean germination time (MGT)

The results of mean germination time of different pre-treatments with seed sources are presented in table 4.4.

Results presented in table 4.4 indicates that in treatment (T-1) seed with seed coat+ cold water for 24 hours was showed lowest (19.92±0.92days) mean germination time in Sadargaun seed source and highest (24.56±5.94days) in Kuteti seed source. Treatment (T-2) seed without seed coat+ cold water for 24 hours was showed lowest (16.28±3.53 days) MGT from Silyara seed source with Sadargaun seed source being highest (18.8±1.11 days). Treatment (T-3) seed nicking+ cold water for 24 hours was showed minimum (17.44±0.43 days) MGT in Sadargaun seed source while Ranichauri seed source was showed maximum (20.16±1.10 days) MGT.

In hot water treatment, results presented in table 4.4 indicates that the lowest (16.92±1.27 days) mean germination time was recorded from Develgaun seed source with Silyara seed source being highest (18.32±0.64 days) in treatment (T-4) seed without seed coat+ hot waterfor100ºC at 24 hours. Treatment (T-5) seed with seed coat+ hot water for 100ºC at 24 hours was showed minimum (19.48±2.36 days) MGT in Develgaun seed source and maximum (20.62±1.40 days) MGT was recorded in Ranichauri seed source. Treatment (T-6) seed nicking+hot water for 100ºC at 24 hours was showed lowest (17.16±2.12 days) MGT in Kuteti seed source while Silyara seed source showed highest MGT (20.20±1.23 days).

In cold stratification for 15 days, results presented in table 4.4 indicates that the lowest (16.62±4.059 days) mean germination time was recorded in Chaurangikhal seed source while Silyara seed source showed highest (17.33±4.68 days) MGT in treatment (T-7) seed with seed coat+cold stratification for 15 days. Treatment (T-8) cold stratification for 15

days +seed nicking was showed minimum (16.68±2.22 days) MGT in Sadargaun seed source with Chaurangikhal seed source being maximum (18.78±0.54 days). Treatment (T-9) seed with seed coat+cold stratification for 15 days + hot water for100ºC at 24 hours was showed minimum (17.00±1.34 days) MGT in Chaurangikhal seed source and Sadargaun seed source was showed maximum (19.16±2.21 days) MGT.

Table- 4.4: Variation on mean germination time of different pre-treatments with seed sources

Treatment	Seed sources(Mean±SD)						Mean
	Silayara	Develgaun	Ranichauri	Sadargaun	Chaurangikhal	Kuteti	
T-1	21.26±0.90	20.34±1.05	22.18±0.99	19.92±0.92	20.90±1.11	24.56±5.94	21.52
T-2	16.28±3.53	17.22±3.84	16.95±3.80	18.8±1.11	18.74±0.89	16.42±1.02	17.40
T-3	18.74±1.20	17.74±0.64	20.16±1.10	17.44±0.43	18.4±0.66	18.44±0.66	18.48
T-4	18.32±0.64	16.92±1.27	18.20±2.97	17.82±1.15	18.04±0.85	17.0±1.934	17.71
T-5	19.84±1.29	19.48±2.36	20.62±1.40	20.62±1.23	20.52±0.67	20.44±0.78	20.25
T-6	20.20±1.23	18.58±1.47	19.60±0.46	19.06±0.75	18.98±1.14	17.16±2.12	18.93
T-7	17.33±4.68	17.02±3.68	17.32±4.68	16.92±1.36	16.62±4.05	16.98±2.75	17.03
T-8	18.14±0.85	18.02±1.46	18.06±0.52	16.68±2.22	18.78±0.54	18.34±1.16	18.00
T-9	18.14±0.903	18.34±0.66	17.78±0.97	19.16±2.21	17.00±1.34	17.76±0.86	18.03
T-10	14.82±3.60	16.2±2.70	16.72±2.48	12.56±0.88	16.74±1.54	15.6±1.677	15.41
T-11	17.04±0.70	16.98±2.10	18.22±0.30	18.99±0.67	17.60±1.04	18.98±1.04	19.88
T-12	23.64±1.44	20.76±0.92	24.64±0.89	21.58±1.64	22.28±0.65	21.10±0.88	18.23
T-13	18.04±3.21	19.72±3.14	19.78±0.31	21.1±1.43	18.38±3.22	21.74±4.23	19.79
T-14	12.26±0.27	10.96±2.00	11.24±2.58	10.26±2.42	12.54±1.19	13.28±3.10	11.75
T-15	13.92±1.58	15.22±2.31	13.90±0.78	13.62±2.86	13.82±0.90	15.56±3.36	14.50
Mean	17.85	17.56	18.35	17.63	17.95	18.22	15.03

T-1: Seed with seed coat +cold water for 24 hours, T-2: Seed without seed coat +cold water for 24 hours, T-3: Seed nicking +cold water for 24 hours, T-4: Seed with seed coat +hot waterfor100º C at 24 hours, T-5: Seed without seed coat + hot waterfor100ºC at 24 hours, T-6: Seed nicking + hot water for100º C at 24 hours, T-7: Seed with seed coat + cold stratification for 15 days, T-8: Cold stratification for 15 days+Seed nicking, T-9: Seed with seed coat + cold stratification for 15 days + hot water for100ºC at 24 hours, T-10: Seed with seed coat + cold stratification for 15 days+ GA_3 1000 ppm,T-11: Seed with seed coat + cold stratification for 15 days+$GA_3$1500ppm,T-12: Cold stratification for 45 days +Seed nicking, T-13: Seed with seed coat +cold stratification for 45 days + hot water for100ºC at 24 hours,T-14: Seed with seed coat + cold stratification for 45 days+$GA_3$1000 ppm,T-15: Seed with seed coat + cold stratification for 45 days+$GA_3$1500 ppm.

Results presented in table 4.4 indicates that treatment (T-10) seed with seed coat+ cold stratification for 15 days+$GA_3$1000 ppm was showed lowest (12.56±0.88 days) mean germination time in Sadargaun seed source with Sadargaun seed source being highest

(16.74±1.54 days). In treatment (T-11), seed with seed coat+ cold stratification for 15 days +$GA_3$1500 ppm was showed minimum (16.98±2.10 days) MGT from Develgaun seed source while maximum (18.99±0.67 days) MGT was found in Sadargaun seed source. Treatment (T-12) cold stratification for 45 days + seed nicking was showed lowest (20.76±0.92days) MGT in Develgaun seed source and highest (24.64±0.89days) MGT was recorded in Ranichauri seed source.

Results presented in table 4.4 showed that treatment (T-13) seed with seed coat+cold stratification for 45 days+ hot for 100ºC at 24 hours was showed lowest (18.04±3.21days) mean germination time in Silyara seed source while highest (21.74±4.23 days) MGT was found in Kuteti seed source. In treatment (T-14), seed with seed coat+cold stratification for 45 days +$GA_3$1000 ppm was showed minimum (10.26±2.42 days) MGT from Sadargaun seed source with Kuteti seed source being maximum (13.08±3.10 days). Treatment (T-15) seed with seed coat+ cold stratification for 45 days+$GA_3$1500 ppm was showed lowest (13.62±2.896 days) MGT in Sadargaun seed source and Kuteti seed source showed highest (15.56±3.36 days) MGT.

4.2.3 Germination index (GI)

The results regarding on germination index with different pre-treatments and various seed sources are presented in table 4.5. The highest (0.14±0.02) germination index was recorded in Kuteti seed source with Ranichauri seed source being least (0.08±0.01) in treatment (T-1) seed with seed coat+ cold water. Treatment (T-2) seed without seed coat+ cold water was showed maximum (0.18±0.02) GI in Sadargaun seed source and minimum (0.09±0.03) was recorded in Develgaun seed source. Treatment (T-3) seed nicking + cold waterwas showed highest (0.14±0.01) GI in Develgaun seed source while Ranichauri seed source showed lowest GI (0.08±0.01).

In hot water treatment, results presented in table 4.5 indicates that the highest(0.14±0.02) germination index was recorded from Chaurangikhal seed source with Ranichauri seed source being least (0.09±0.03) in treatment (T-4)seed without seed coat+hot water for100ºC at 24 hours. Treatment (T-5) seed with seed coat+hot water for 100ºC at 24 hourswas showed maximum (0.18±0.09) GI in Chaurangikhal seed source and minimum (0.11±0.06) GI was recorded in Ranichauri seed source. Treatment (T-6) seed nicking+hot water for 100ºC at 24 hours was showed highest (0.18±0.03) GI in Chaurangikhal seed source while Ranichauri seed source showed lowest (0.08±0.03).

Table- 4.5: Variation on germination index of different pre-treatments with seed sources

Treatment	Seed source						Mean
	Silayara	Develgaun	Ranichauri	Sadargaun	Chaurangikhal	Kuteti	
T-1	0.13±0.03	0.09±0.22	0.08±0.01	0.09±0.02	0.10±0.02	0.14±0.02	0.10
T-2	0.10±0.04	0.09±0.03	0.14±0.99	0.18±0.02	0.14±0.01	0.10±0.01	0.12
T-3	0.12±0.01	0.14±0.01	0.08±0.01	0.11±0.01	0.10±0.02	0.12±0.03	0.11
T-4	0.13±0.02	0.12±0.03	0.09±0.03	0.12±0.02	0.14±0.02	0.13±0.03	0.12
T-5	0.13±0.6	0.12±0.10	0.11±0.06	0.14±0.09	0.18±0.09	0.17±0.07	0.18
T-6	0.12±0.01	0.13±0.02	0.08±0.03	0.14±0.03	0.18±0.03	0.12±0.02	0.13
T-7	0.11±0.04	0.14±0.03	0.12±0.24	0.15±0.02	0.18±0.02	0.14±0.03	0.14
T-8	0.14±0.04	0.18±0.03	0.12±0.02	0.16±0.02	0.14±0.03	0.13±0.02	0.14
T-9	0.20±0.03	0.18±0.02	0.17±0.03	0.19±0.03	0.18±0.05	0.16±0.03	0.18
T-10	0.18±0.02	0.15±0.02	0.10±0.02	0.17±0.04	0.15±0.04	0.15±0.02	0.15
T-11	0.15±0.02	0.14±0.04	0.17±0.10	0.13±0.03	0.12±0.02	0.15±0.04	0.16
T-12	0.16±0.01	0.13±0.03	0.18±0.24	0.21±0.13	0.12±0.04	0.08±0.02	0.16
T-13	0.13±0.03	0.14±0.02	0.11±0.03	0.12±0.02	0.13±0.01	0.10±0.01	0.12
T-14	0.19±0.03	0.17±0.02	0.16±0.02	0.18±0.01	0.17±0.02	0.18±0.02	0.17
T-15	0.17±0.08	0.14±0.03	0.14±0.03	0.16±0.03	0.12±0.02	0.14±0.04	0.14
Mean	0.14	0.14	0.13	0.16	0.14	0.13	0.14

