Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings

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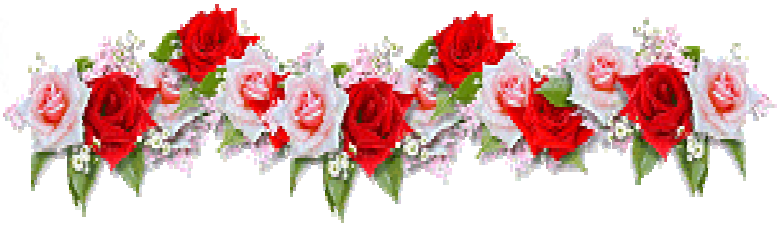
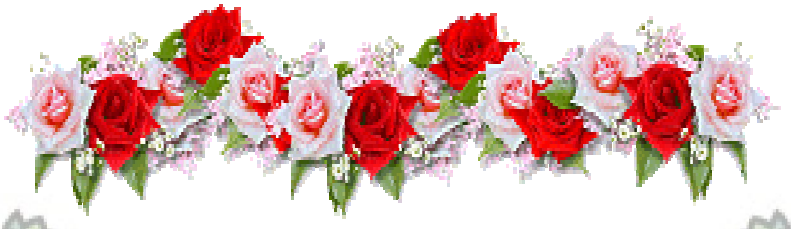


Dedicated

To my
Beloved Parents



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Faculty of Forestry, Division of Forest Biology and Tree Improvement

Certificate – I

This is to certify that the thesis **entitled "Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings"** submitted in partial fulfilment of the requirements for the award of the degree of Master of Science in Forestry to the Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir is a record of bonafide research work carried out by **Ms. Midhat Bilal (Regd. No. MSF-2018-101**) under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation have duly been acknowledged.

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Endorsed

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We, the members of the Advisory committee of **Ms. Midhat Bilal (Regd. No. MSF-2018-101)**, a candidate for the degree of **Master of Science in Forestry**, have gone through the manuscript of the thesis entitled, **"Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of degree.

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Certificate – III

This is to certify that the thesis entitled **"Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings"** submitted by **Ms. Midhat Bilal (Regd. No. MSF-2018-101)**, to the Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, in partial fulfilment of the requirements for the award of the degree of **Master of Science in Forestry** was examined and approved by the Advisory Committee and external examiner on ……..

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ABSTRACT

The present investigation entitled **"Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings"** was undertaken in the experimental field of Division of Forest Biology and Tree Improvement, Faculty of Forestry, Benhama during the years 2018 and 2019 under a set of experiments.

In experiment-I, the seeds of *Platanus orientalis* L. were collected from ten randomly selected trees in District Ganderbal in the month of January. The collected seeds were subjected to 7 stratification periods at 10 days interval viz., 0, 10, 20, 30, 40, 50 and 60 days at 4±1°C. The treated seeds were sown simultaneously in trays in three replicates per chilling treatment per tree and the design followed was the CRD (Factorial) with ten treatments (trees) in polyhouse. In case of different stratification periods, maximum germination (73.07%), germination energy (29.60), mean daily germination (2.85), peak value (4.03), germination value (12.08), germination speed (18.90), vigour index (5568.77),

length of shoot (42.22 cm) and length of root (33.68 cm) was recorded when seeds were stratified for 60 days and in case of different trees, tree located at Tulmulla with height (30 m), DBH (4.99 m) and 1000 seed weight (5.51 g) resulted in higher values for germination (61.35%), germination energy (32.19), mean daily germination (2.43), peak value (3.21), germination value (9.15), germination speed (15.00), vigour index (3939.39), length of shoot (37.19 cm) and length of root (24.04 cm) respectively as compared to other trees.