T-1: Seed with seed coat +cold water for 24 hours, T-2: Seed without seed coat +cold water for 24 hours, T-3: Seed nicking +cold water for 24 hours, T-4: Seed with seed coat +hot waterfor100º C at 24 hours, T-5: Seed without seed coat + hot waterfor100ºC at 24 hours, T-6: Seed nicking + hot water for100º C at 24 hours, T-7: Seed with seed coat + cold stratification for 15 days, T-8: Cold stratification for 15 days+Seed nicking, T-9: Seed with seed coat + cold stratification for 15 days + hot water for100ºC at 24 hours, T-10: Seed with seed coat + cold stratification for 15 days+ GA_3 1000 ppm,T-11: Seed with seed coat + cold stratification for 15 days+$GA_3$1500ppm,T-12: Cold stratification for 45 days +Seed nicking, T-13: Seed with seed coat +cold stratification for 45 days + hot water for100ºC at 24 hours,T-14: Seed with seed coat + cold stratification for 45 days+$GA_3$1000 ppm,T-15: Seed with seed coat + cold stratification for 45 days+$GA_3$1500 ppm.

In cold stratification for 15 days, results presented in table 4.5 indicates that the highest germination index value (0.18±0.03) was recorded in Chaurangikhal seed source and Ranichauri seed source showed minimum GI value (0.08±0.03) in treatment (T-7) seed with seed coat+cold stratification for 15 days. Treatment (T-8) cold stratification for 15 days+seed nicking was showed highest (0.18±0.03) GI in Develgaun seed source with Ranichauri seed

source being least (0.12±0.02). Treatment (T-9)seed with seed coat+cold stratification for 15 days + hot water for 100ºC at 24 hours was showed maximum (0.20±0.03) GI in Silyara seed source while Kuteti seed source was minimum (0.16±0.03).

Results presented in table 4.5 indicates that treatment (T-10) seed with seed coat + cold stratification for 15 days + $GA_3$1000 ppm was showed highest (0.18±0.02) germination index in Silyara seed source with Ranichauri seed source being least (0.10±0.02). In treatment (T-11), seed with seed coat+ cold stratification for 15 days+$GA_3$1500 ppm was showed maximum GI (0.7±0.10) from Ranichauri seed source while minimum (0.12±0.02) was recorded in Chaurangikhal seed source. Treatment (T-12) cold stratification for 45 days+ seed nicking was showed highest (0.21±0.13) GI in Sadargaun seed source and lowest (0.08±0.02) was recorded in Kuteti seed source.

Results presented in table 4.5 indicates that treatment (T-13)seed with seed coat+cold stratification for 45 days + hot water for 100ºC at 24 hours was showed highest (0.14±0.02) germination index in Develgaun seed source while lowest (0.10±0.01) was found in Kuteti seed source. In treatment (T-14), seed with seed coat+ cold stratification for 45 days +$GA_3$1000 ppm was showed maximum (0.19±0.03) GI from Silyara seed source with Ranichauri seed source being minimum (0.16±0.02). Treatment (T-15) seed with seed coat+ cold stratification for 45 days +$GA_3$1500 ppm was showed highest (0.17±0.08) GI in Silyara seed source and Chaurangikhal seed source was showed minimum (0.12±0.02).

4.2.4 Growth Parameters

After 28 days of seed germination, fifteen pre-sowing treatments and six seed sources were investigated and the observations regarding on various growth parameters are presented in table 4.6 and 4.7.

4.2.4.1 Plumule length

The plumule length was varied between the treatment and seed source. Seeds were treated with three types; (T-1) seed with seed coat, (T-2) seed without seed coat and (T-3) seed nicking in cold water for 24 hours at room temperature. Results indicated that treatment (T-2) seed without seed coat+cold water for 24 hours was produced highest (2.42cm) plumule length in Ranichauri seed source and lowest (0.52cm) in Sadargaun seed source.

In hot water treatment seeds were treated with, (T-4) seed with seed coat, (T-5) seed without seed coatand (T-6) seed nicking in hot water for 100ºC at 24 hours. Treatment (T-6)

seed nicking+hot water for 100ºC at 24 hours was produced highest (3.82cm) plumule length in Sadargaun seed source while lowest (0.89cm) in Develgaun seed source.

In cold stratification, treatment (T-7) seed with seed coat+cold stratification for 15 days, (T-8) cold stratification for 15 days+ seed nicking and (T-9) seed with seed coat +cold stratification for 15 days + hot water for100ºC at 24 hours were studied. The maximum (3.84cm) plumule length was recorded from Develgaun seed source while lowest (0.88cm) from Sadargaun seed source in treatment (T-9) seed with seed coat +cold stratification for 15 days + hot water for 100ºC at 24 hours.

Treatment (T-10) seed with seed coat +cold stratification for 15 days+$GA_3$1000 ppm, (T-11) seed with seed coat +cold stratification for 15 days+$GA_3$1500 ppm and (T-12) cold stratification for 45 days +seed nicking was investigated with respect to plumule length. The highest (2.87cm) plumule length was observed from Sadargaun seed source and lowest (1.44cm) from Silyara seed source in treatment (T-11) seed with seed coat+ cold stratification for 15 days+$GA_3$1500 ppm.

Treatment (T-13)seed with seed coat+cold stratification for 45 days + hot water for 100ºC at 24 hours, (T-14) seed with seed coat+ cold stratification for 45 days+$GA_3$1000 ppm and (T-15) seed with seed coat+ cold stratification for 45 days+$GA_3$1500 ppm were studied regarding on plumule length. Kuteti seed source was produced highest (4.25cm) plumule length and Silyara seed source lowest (1.2cm) in treatment (T-14) seed with seed coat+ cold stratification for 45 days+$GA_3$1000 ppm.

4.2.4.2 Radicle length

The radicle length was varied between the treatment and seed source. Seeds were treated with three types; (T-1) seed with seed coat, (T-2) seed without seed coatand (T-3) seed nicking in cold water for 24 hours at room temperature. A result presented in table indicates that highest (6.00cm) radicle length was recorded from Sadargaun seed source and lowest (1.25cm) from Develgaun seed source in treatment (T-1) seed with seed coat+ cold water for 24 hours.

In hot water treatment seeds were treated with, (T-4) seed with seed coat, (T-5) seed without seed coatand (T-6) seed nicking in hot water for 100ºC at 24 hours. Results revealed that treatment (T-5) seed without seed coat+ hot water for 100ºC at 24 hours was produced

maximum (5.12cm) radicle length in Silyara seed source while lowest (2.56cm) in Chaurangikhal seed source.

In cold stratification, treatment (T-7) seed with seed coat+cold stratification for 15 days, (T-8) cold stratification for 15 days+seed nicking and (T-9) seed with seed coat+cold stratification for 15 days + hot water for 100ºC at 24 hours were investigated. The highest (4.50cm) radicle length was recorded from Develgaun and Ranichauri seed source while lowest (2.68cm) from Sadargaun seed source in treatment (T-8) cold stratification for 15 days+seed nicking.

Treatment (T-10) seed with seed coat+ cold stratification for 15 days+$GA_3$1000 ppm, (T-11) seed with seed coat + cold stratification for 15 days +$GA_3$1500 ppm and (T-12) cold stratification for 45 days +seed nicking was studied regarding on radicle length. The maximum (5.85cm) radicle length was recorded from Develgaun seed source while minimum (2.74cm) from Kuteti seed source in treatment (T-11) seed with seed coat+ cold stratification for 15 days+$GA_3$1500 ppm.

Treatment (T-13)seed with seed coat+cold stratification for 45 days + hot water for 100ºC at 24 hours, (T-14) seed with seed coat+ cold stratification for 45 days +$GA_3$1000 ppm and (T-15) seed with seed coat + cold stratification for 45 days+$GA_3$1500 ppm were investigated with respect to radicle length. The highest (5.28cm) radicle length was observed from Develgaun seed source while lowest (3.46cm) from Chaurangikhal seed source in treatment (T-14)seed with seed coat+ cold stratification for 45 days+$GA_3$1000 ppm.

4.2.4.3 Seedling length

The total seedling length was varied among the treatment and seed source. Seeds were treated with three types; (T-1) seed with seed coat, (T-2) seed without seed coat and (T-3) seed nicking in cold water for 24 hours at room temperature. Results presented in table 4.6 showed that treatment (T-1) seed with seed coat+ cold water for 24 hours was produced maximum (8.05cm) seedling length in Silyara seed source and minimum (3.16cm) in Ranichauri seed source.

In hot water treatment seeds were treated with, (T-4) seed with seed coat, (T-5) seed without seed coat and (T-6) seed nicking in hot water for 100ºC at 24 hours. Results indicated that treatment (T-6) seed nicking+ hot water for100ºCat 24 hours was showed

highest (7.24cm) seedling length in Sadargaun seed source and lowest (2.47cm) in Develgaun seed source.

In cold stratification, treatment (T-7) seed with seed coat +cold stratification for 15 days,(T-8)cold stratification for 15 days+ seed nicking and (T-9)seed with seed coat+cold stratification for 15 days + hot water for 100ºC at 24 hours were investigated with respect to seedling length. The maximum (6.50cm) seedling was found from Ranichauri seed source while lowest (3.70cm) from Sadargaun seed source in treatment (T-8) cold stratification for 15 days+ seed nicking.

Treatment (T-10) seed with seed coat + cold stratification for 15 days+$GA_3$1000 ppm, (T-11) seed with seed coat+ cold stratification for 15 days+$GA_3$1500 ppm and (T-12) cold stratification for 45 days +seed nicking was studied regarding on seedling length. The highest (8.15cm) seedling length was observed from Develgaun seed source and lowest (4.61cm) from Silyara seed source in treatment (T-11) seed with seed coat + cold stratification for 15 days+$GA_3$1500 ppm.

Treatment (T-13) seed with seed coat +cold stratification for 45 days + hot water for 100ºC at 24 hours, (T-14) seed with seed coat + cold stratification for 45 days +$GA_3$1000 ppm and (T-15) seed with seed coat + cold stratification for 45 days+$GA_3$1500 ppm were investigated with respect to seedling length. The highest (8.89cm) seedling length was recorded from Kuteti seed source and lowest (6.30cm) from Silyara seed source in treatment (T-14) seed with seed +coat cold stratification for 45 days+$GA_3$1000 ppm.

4.2.4.4 Plumule/radicle length ratio

The plumule/radicle length ratio was varied between the treatment and seed source. Seeds were treated with three types; (T-1) seed with seed coat, (T-2) seed without seed coat and (T-3) seed nicking in cold water for 24 hours at room temperature. Results indicated that treatment (T-2) seed without seed coat+ cold water for 24 hours was showed highest (6.17) P/R length ratio in Develgaun seed source and lowest (0.10) in Sadargaun seed source.

In hot water treatment seeds were treated with, (T-4) seed with seed coat, (T-5) seed without (T-6) seed coat and seed nickingin hot water for 100ºC at 24 hours. Treatment (T-6) seed nicking+ hot water for 24 hours at a temperature 100ºC was showed maximum (1.11) P/R length ratio in Sadargaun seed source while minimum (0.49) in Chaurangikhal seed source.

In cold stratification, treatment (T-7) seed with seed coat +cold stratification for 15 days, (T-8)cold stratification for 15 days+ seed nicking and (T-9) seed with seed coat+cold stratification for 15 days + hot water for 100ºC at 24 hours were studied. The highest (2.26) P/R length ratio was recorded from Kuteti seed source while lowest (0.29) from Sadargaun seed source in treatment (T-7) seed with seed coat +cold stratification for 15 days + hot water for 100ºC at 24 hours.

Treatment (T-10) seed with seed coat + cold stratification for 15 days+$GA_3$1000 ppm, (T-11) seed with seed coat + cold stratification for 15 days +$GA_3$1500 ppm and (T-12) cold stratification for 45 days +seed nicking was investigated with respect to P/R length ratio. The highest (1.38) P/R length ratio was observed from Chaurangikhal seed source and lowest (0.35) from Develgaun and Kuteti seed source in treatment (T-12)cold stratification for 45 days +seed nicking.

Treatment (T-13)seed with seed coat+cold stratification for 45 days + hot water for 100ºC at 24 hours, (T-14) seed with seed coat+ cold stratification for 45 days +$GA_3$1000 ppm and (T-15) seed with seed coat+ cold stratification for 45 days+$GA_3$1500 ppm were studied regarding on P/R length ratio. The maximum (0.87) P/R length ratio was recorded from Silyara seed source and minimum (0.44) from Ranichauri seed source in treatment (T-15) seed with seed coat + cold stratification for 45 days+$GA_3$1500 ppm.

4.2.4.5 Seed vigour index

The seed vigour index was varied between the treatment and seed source. Seeds were treated with three types; (T-1) seed with seed coat, (T-2) seed without seed coatand (T-3) seed nicking in cold water for 24 hours at room temperature. Results presented in table 4.7 showed that highest value (496.80) SVI was recorded from Silyara seed source and lowest value(232.96) from Develgaun seed source in treatment (T-2) seed without seed coat+ cold water for 24 hours.

In hot water treatment seeds were treated with, (T-4) seed with seed coat, (T-5) seed without seed coatand (T-6) seed nicking in hot water for 100ºC at 24 hours. Results revealed that treatment (T-5) seed without seed coat+ hot water for 100ºC at 24 hours was showed maximum value (512.44) SVI in Silyara seed source while minimum value (228.00) in Chaurangikhal seed source.

In cold stratification, treatment (T-7) seed with seed coat+cold stratification for 15 days, (T-8) cold stratification for 15 days +seed nicking and (T-9) seed with seed coat+cold stratification for 15 days + hot water for 100ºC at 24 hours were investigated. The highest value (419.04) SVI was recorded from Chaurangikhal seed source while lowest value (272.64) from Sadargaun seed source in treatment (T-8) cold stratification for 15 days+ seed nicking.

Treatment seed with (T-10) seed with seed coat+ cold stratification for 15 days+$GA_3$1000 ppm, (T-11) seed with seed coat+ cold stratification for 15 days +$GA_3$1500 ppm and (T-12) cold stratification for 45 days +seed nicking was studied regarding on seed vigour index. The maximum value (521.60) SVI was recorded from Develgaun seed source while minimum value (296.92) from Kuteti seed source in treatment (T-11) seed with seed coat+ cold stratification for 15 days+$GA_3$1500 ppm.

Treatment (T-13) seed with seed coat +cold stratification for 45 days + hot water for 100ºC at 24 hours, (T-14) seed with seed coat + cold stratification for 45 days +$GA_3$1000 ppm and (T-15) seed with seed coat+ cold stratification for 45 days+$GA_3$1500 ppm were investigated with respect to seed vigour index. The highest value (746.76) SVI was recorded from Kuteti seed source while lowest value (418.56) from Ranichauri seed source in treatment (T-14) seed with seed coat+ cold stratification for 45 days+$GA_3$1000 ppm.

Table-4.6: Plumule, Radicle and Seedling length of *P.cerasoides*

Treatment	Seed Sources																	
	Silyara			Develgaun			Ranichauri			Sadargaun			Chaurangikhal			Kuteti		
	PL	RL	SL	PL	RL	SL	PL	RL	SL	PL	RL	SL	PL	RL	SL	PL	RL	SL
T-1	2.60±1.60	5.45±1.28	8.05±2.0	1.60±0.96	1.25±0.75	3.83±1.65	1.08±1.40	2.08±0.95	3.16±1.30	1.30±0.90	6.00±2.90	7.3±3.12	1.92±0.85	3.40±2.50	5.32±3.12	1.64±0.85	4.46±2.55	6.1±3.18
T-2	2.5±1.27	4.40±1.15	6.9±1.40	1.60±0.95	0.58±0.25	4.16±2.30	2.42±1.78	2.21±0.25	4.16±2.40	0.52±0.25	5.18±2.50	5.7±3.12	1.92±0.90	2.10±1.40	4.02±2.60	2.34±0.25	3.18±2.78	5.52±2.98
T-3	3.1±1.15	4.11±1.10	7.21±1.70	0.22±0.11	2.4±1.90	4.24±2.72	0.67±0.80	1.44±1.30	4.24±2.41	2.44±1.40	2.96±1.95	5.4±3.14	2.50±1.15	2.52±1.62	5.02±2.48	2.54±1.26	3.32±2.90	5.86±3.45
T-4	1.56±0.92	4.01±1.14	5.57±1.25	1.33±0.85	1.90±0.86	3.00±1.45	1.36±1.15	1.91±0.85	3.00±1.02	1.68±0.98	4.36±2.75	6.04±3.45	0.78±0.56	2.66±1.72	3.44±2.72	3.82±2.15	3.18±2.78	7±3.56
T-5	1.93±1.40	5.12±1.12	7.05±1.30	2.47±1.45	2.58±1.25	3.18±1.56	1.04±0.46	2.58±1.40	3.18±1.20	2.38±1.35	2.90±1.90	5.28±3.26	2.30±1.12	2.56±1.63	4.86±2.88	2.20±1.35	3.24±2.80	5.44±3.25
T-6	2.41±1.87	4.2±1.24	6.61±1.17	1.70±1.25	1.58±0.97	2.47±2.90	1.68±0.59	1.92±0.75	2.47±1.56	3.82±2.10	3.42±2.10	7.24±3.06	1.48±0.92	3.02±2.65	4.5±3.01	2.74±1.52	3.30±2.85	6.04±3.06
T-7	0.64±1.40	3.5±1.30	4.14±1.11	2.09±1.60	5.37±3.95	6.21±3.30	1.99±0.54	3.07 ±1.25	6.21±2.56	1.08±0.75	2.86±2.06	3.94±2.98	3.56±2.80	2.48±159	6.04±3.20	1.47±0.68	3.30±2.85	4.77±2.68
T-8	1.47±0.95	4.1±1.20	5.57±1.25	1.40±0.82	4.5±2.35	5.92±2.29	2.3±0.70	4.50±1.25	5.92±1.65	1.02±0.65	2.68±2.01	3.7±2.60	2.60±1.25	3.22±2.70	5.82±2.38	0.56±0.23	3.70±2.92	4.26±2.26
T-9	3.20±1.97	3.10±1.11	6.30±1.06	2.70±1.56	2.98±1.23	6.82±3.30	2.1±1.91	2.98±1.45	6.82±2.59	0.88±0.45	2.94±2.15	3.82±2.65	1.84±0.74	3.20±2.68	5.04±2.99	2.40±1.24	1.06±0.75	3.46±2.47
T-10	2.41±1.01	5.12±1.52	7.53±1.75	3.29±1.35	3.02±1.30	4.14±2.99	0.98±1.20	3.02±1.80	4.14±2.40	3.88±2.12	2.34±1.90	6.22±2.06	2.74±1.48	4.56±3.01	7.3±3.18	1.64±0.85	3.08±2.18	4.72±2.56
T-11	1.44±0.87	3.17±1.37	4.61±1.15	3.2±1.25	5.85±3.60	8.15±4.30	1.86±1.30	3.85±1.40	8.15±3.40	6.10±3.20	3.32±2.09	9.42±3.90	2.64±1.38	3.22±2.80	5.86±2.86	2.82±1.35	2.74±2.26	5.56±3.65
T-12	2.96±1.20	3.81±1.08	6.77±1.27	2.56±1.55	2.14±1.56	2.89±1.60	2.06±0.85	2.14±1.20	2.89±1.62	2.06±1.20	3.36±2.12	5.42±3.40	2.46±1.24	1.78±0.95	4.24±2.80	1.22±0.90	3.40±2.95	4.62±2.65
T-13	3.30±1.46	4.62±1.10	7.92±2.12	0.99±0.45	3.92±1.85	6.59±3.16	1.34±1.45	3.92±1.89	6.59±3.02	2.31±1.20	3.97±2.58	6.28±3.55	1.1±0.71	2.24±1.42	3.34±2.28	3.14±099	3.50±2.98	6.64±2.85
T-14	1.20±0.98	5.10±1.17	6.30±1.10	3.09±1.95	5.28±3.60	7.15±3.90	1.92±1.82	4.28±1.95	6.15±4.02	3.66±1.95	4.54±2.98	8.2±3.90	3.68.75	3.46±2.55	7.14±3.12	4.25±2.15	4.64±2.95	8.89±3.94
T-15	3.6±1.60	4.12±1.01	7.72±1.80	2.37±1.30	5.28±3.54	6.98±3.65	1.54±1.48	3.47±2.14	3.98±3.56	2.12±1.13	3.22±2.78	5.34±2.92	2.32±1.56	3.44±2.90	5.76±2.25	2.68±0.12	3.60±2.98	6.28±2.35
Mean	2.26	4.262	6.55	2.04	3.18	5.04	1.62	2.91	4.64	2.35	3.60	5.738	2.25	2.94	5.18	2.36	3.31	5.45

T-1: Seed with seed coat +cold water for 24 hours, T-2: Seed without seed coat +cold water for 24 hours, T-3: Seed nicking +cold water for 24 hours, T-4: Seed with seed coat +hot waterfor100º C at 24 hours, T-5: Seed without seed coat + hot waterfor100ºC at 24 hours, T-6: Seed nicking + hot water for100º C at 24 hours, T-7: Seed with seed coat + cold stratification for 15 days, T-8: Cold stratification for 15 days+Seed nicking, T-9: Seed with seed coat + cold stratification for 15 days + hot water for100ºC at 24 hours, T-10: Seed with seed coat + cold stratification for 15 days+ GA_3 1000 ppm,T-11: Seed with seed coat + cold stratification for 15 days+$GA_3$1500ppm,T-12: Cold stratification for 45 days +Seed nicking, T-13: Seed with seed coat +cold stratification for 45 days + hot water for100ºC at 24 hours,T-14: Seed with seed coat + cold stratification for 45 days+$GA_3$1000 ppm,T-15: Seed with seed coat + cold stratification for 45 days+$GA_3$1500 ppm.

Table-4.7: Plumule/radicle length ratio and seed vigour index of *P. cerasoides*

Treatment	Seed Sources											
	Silyara		Develgaun		Ranichauri		Sadargaun		Chaurangikhal		Kuteti	
	P/R Ratio	SVI	P/R Ratio	SVI	P/R Ratio	SVI	P/R Ratio	SVI	P/R Ratio	SVI	P/R Ratio	SVI
T-1	0.47±0.38	483±213	2.064±1.10	214.48±115.33	0.51±0.24	164.32±75.62	0.21±0.12	467.2±257.65	0.56±0.30	234.08±121.4	0.36±0.17	341.6±125.41
T-2	0.56±0.42	496.8±154.00	6.17±3.13	232.96±139.45	1.09±2.98	240.76±79.56	0.10±0.2	387.6±125.98	0.91±0.25	289.44±87.56	0.73±0.50	375.4±54.21
T-3	0.75±0.65	461.4±170.0	0.76±0.18	305.28±82.65	0.47±0.43	99.36±79.56	0.82±0.48	302.4±114.58	0.99±0.28	281.44±78.54	0.76±0.34	375.04±135.66
T-4	0.38±0.35	512.44±201.0	0.57±0.9	228±116.3	0.71±0.38	281.22±113.25	0.38±0.15	459.04±147.52	0.29±0.15	261.44±64.58	1.20±2.21	420±146.00
T-5	0.37±0.32	423±145.00	0.23±0.05	178.08±79.56	0.40±0.12	173±7.21	0.82±0.32	295.68±86.74	0.89±0.35	330.48±106.54	0.67±0.54	348±124.32
T-6	0.57±0.29	449.48±145.00	0.56±0.20	167.92±85.47	0.87±0.37	187±65.12	1.11±0.95	550.68±142.95	0.49±0.28	288±89.74	0.83±0.64	362±123.54
T-7	0.18±0.10	231.84±98.23	0.15±0.05	397.44±84.57	0.64±0.42	242.88±55.86	0.37±0.14	283.63±88.57	1.43±0.95	362.4±107.1	0.44±0.18	362.52±191.42
T-8	0.35±0.20	401.4±146.00	0.31±0.14	331.52±1.10.5	0.51±39	380.8±145.85	0.38±0.15	281.2±78.54	0.80±0.35	419.04±134.25	0.15±0.02	272.64±75.21
T-9	1.03±0.92	453.6±148.00	1.28±0.27	381.92125.87	0.70±0.52	246.16±125.65	0.29±0.16	275.04±67.41	0.57±0.30	302.4±134.25	2.26±1.54	179.92±87.56
T-10	0.47±0.35	602.4±219.36	0.37±0.16	248.4±137.58	0.32±0.19	208±141.02	1.65±1.02	373.2±118.45	0.60±0.28	467.04±257.64	0.53±0.21	302.08±98.54
T-11	0.45±0.28	368.8±135.00	0.39±0.18	521.6±118.24	0.48±0.22	296.92±154.16	0.83±0.65	396.16±172	0.81±0.48	351.6±124.74	1.02±0.72	378.08±63.21
T-12	0.77±0.35	649.92±182.0	0.35±0.19	208.08±138.45	0.96±0.20	235.2±50.23	0.61±0.35	325.00±101.25	1.38±0.98	254.4±70.35	0.35±0.18	221.76±67.41
T-13	0.71±0.26	601.92±180.92	0.68±0.25	527.2±81.54	0.34±0.21	294.56±89.36	0.58±0.28	427.04±139.2	0.49±0.24	213.76±124.40	0.89±0.16	371±78.24
T-14	0.23±0.15	516.6±208.00	0.35±0.19	586.3±150.74	0.41±0.24	418.56±116.35	0.80±0.45	590.4±158.45	1.06±0.87	456.96±130.10	0.91±0.38	746.44±215.20
T-15	0.87±0.35	617.6±113.20	0.57±0.28	307.32±114.65	0.44±0.26	260.52±118.54	0.65±0.38	277.68±58.45	0.67±0.24	345.6±124.12	0.74±0.50	502.4±121.2
Mean treatment	0.54	484.659	0.99	322.423	0.59	249.88	0.64	379.45	0.80	323.86	0.79	370.70

T-1: Seed with seed coat +cold water for 24 hours, T-2: Seed without seed coat +cold water for 24 hours, T-3: Seed nicking +cold water for 24 hours, T-4: Seed with seed coat +hot waterfor100º C at 24 hours, T-5: Seed without seed coat + hot waterfor100ºC at 24 hours, T-6: Seed nicking + hot water for100º C at 24 hours, T-7: Seed with seed coat + cold stratification for 15 days, T-8: Cold stratification for 15 days+Seed nicking, T-9: Seed with seed coat + cold stratification for 15 days + hot water for100ºC at 24 hours, T-10: Seed with seed coat + cold stratification for 15 days+ GA_3 1000 ppm,T-11: Seed with seed coat + cold stratification for 15 days+$GA_3$1500ppm,T-12: Cold stratification for 45 days +Seed nicking, T-13: Seed with seed coat +cold stratification for 45 days + hot water for100ºC at 24 hours,T-14: Seed with seed coat + cold stratification for 45 days+$GA_3$1000 ppm,T-15: Seed with seed coat + cold stratification for 45 days+$GA_3$1500 ppm.

4.3 Estimation of genetic variability among the different *Prunus cerasoides* seed sources.

4.3.1 Variances, coefficient of variability and genetic components for morphological traits of fruits and seeds of *Prunus cerasoides*

The variance, coefficient of variability and genetic components for morphological traits of fruits and seeds of *Prunus cerasoides* were investigated. The observations with respect to variance, coefficient of variability and genetic components of morphological traits are presented in table 4.8. The highest (708.68, 604.68 & 104.01) phenotypic variance (Vp), genotypic variance (Vg) and environmental variance (Ve) were recorded in fruit moisture while, lowest (0.024, 0.015 & 0.009), were recorded infruit thickness in fruit morphological traits. In seed morphological traits, the maximum (53.699, 51.67 and 2.032), phenotypic variance (Vp), genotypic variance (Vg) and environmental variance (Ve) was observed in seed weight with minimum 0.0094 (Vp) was recorded in peel thickness, while minimum (0.0002) Vg and (0.010) Ve was observed in seed thickness respectively.

The highest (42.47) phenotypic coefficient of variation (PCV) was recorded in fruit moisture and lowest (13.62) in fruit length. The maximum (40.95) genotypic coefficient of variation (GCV) was recorded for fruit length/width ratio while minimum 11.31 was recorded in fruit weight. The highest (18.27) environmental coefficient of variation was observed for fruit thickness with fruit length being least (5.52) in fruit morphological traits. In seed morphological traits, the highest (65.56 & 64.89) phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) was recorded in seed length while lowest (10.58 &1.48) PCV and GCV was observed in seed thickness. The maximum (28.43) environmental coefficient of variance (ECV) was recorded for peel thickness with seed weight being recorded least (5.15).

The maximum (90.99 & 1.87) heritability and genetic advance was recorded for fruit length/width ratio while minimum (62.80 & 1.29) heritability and genetic advance was observed in fruit thickness. The highest (249.28) genetic gain was found in fruit thickness with fruit weight being least (1.21) in fruit morphological traits. In seed morphological traits, the highest (270.21, 5.56 & 1250.85) heritability, genetic advance and genetic gain was recorded in peel thickness while lowest (1.96, 0.04& 0.0004) for heritability, genetic advance and genetic gain was recorded in seed thickness.

Table 4.8 Phenotypic, Genotypic and environmental variance and variation of fruits and seeds traits of *Prunus cerasoides*

Parameter	Vp	Vg	Ve	PCV	GCV	ECV	Heritability	Genetic advance	Genetic gain
Fruit length	0.03	0.03	0.006	13.62	12.42	5.52	83.50	1.72	122.59
Fruit width	0.10	0.09	0.01	36.95	34.99	10.58	89.88	1.85	207.35
Fruit thickness	0.02	0.01	0.009	29.97	23.75	18.27	62.80	1.29	249.28
Fruit length/width ratio	0.44	0.40	0.04	39.06	40.95	12.29	90.99	1.87	115.18
Fruit weight	231.84	149.4	82.44	14.09	11.31	8.40	64.26	1.32	1.21
Fruit moisture	708.68	604.68	104.01	42.47	39.23	16.27	85.32	1.75	2.80
Seed length	0.27	0.26	0.0009	65.56	64.89	11.81	96.82	1.99	248.31
Seed width	0.02	0.008	0.01	30.19	16.89	25.03	31.27	0.64	120.27
Seed thickness	0.01	0.0002	0.01	10.58	1.48	10.48	1.96	0.04	0.0004
Length /width ratio	0.07	0.05	0.01	16.65	14.47	8.24	75.47	1.55	95.92
Peel thickness	0.009	0.02	0.01	21.79	35.54	28.43	70.21	5.56	250.85
Seed moisture	7.83	6.04	1.78	41.96	36.86	20.05	77.16	1.58	23.85
Seed weight	53.69	51.67	2.03	25.98	26.48	5.15	96.23	1.98	7.16

Vp- phenotypic variance, Vg- genotypic variance, Ve- environmental variance, PCV- phenotypic coefficient of variance, GCV- genotypic coefficient of variance, ECV- environmental coefficient of variance.

Table 4.9 Phenotypic, Genotypic and environmental variance and variation of seed germination and growth traits of *Prunus cerasoides*.

Parameter	Vp	Vg	Ve	PCV	GCV	ECV	Heritability	Genetic advance	Genetic gain
Germination	253.32	68.66	184.67	22.303	11.616	19.051	27.104	0.558	0.7822
Radical length	14.05	8.5	5.54	70.563	32.75	32.143	60.44	1.246	23.456
Plumule length	2.14	0.64	1.54	71.013	38.834	38.834	29.90	0.616	29.902
Seedling length	11.64	7.70	3.94	50.322	40.933	40.933	66.151	1.362	20.091
Plumule/Radical Ratio	1.49	0.74	0.760	115.150	80.621	81.70	49.60	1.023	95.876

Vp- Phenotypic variance, Vg- Genotypic variance, Ve- Environmental variance, PCV- Phenotypic coefficient of variance, GCV- Genotypic coefficient of variance, ECV- Environmental coefficient of variance.

4.3.2 Variances, coefficient of variation and genetic components for germination and growth traits of *Prunus cerasoides*

The observations table regarding on germination and growth traits are presented in table 4.9. The maximum (253.32) phenotypic variance (Vp) was recorded in germination percent and minimum (1.49) was observed in plumule/radical length ratio. The highest (68.66) genotypic variance (Vg) was found in germination percent with plumule length being least 0.64. The maximum (184.67) environmental variation (Ve) was observed in germination percent while minimum (0.76) was recorded in plumule/radical length ratio. In coefficient of variation, the maximum 115.15 phenotypic coefficient of variation (PCV) was recorded in plumule/radical length ratio and minimum (22.30) was found in germination percent. The highest (80.62) genotypic coefficient of variance (GCV) was recorded in plumule/radical length ratio and minimum (11.61) was observed in germination percent. The maximum (81.70) environmental coefficient of variation (ECV) was recorded in plumule/radical length ratio while minimum (19.05) was found in germination percent. In genetic components with respect to germination and growth traits, the highest (66.15%) heritability was recorded in seedling length with germination percent being least (27.10). The maximum (1.36) genetic advance was recorded in seedling length and minimum (0.55) was observed in germination percent. The highest (95.87%) genetic gain was recorded in plumule/radical length ratio while lowest (0.78) was observed in germination percent.

4.3.3 Correlations coefficient of different parameters with altitude, latitude, longitude, temperature, rainfall, pH of seed source.

Correlation coefficient between altitude, latitude, longitude, temperature, rainfall, pH with fruit, seeds and seedling parameters of *Prunus cerasoides* are presented in table 4.10. Altitude showed significant (<0.05) negative correlation with peel thickness (-0.82*) and germination percent (-0.79*). Latitude showed non-significant correlation all the fruits, seed and seedling characters. Longitude showed positive significant (<0.01) correlation with seed weight (0.88**) and germination percent (0.91**). Temperature showed positive significant (<0.01) correlation with fruit length (0.93**) and germination percent (0.85**). Rainfall showed significant (<0.05) inverse correlation with fruit thickness (-0.75*) and germination percent (-0.75*). pH showed significant (<0.05) positive correlation with plumule/radicle

length ratio (0.78*) while significant inverse correlation with peel thickness (-0.87**) and fruit thickness (-0.79*), seed weight (-0.81*), germination percent (-0.75*).

Table 4.10- Correlationcoefficient of different parameters with altitude, latitude and longitude, Temperature, Rainfall, pH of seed source.

Parameters	Altitude	Latitude	Longitude	Temperature	Rainfall	pH
Fruit length	-0.72^{NS}	0.14^{NS}	0.73^{NS}	**0.93****	0.46^{NS}	-0.36^{NS}
Fruit width	0.16^{NS}	-0.06^{NS}	-0.29^{NS}	-0.30^{NS}	0.16^{NS}	-0.22^{NS}
Fruit thickness	-0.72^{NS}	0.06^{NS}	0.73^{NS}	0.70^{NS}	**-0.75***	**-0.79***
Fruit length /width	0.12^{NS}	0.16^{NS}	0.06^{NS}	0.13^{NS}	-0.11^{NS}	0.47^{NS}
Fruit moisture	0.31^{NS}	0.15^{NS}	-0.28^{NS}	-0.02^{NS}	0.18^{NS}	0.72^{NS}
Fruit weight	0.45^{NS}	0.39^{NS}	-0.13^{NS}	-0.29^{NS}	0.49^{NS}	0.52^{NS}
Seed length	-0.31^{NS}	0.47^{NS}	0.74^{NS}	0.37^{NS}	-0.39^{NS}	-0.50^{NS}
Seed width	-0.58^{NS}	-0.59^{NS}	0.26^{NS}	0.47^{NS}	-0.61^{NS}	-0.18^{NS}
Seed thickness	0.48^{NS}	-0.01^{NS}	-0.60^{NS}	-0.21^{NS}	0.06^{NS}	0.72^{NS}
Seed moisture	0.34^{NS}	-0.07^{NS}	-0.41^{NS}	-0.22^{NS}	0.37^{NS}	0.68^{NS}
Seed length /width	-0.49^{NS}	0.06^{NS}	0.59^{NS}	-0.65^{NS}	-0.58^{NS}	-0.09^{NS}
Peel thickness	**-0.82***	-0.20^{NS}	0.74^{NS}	0.57^{NS}	-0.49^{NS}	**-0.87****
Seed weight	-0.65^{NS}	0.32^{NS}	**0.88****	0.67^{NS}	-0.66^{NS}	**-0.81***
Germination %	**-0.79***	0.23^{NS}	**0.91****	**0.85****	**-0.75***	**-0.75***
Mean germination time	0.59^{NS}	0.27^{NS}	-0.33^{NS}	-0.64^{NS}	0.46^{NS}	0.11^{NS}
Germination index	-0.47^{NS}	0.36^{NS}	0.71^{NS}	0.62^{NS}	-0.66^{NS}	-0.54^{NS}
Radical length	0.39^{NS}	0.66^{NS}	0.18^{NS}	-0.53^{NS}	0.66^{NS}	-0.30^{NS}
Plumule length	0.26^{NS}	0.06^{NS}	-0.41^{NS}	0.02^{NS}	-0.10^{NS}	0.44^{NS}
Seedling length	-0.02^{NS}	0.46^{NS}	0.23^{NS}	0.05^{NS}	0.14^{NS}	-0.32^{NS}
Plumule /radical	0.47^{NS}	-0.06^{NS}	-0.64^{NS}	-0.17^{NS}	0.05^{NS}	**0.78***

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

4.3.4 Correlation of coefficient between different parameters of *Prunus cerasodes*

Karl pearson's correlation coefficient for 20 parameters of fruit, seed, seedling characteristics and seed germination of *Prunus cerasoides* were studied and the observations are presented in table 4.11. Between the different parameters, correlations at 10 were found highly positive significant at $p \leq 0.01$ and 15 correlations were found significant at $p \leq 0.05$. Fruit length vs germination %, fruit width vs fruit length/width ratio, seed length/width ratio, fruit thickness vs fruit weight, seed moisture, germination %,germination index , fruit length/width ratio vs seed length/ width ratio, fruit moisture vs fruit weight, seed moisture, fruit weight vs seed moisture, seed length vs seed weight, germination index, seed width vs seedling length, seed thickness vs peel thickness, plumule length, plumule length/radical ratio, seed moisture vs seed weight, germination index, peel thickness vs plumule and radical length, seed weight vs germination %, germination index, germination % vs germination index, plumule length vs plumule and radical ratio.

Table 4.11 Correlation coefficient between various fruit, seed and seedling of *Prunus cerasoides*.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	-0.360																		
2	0.606	0.306																	
3	0.227	-0.839*	-0.290																
4	0.201	-0.588	-0.635	0.533															
5	-0.062	-0.709	-0.740	0.567	0.805*														
6	0.403	-0.226	0.626	0.370	-0.408	-0.177													
7	0.214	-0.435	0.261	0.445	-0.256	-0.265	0.376												
8	-0.117	0.204	-0.184	0.290	0.293	-0.089	-0.147	-0.096											
9	-0.097	-0.591	-0.840*	0.408	0.896**	0.852*	-0.597	-0.184	0.046										
10	0.664	-0.850*	0.208	0.791*	0.273	0.292	0.590	0.644	-0.138	0.132									
11	0.409	-0.078	0.545	-0.369	-0.437	-0.280	0.225	0.305	-0.879**	-0.295	0.229								
12	0.660	0.096	0.942**	-0.116	-0.531	-0.497	0.795*	0.205	-0.304	-0.752	0.371	0.558							
13	0.873l*	-0.080	0.832*	-0.123	-0.271	-0.298	0.541	0.126	-0.419	-0.434	0.448	0.685	0.890**						
14	-0.629	0.501	0.001	-0.069	-0.500	-0.296	0.290	-0.125	0.406	-0.508	-0.413	-0.511	-0.013	-0.450					
15	0.647	0.071	0.877**	0.112	-0.408	-0.479	0.845*	0.242	0.065	-0.733	0.433	0.220	0.922**	0.748	0.158				
16	-0.647	0.122	-0.144	-0.262	-0.218	0.306	0.183	-0.535	0.517	-0.074	-0.309	0.145	0.067	-0.054	0.331	-0.117			
17	0.139	0.467	0.088	-0.118	0.236	-0.268	-0.257	-0.386	0.837**	-0.076	-0.325	-0.614	-0.074	-0.064	0.167	0.181	-0.473		
18	0.222	0.375	0.168	-0.627	0.074	0.049	-0.225	-0.804	-0.321	-0.003	-0.425	0.273	0.211	0.410	-0.281	0.010	0.452	0.182	
19	-0.075	0.140	-0.259	0.302	0.418	-0.006	-0.258	-0.122	0.987**	0.179	-0.122	0.870*	-0.382	-0.425	0.271	-0.025	-0.569	0.849	-0.278

Note: 1. Fruit length, 2. Fruit width, 3. Fruit thickness, 4. Fruit length/width ratio, 5. Fruit moisture, 6. Fruit weight, 7. Seed length, 8.Seed width, 9. Seed thickness, 10. Seed moisture, 11. Seed length/width ratio, 12. Peel thickness, 13. Seed weight, 14. Germination %, 15. Mean germination

time, 16. Germination index, 17. Radical length, 18. Plumule length, 19. Seedling length, 20.Plumule and radical ratio, * Significant at <0.05,** significant at <0.01.

CHAPTER-5 DISCUSSION

The present study entitled "**Effect of seed sources on fruit, seed characteristics and seed germination of *Prunus cerasoides* (D. Don**)" have been discussed in this chapter under different objectives as stated earlier.

5.1 To study the effect of seed source variation on fruit, seed and seedling morphology in *Prunus cerasoides.*

5.2 Effect of pretreatments on seed germination of *Prunus cerasoides* from different sources.

5.3 Estimation of genetic variability among the different *Prunus cerasoides*sources.

5.1 To study the effect of seed source variation on fruit, seed and seedling morphology in *Prunus cerasoides.*

Morphological variations in fruit and seed traits between the population is essential approach to identify the better genotypes for help the breeder for further selection and breeding of superior genotypes. It is also important to improve the tree species through tree breeding programs, establishment of superior forest nurseries and plantations. Seed source variation studies are also important to obtain the better growth and yields of valuable forest tree species. The present study variation on fruits and seeds of *Prunus cerasoides* were conducted owing to its importance, uses, poor regeneration of in forestas well asto identify the better seed lots for seed germination and seedling growth.

5.1.1 Morphological variation of fruit

Significant ($p \leq 0.05$) variation was recordedfor fruit length, width, weight, moisture and fruit length/width ratio while fruit thickness was not showed significant ($p \leq 0.05$) variation between the seed source. Among the seed source, maximum fruit length, weight of 100 fruits and fruit length/width ratio were recorded in Silyara seed source, while highest fruit width and fruit thickness were observed in Develgaun seed source and fruit moisture was recorded in Sadargaun seed source as compared to other seed source. The minimum fruit length and fruit thickness were recorded in Chaurangikhal seed source, while the lowest fruit length/width ratio, fruit weight and fruit moisture were observed in Develgaun seed

source and Sadargaun seed source was showed minimum fruit width as compared to other seed source.

Fruit size and fruit weight are important characteristics of plant species which depends on a different factor such as; seed source, genetic makeup and geographical environment where it is growing was reported by **(Carvers and Steel, 1984).** The present study supports earlier work done by **Tewari *et al.* (2010)** wherein they concluded that all *Prunus cerasoides* fruit parameters showed significant variation between the seed source. On other hand, **Coutts *et al.* (2012)** reported that *Pinus nigra* produced largest number of seeds, when the environmental conditions were dry and windy of seed source that potentially would increase the proportion of scattered-seeds in a far distance. The size of fruit is influenced by internal factors such as the success of reproduction, environmental factors and availability of nutrients. Similarly, **Ugese *et al.* (2010)** also reported that relationship among the fruit size and environmental condition was observed on *Vitellaria paradoxa*, where the size of fruit was significantly influenced by agroecology zones. Our results are in line with, **Anita and Vidya (2012)** assessed the seed source variation in fruit, seed and seedling traits of *Hippophae salicifolia* and the seeds were collected from various 12 seed sources of Uttarakhand. They found that significant variation on fruit morphological parameters. Similarly, **Tiwari and Dhuria (2018)** in *Albizia procera* and **Kumar *et al.* (2018)** in *Celtis australis.*

5.1.2 Morphological variation of seeds in *Prunus cerasoides*

Significant ($p \leq 0.05$) difference were recorded for seed length, seed width,seed moisture, seed weight, seed length/width ratio while seed thickness and peel thickness was not showed significant ($p \leq 0.05$) variation between the seed source. Between the seed source, maximum seed length, seed width and seed length/width ratio were recorded in Silyara seed source, while the highest seed thickness and seed moisture were observed in Sadargaun seed source with Develgaun seed source were showed maximum seed weight and peel thickness. The minimum seed length, seed length/width ratio and seed weight were observed in Ranichauri seed source, while lowest seed width and seed thickness were recorded in Kuteti

seed source with lowest seed moisture and peel thickness were recorded in Develgaun and Sadargaun seed source respectively.

The present investigation supports earlier work done by **Tewari and Tewari (2016)** wherein they concluded that the seed length, width and weight were varied significantly across sites. Similarly, **Parthiban *et al.* (2013)** also reported that seed source variation among the seed source in *Pongamia pinnata.* On other hand similar work also done by other workers in various forest tree species. **Tamta and Tewari (2018)** in *Prunus armenica,* **Singh *et al.* (2010)** in *Quercus glauca* Thunb., **Nagar (2016)** in *Bauhinia variegata* lin., **Renuka (2013)** in *Cassia fistula,* **Pramono *et al.* (2019)** in *Swietenia macrophylla,* **Tiwari and Dhuria (2018)** in *Albizia procera* and **Kumar *et al.* (2018)** in *Celtis australis.*

5.2 Effect of pre-treatments on seed germination of *Prunus cerasoides* from different seed sources.

5.2.1 Seed germination characteristics

Significant ($p \leq 0.05$) variation was recorded between the treatments and seed source with respect to seed germination percent. Seeds of *prunus cerasoides* with seed coat were kept stored for 45 days in refrigerator for cold stratification to break the dormancy of seeds. After 45 days of stratification seeds were dipped in GA_3 solution with various concentrations to increase the germination rate and growth of seedlings. There after, these seeds were put in petri dish and placed on germinator for germination. The highest (79.66%) germination percent was recorded in treatment (T-14) seed with seed coat + cold stratification for 45 days+ $GA_3$1000 ppm and lowest (49.50%) was recorded in treatment (T-1) seed with seed coat +cold water for 24 hours. Scientist have used the variety of pre-treatments to break the dormancy of *Prunus* seeds with stratification being the most popular was reported by **Grisez *et al.*, (2008).** GA_3 is a most effective growth hormone and it is also used to break the dormancy of seeds which increase the germination percent rapidly. On other hand, **Nayak *et al.* (2004)** reported that variation in germination may be attributed by dormancy of seed caused by im-permeability of hard seed coat or may be dormancy in embryo.

The present findings supports earlier work done by **Mello *et al.* (2009)** wherein they examined the effect of Gibberellic acid (GA_3) on seed germination of *Penstemon digitalis and* found that GA_3 increased the germination percentage and rate of seed germination, the treatment 1000 mg/L^{-1} GA_3 was found best for seed germination in all three experiments. Similarly, **Universitesi *et al.* (1999)** investigated the effects of seed coat removal, GA_3, H_2SO_4, preserved in cold and hot water and stratification (20-24°C and 2-4°C) in seed germination of *Prunus mahaleb*. Whereas they observed that the highest mean germination was recorded in a solution of GA_3 at 1000 ppm + cold stratification for twelve weeks on 2-4°C. On the country, **Thapliyal *et al.* (2021)** examined the seed germination response of *Pyrus pashia* and they concluded that the highest (94 %) germination percent was observed in the seeds pre-treated with GA_3 500 ppm. Similarly, **Chukwu *et al.* (2020)** in *Prosopis Africana*.

In seed source, maximum (72.86%) germination percent was observed in Silyara seed source and Ranichauri seed source being least (55.00%).The variation in germination percent might be due to the seed size, while the highest seed length, seed width and seed length/width ratio was recorded in Silyara seed source. Large size seed hold more reserve food **Kandya, (1978)** which are expectant to give higher germination percent. Our results are in line with **Sridhar (2006)** they concluded that the highest germination percent varied from 61.90% to 95.23% in heavy and large seed followed by medium seed 47.61% to 91.47% and small seed 39.09% to 71.42% in *Jatropha curcus.* Similar observations were also reported by **Reddy *et al.* (2007)** in *Pongamia pinnata,* **Tamta and Tewari (2018)** in *Prunus armenica*, **Tewari *et al.* (2010)** in *Prunus cerasoides,* **Palanikumaran *et al.* (2015)** in *Calophyllum inophyllum* L. and **Kumar *et al.* (2018)** in *Celtis australis.*

Significant ($p \leq 0.05$) variation was recorded between the treatments and seed source with respect to mean germination time and germination index. The lowest (11.75days) mean germination time was recorded in treatment (T-14) seed with seed coat + cold stratification for 45 days+ $GA_3$1000 ppm and highest (21.52days) MGT was observed in treatment (T-1) Seed with seed coat +cold water for 24 hours. In seed source, minimum (17.56days) mean germination time was recorded in Develgaun seed source with Ranichauri seed source being maximum (18.35). The maximum (0.18) germination index was recorded in treatment (T-5)

seed without seed coat + hot water for 100ºC at 24 hours and (T-9) seed with seed coat + cold stratification for 15 days + hot water for 100ºC at 24 hours, while the lowest (0.10) GI was observed in treatment (T-1) seed with seed coat +cold water for 24 hours. In seed source, the highest (0.16) germination index was found in Sadargaun seed source with Ranichauri and Kuteti seed source being least (0.13). The variation in germination characteristics may be depending on the seed morphology, seed viability, seed dormancy, genetic material of mother plants as well as type and application of pre-sowing treatments, stratification, geographical, climatic and edaphic factors of seed source where it is growing and collecting. The finding of present investigation is similar to **Roy *et al.* (2004)** wherein they concluded that seeds collected from higher latitude or altitude seed sources take more time to complete germination. On other hand, **Nayak *et al.* (2004)** assessed the seed source variation of *Albezia lebbeck* in Karnataka, India and they reported that between five provenances, mean daily germination ranges varied from 0.728 (Chickmagalur) to 1.382 (Mandya). Similarly, **Palanikumaran *et al.* (2015)** were assessed the different populations of South India for seed germination in Undi (*Calophyllum inophyllum* L.). He has reported that significant variation was recorded in mean daily germination (1.79) and germination value (5.11). Similar results were also reported by other workers **Reddy *et al.* (2007)** in *Pongamia pinnata*, **Uniyal *et al.* (2003)** in *Grewia oppositifolia*, **Wani and Singh, (2016)** in *Pongamia pinnata,* **Aslam *et al.* (2017)** in *Pinus wallichiana* and **Kumar *et al.* (2018)** in *Celtis australis.*

5.2.2 Growth Parameters

Significant ($p \leq 0.05$) variations were observed in treatment and seed source regarding on various growth parameters of *Prunus cerasoides*. The highest plumule length, radicle length, seedling length and seed vigour index was recorded in treatment (T-14) seed with seed coat +$GA_3$1000 ppm + cold stratification for 45 days while highest plumule/radical length ratio was recorded in treatment (T-2)seed without seed coat +cold water for 24 hours. GA_3 is a most effective growth hormone which promotes growth of seedlings. Our investigation is line with **Opoku *et al.* (2018)** wherein they examined the effect of pre-sowing treatments on seed germination and seedling growth of *Bauhinia rufescens.* They concluded that GA_3 1000 ppm showed highest plant height 14.57cm after 28 days of seed

germination. On other hand, **Thangjam and Sahoo (2017)** reported that all seedling growth parameters showed better response in application of hormonal (GA_3) treatment as compared to H_2SO_4 treatment. Similarly, **Nasiri *et al.* (2018)** investigated the effects of plant hormone (500 and 1000 mg/L. GA_3), magnetic field (3, 15, 30 mT) and laser irradiation at 650 nm (200 mw) on the germination and the growth of *Salvia officinalis*. Wherein they concluded that GA_3 (500 and 1000 mg/L.) significantly increased the plumule length (11.11mm and 12.20mm) respectively, as compared to control and other treatments.

In seed source, the maximum radical length, seedling length and seed vigour index were found in Silyara seed source and lowest plumule length, radical length, seedling length and seed vigour index were observed in Ranichauri seed source, while the highest plumule length and plumule/radicle length ratio were found in Kuteti and Develgaun seed source, respectively and lowest plumule/radicle length ratio was found in Silyara seed source. Among the seed source Silyara seed source was showed better growth with respect to radical length, seedling length and seed vigour index because of seeds of Silyara seed source were larger than other seed source. The variation in growth characteristics were may be attributed by seed sizes. The present study supports previous work done by other workers whereas, **Rawat and Bakshi (2011)** concluded that larger seed size significantly correlated with initial seedling growth. Similarly, **Nawahbahar (2008)** also reported that heavy and large seed contains more food reserve than smaller ones, which helpful in germination and growth of seedlings by providing more energy. On other hand, **Anita and Vidya (2012)** also reported variation in fruit, seed and seedling traits of *Hippophae salicifolia* between the seed source. Similarly, **Reddy *et al.* (2007)** observed the seed source variation in *Pongamia pinnata* for seed and seedling traits. Similarly, **Kumar *et al.* (2018 & 2021)** in *Celtis australis*

5.3 Estimation of genetic variability among the different *Prunus cerasoides* sources.

5.3.1 Variances, coefficient of variability and genetic components for fruits, seeds morphological traits with germination and growth traits of *Prunus cerasoides.*

The variance, coefficient of variability and genetic components for fruits, seeds morphological traits with germination and growth traits of *Prunus cerasoides* were studied.

The highest phenotypic variance (Vp), genotypic variance (Vg) and environmental variance (Ve) were recorded in fruit moisture and seed weight in fruit and seed morphological traits, while in germination and growth traits, the maximum (Vp), (Vg) and (Ve) was found in germination percent. The highest phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) was recorded in fruit moisture, fruit length/width ratio and fruit thickness respectively, in fruit morphological traits, while in seed morphological traits, the highest (PCV) and (GCV) was recorded in seed length with highest (ECV) was observed in seed weight. In germination and growth traits, the maximum (PCV), (GCV) and (ECV) were recorded in plumule/radical length ratio. The highest heritability and genetic advance were recorded for fruit length/width ratio with maximum genetic gain was found in fruit thickness in fruit morphological traits, while in seed morphological traits, the highest heritability, genetic advance and genetic gain was recorded in peel thickness. In germination and growth traits, the maximum heritability and genetic advance were observed in seedling length with highest genetic gain was found in plumule/radical length ratio. The above described results showed that these are exists an environmental effect on these characteristics. The findings of present study support previous work done by other workers, **Kumar and Kaushik (2015)** in *Pongamia pinnata,* **Singh and Bhat (2008)** in *Dalbergia sissoo,* **Singh and Bhatt (2008)** in *Celtis australis,* **Shankar and Synrem (2012)** in *Prunus nepaulensis,* **Palanikumaran *et al.* (2016)** in *Pongamia pinnata,* **Kumar and Dhuria (2018)** in *Albizia procera* and **Kumar *et al.* (2021)** in Celtis australis.

5.3.2 Correlations coefficient of different parameters with altitude, latitude, longitude, temperature, rainfall, pH of seed source.

Correlation coefficient between altitude, latitude, longitude, temperature, rainfall, pH with fruit, seeds and seedling parameters of *P. cerasoides* showed significant (<0.05) correlation with longitude, temperature, rainfall and pH. Longitude showed significant (<0.05) positive correlation with seed weight and germination percent. Temperature showed significant (<0.05) positive correlation with fruit length and germination percent. Rainfall showed significant (<0.05) positive correlation with fruit thickness and germination percent, while pH showed significant (<0.05) positive correlation with plumule /radical length ratio.

The above-described parameters regarding on fruit, seed, seedling and germination characteristics of *P. cerasoides* was showed significant (<0.05) positive correlation with longitude, temperature, rainfall and pH. It might be due to the effect of geographical and climatic factors of seed source where it is growing. The similar observations were also reported by other workers, **Roy *et al.* (2004)** on *Pinus roxburghii*, **Bisht *et al*. (2002)** on *Azadirachta indica*, **Singh and Bhatt (2008)** on *Dalbergia sissoo*, **Saklani *et al.* (2012)** on *Quercus leucotrichophora*, **Kumar *et al.* (2021&2018)** in *Celtis australis*

5.3.2 Correlation of coefficient between different parameters of *Prunus cerasodes:*

Correlation studies are important to understand the relationship of various fruit, seed, seedling and germination characteristics in forest tree species. For example, seed germination, growth of seedlings and yields are highly affected by seed sizes and geographical, climatic factors of seed source where it is growing. In present investigation, correlation of coefficient for 20 parameters of fruit, seed, seedling characteristics and seed germination of *Prunus cerasoides* were studied. Between the different parameters, 10 correlations were found highly positive significant at $p \leq 0.01$ and 12 correlations were found positive significant at $p \leq 0.05$ in each other. The relationship was may be due to the inter-dependence of various parameters with each other. Similar finding was reported by **Samita *et al.* (2015)** they investigated the seed traits variation with seed germination in *Calophyllum inophyllum.* Wherein they concluded that seed thickness and seed length showed positive effect on seed germination. On other hand, **Dar *et al.* (2011)** conducted study on genetic analysis for pod and seeds in *Acacia nilotica* and he has concluded that correlation study indicated that pod thickness, seed length, seed thickness, seed width, pod weight and weight of 100 seeds was showed significant and positive correlation with germination percent. The similar findings were also reported by other workers; **Dhanai *et al.* (2003)** on *Albizia chinensis*, **Singh *et al.* (2015)** on *Pinus kesiya*, **Singh and Bhatt (2008)** on *Celtis australis*, **Thakur and Thakur (2015)** on *Melia azedarach*, **Dhilon *et al.* (2008)** on *Jatropha curcus* and **Kumar *et al.* (2018&2021)** in *Celtis australis*.

CHAPTER-6 SUMMARY AND CONCLUSION

Variations due to nature are responsible for creating provenances, clones, races, ecotypes and it is also important source for a tree breeder to improve the tree species. *Prunus cerasoides* (D. Don) is a sacred plant in Hindu mythology which belongs to the Rosaceae family. It is one of the 31 multipurpose tree species of the Himalayan regions. It is traditionally used for edible fruit, seed and gum as well as different medical applications, lumber, dyestuff, tannins and beads. It is mainly used as rootstock for cultivation of cherries and is also used in rituals by the local inhabitants, especially in Garhwal Himalaya. It produces a large number of seeds with hard seed coat and the regeneration of this species is very poor in its natural habitat.

The present study entitled "Effect of seed sources on fruit, seed characteristics and seed germination of *P. cerasoides* (D. Don)" was conducted owing to its importance, uses and poor regeneration of in nature as well as to fulfill the demands of modern life. The research explorations presented in the preceding chapter were conducted on various aspects such as; effect of seed source on fruit, seed, seedling morphology, effect of pre-treatments on seed germination by seed source and estimation of genetic variability of *P. cerasoides*. The summary and conclusions of present investigation are described below:

The experiment was conducted in Forestry lab, Department of Forestry, College of Forestry, Ranichauri, Tehri Garhwal, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand during the year 2020-21. The seeds of *P. cerasoides* were collected from six different locations; Silyara, Develgaun, Ranichauri, Sadargaun, Chaurangkahl and Kuteti of Uttarakhand, India.

The fifteen different pre-sowing treatments; seed with seed coat +cold water for 24 hours, seed without seed coat +cold water for 24 hours, seed nicking +cold water for 24 hours, seed with seed coat +hot water for 24 hours at a temperature 100ºC, seed without seed coat + hot water for 24 hours at a temperature 100ºC, seed nicking + hot water for 24 hours at a temperature 100ºC, seed with seed coat + cold stratification for 15 days, cold stratification for 15 days+ seed nicking, seed with seed coat + cold stratification for 15 days

+ hot water for 24 hours at 100ºC, seed with seed coat + cold stratification for 15 days+ GA_3 1000ppm, seed with seed coat + cold stratification for 15 days+$GA_3$1500ppm, cold stratification for 45 days+ seed nicking, seed with seed coat +cold stratification for 45 days + hot water for 24 hours, seed with seed coat + cold stratification for 45 days+$GA_3$1000ppm and seed with seed coat + cold stratification for 45 days+$GA_3$1500 ppm were selected and designated as; T-1, T-2, T-3, T-4, T-5, T-6, T-7, T-8, T-9, T-10, T-11, T-12, T-13, T-14 and T-15 respectively, for the seed germination of *P. cerasoides.*

The fruit and seed morphological data of *P. cerasoides* were analyzed according to the procedure of analysis of variance for Randomized Block Design, while seed germination and seedling growth data were analyzed according to the procedure of analysis of variance for Completely Randomized Design.

The main findings of the present study are summarized below:

- The six seed sources were evaluated with respect to various fruit morphological parameters. Between the seed source the highest fruit length (1.53cm), weight of 100 fruits (116.72gm) and fruit length/width ratio (15.75) were recorded in Silyara seed source, while the maximum fruit width (1.02mm) and fruit thickness (1.02mm) were recorded in Develgaun seed source and fruit moisture (15.75%) was observed in Sadargaun seed source.
- In seed morphological parameters, among the seed source maximum seed length (0.97cm), seed width (0.69cm) and seed length/width ratio (2.64) were recorded in Silyara seed source, while the highest seed thickness (0.61mm) and seed moisture (8.17%) were observed in Sadargaun seed source with the maximum peel thickness (0.52mm) and weight of 100 seeds (31.00gm) in Develgaun seed source.
- For seed germination attributes, six seed sources and fifteen several pre-sowing treatments were investigated with observed their influence on various seed germination parameters. In germination percent, the average highest (79.66%) germination percent was observed in treatment (T-14) as compared to other treatments. In seed source, the average maximum (72.86%) germination percent was found in Silyara seed source as compared to other seed sources.

- The average minimum (11.75days) mean germination time was observed in treatment T-14, while the Develgaun seed source was showed average lowest (17.56days) mean germination time as compared to other treatments and seed sources.
- The average maximum (0.18) germination index was observed in treatment (T-5) and (T-9), while the Sadargaun seed source was showed average highest (0.16) germination index as compared to other treatments and seed sources.
- In growth parameters attributes, the highest plumule length (2.76cm), radicle length (4.60cm), total seedling length (7.37cm) and seed vigour index (552.59) was recorded in treatment T-14, while the maximum (1.59) plumule/radicle length ratio was observed in treatment T-2 as compared to other treatments.
- In seed source, the highest radicle length (4.26cm), total seedling length (6.55cm) and seed vigour index (484.65) were recorded in Silyara seed source, while the maximum plumule length (2.36cm) and plumule/radicle length ratio (0.99) were recorded in Kuteti and Develgaun seed source respectively, as compared to other seed sources.
- The highest heritability and genetic advance were recorded for fruit length/width ratio with maximum genetic gain was found in fruit thickness in fruit morphological traits, while in seed morphological traits, the highest heritability, genetic advance and genetic gain was recorded in peel thickness. In germination and growth traits, the maximum heritability and genetic advance were observed in seedling length with highest genetic gain was found in plumule/radical length ratio.
- Correlation coefficient between altitude, latitude, longitude, temperature, rainfall, pH with fruit, seeds and seedling parameters of *P. cerasoides* were studied. Some parameters of fruits, seeds, seedlings and germination characteristics of *P. cerasoides* showed significant (<0.05) correlation with longitude, temperature, rainfall and pH.
- For correlation studies different parameters of fruit and seed morphology, seedling and germination characteristics of *P. cerasoides* were investigated. Between the various parameters, 10 correlations were found highly positive significant at $p \leq 0.01$ and 15correlations were significant at $p \leq 0.05$.
- The overall findings of present study indicates that the variation in fruit and seed size significantly (<0.05) influenced by seed source. The superior fruits and seeds with

respect to their morphology were recorded in Silyara, Kuteti and Sadargaun seed source which was significantly affected seed germination and seedling growth. The maximum seed germination and seedling growth were obtained in Silyara, Sadargaun and Kuteti seed source. On other hand, pre-sowing stratification with treatment (GA_3) and hot water treatment for 24 hrs were significantly enhance the seed germination and seedling growth, which was more effective as compared to other treatments in case of *P. cerasoides.* In generally seed stratification with treated (GA_3) is not economically suitable for the poor nursery growers and farmers because lack of resource. The hot water treatment is an easy and cheapest method for mass multiplication of *P. cerasoides* in forest nurseries and plantations.

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PHOTO PLATES

Plate-1 Fruits of *P.cerasoides*

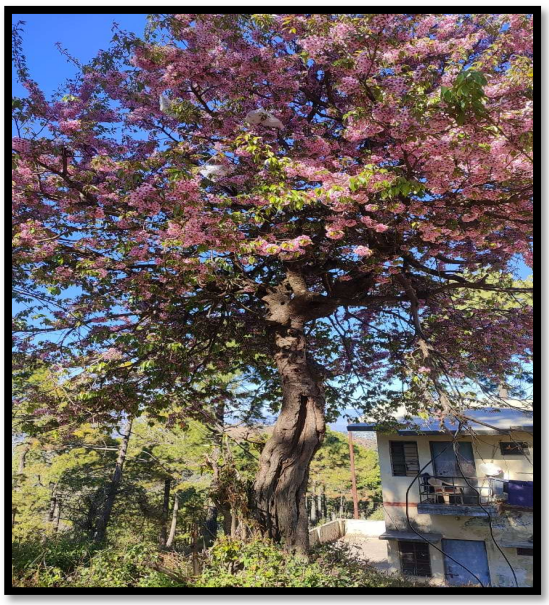

Plate-2 Flowering in *P.cerasoides*


Plate-3 and 4 Mature fruits and after removal of pulp of *Prunus cerasoides* fruits


Plate-5 Petri dish placed on germination **Plate-6 See the germination on seeds**


Plate-7 and 8 Germinated seeds of *P. cerasoides*


Plate-9 Radicle of *P. cerasoides* Plate-10 Seedling of *P. cerasoides*

Plate- 11 and 12 seedlings of *P.cerasoides* after 28 days of transplanting

APPENDICES

Appendix 1: Analysis of variance (ANOVA) for fruit length, fruit width and fruit thickness.

Source of variation	Df	Fruit length	Fruit width	Fruit thickness
Treatments	5	24.399**	9.342**	1.919 ^{NS}
Replications	4	4.930 ^{NS}	0.678 ^{NS}	0.366 ^{NS}

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

Appendix 2: Analysis of variance (ANOVA) for fruit length/width ratio, fruit moisture and fruit weight (100 fruit).

Source of variation	Df	Fruit length/ width ratio	Fruit moisture	Fruit weight
Treatments	5	10.209**	6.013**	10.066**

Replications	4	2.778 ^{NS}	0.321 ^{NS}	1.195 ^{NS}

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

Appendix 3: Analysis of variance (ANOVA) for seed length, seed width and seed thickness.

Source of variation	Df	Seed length	Seed width	Seed thickness
Treatments	5	28.890**	3.353*	1.038 ^{NS}
Replications	4	1.205 ^{NS}	1.632 ^{NS}	0.758 ^{NS}

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

Appendix 4: Analysis of variance (ANOVA) for seed moisture, seed length/width ratio and peel thickness, seed weight.

Source of variation	Df	Seed moisture	Seed length/width ratio	Peel thickness	Seed weight
Treatments	5	3.579*	3.743*	2.057 ^{NS}	25.636**
Replications	4	2.050 ^{NS}	2.247 ^{NS}	0.455 ^{NS}	0.775 ^{NS}

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

Appendix 5: Analysis of variance (ANOVA) for germination percent, MGT and GI.

Source of variation	Df	Germination percent	MGT	GI
Treatments	5	2.859*	0.968 ^{NS}	2.234 ^{NS}
Replications	4	0.253 ^{NS}	0.734 ^{NS}	1.446 ^{NS}

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

Appendix 6: Analysis of variance (ANOVA) for Radical length, plumule length and seedling length, plumule/radical length ratio.

Source of variation	Df	Radical length	Plumule length	Seedling length	Plumule /radical length
Treatments	5	8.658**	3.108*	10.769**	5.856**
Replications	4	1.827	0.840 ^{NS}	2.792 ^{NS}	0.564 ^{NS}

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

VITAE

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