As far as genetic parameters are considered, highest PCV was recorded for vigour index (49.81), followed by length of root (40.57), germination energy (31.77), germination value (26.68), length of shoot (26.59), germination speed (18.98), germination percent (12.05), mean daily germination (11.99), 1000 seed weight (9.55) while as peak value exhibited lowest PCV (9.01). The highest GCV was recorded for vigour index (49.30), followed by length of root (39.90), germination energy (31.76), germination value (25.92), length of shoot (25.78), germination speed (18.44), germination percent (11.82), mean daily germination (10.31), 1000 seed weight (9.42) while as peak value exhibited lowest GCV (7.68). Heritability estimates were recorded highest for germination energy (99.90), followed by vigour index (97.90), 1000 seed weight (97.24), length of root (96.70), germination percent (96.10), germination speed (94.34), germination value (94.30), length of shoot (94.00), mean daily germination (73.89), while as peak value (72.71) recorded minimum heritability as compared to other characters. Genetic advance was recorded highest for vigour index (100.49), followed by 1000 seed weight (85.10), length of root (80.82), germination energy (65.39), germination value (51.85), length of shoot (51.49), germination speed (25.83), germination percent (23.87), whereas moderate genetic advance was recorded for mean daily germination (13.32) and peak value (12.82).

In experiment- II, cuttings of 8 inches length were prepared from different sections (upper, lower and middle) of branches collected from one available *Platanus orientalis* L. tree in January. Before planting in March, the cuttings were treated with varying concentrations of IBA in a quick dip method for 60 seconds. The experiment was laid in Completely Randomised Design (Factorial). In all, there were thirty nine treatment combinations comprising of twelve concentrations of IBA (1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000, 11000 and 12000ppm) and Control with three cutting sections (apical, middle and basal). In case of IBA concentrations, cuttings of *Platanus orientalis* L. treated with IBA@6000ppm yielded best results for all the growth parameters viz., sprouting (98.89%), rooting/survival (41.33%), root length (26.48 cm), average number of

roots per plant (8.56), shoot length (35.84 cm), number of branches per plant (2.67), leaf area (44.67 cm^2), collar diameter (6.45 mm), fresh and dry biomass of shoot (21.57 g) and (10.97 g) respectively, fresh and dry biomass of root (15.49 g) and (5.11 g) respectively and in case of cutting sections, basal cuttings proved to be superior as they recorded highest results for all the characters like rooting/survival (45.18%), root length (24.59 cm), average number of roots per plant (7.77), shoot length (33.32 cm), number of branches per plant (2.54), leaf area (39.04 cm^2), collar diameter (6.18 mm), fresh and dry biomass of shoot (21.67 g) and (7.96 g) respectively, fresh and dry biomass of root (14.14 g) and (4.67 g) respectively.

Key words: *Platanus orientalis* L., variability, stratification period, growth hormones, branch cuttings.

Signature of Student
Dated_____

Signature of Major Advisor
Dated _____

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All praises are to Allah, the Creator and Sustainer of the World and endless blessings of Allah be upon Mohammad^{SAW} the greatest benefactor of mankind

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Midhat Bilal

Place: Faculty of Forestry, Benhama, SKUAST-K
Dated: …….…….

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Chapter -1

INTRODUCTION

Platanaceae is a flowering plant family which belongs to the order of Proteales. Nearly all taxonomists have recognized this family, and it is often called the "plane-tree family". The family consists of only one single existent genus *Platanus* with eight recognized species (Christenhusz and Byng, 2016). All the members of *Platanus* are tall, reaching a height of 30.5 m (98-164 ft). All, except *Platanus kerri,* are deciduous and most are found in the wild in riparian or other wetland environments, though the cultivation appears to be drought-tolerant. They are also called planes or plane trees in English.

The literature reveals that the Platanaceae is a Northern Hemisphere feature since mid-Creraceous age (Pilloti *et al.,* 2009). Most diversity of the species and taxonomy is reported from North America and North Latin America where *P.occidentalis* L. is predominant. The London plane tree (*Platanus acerfolia* Willd), a crossbred of *Platanus orientalis* L. and *Platanus occidentalis* has many useful features: rapid vegetation, large crown, vast susceptibility, polluted atmosphere resistance and the ability to engulf damaging gases and metals (Kim and Lee, 1993). *Platanus acerfolia* is widely planted on roadsides or open areas in China and in the temperate, sub-tropical regions and cities in Europe to improve the ecosystem. However, during spring, the wide dispersal of pollen and seed hairs not only pollute the environment but also result in health hazard (Subizia *et al*., 1994; Varela *et al*., 1997). These drawbacks have seriously tarnished its good image (Walter, 1946; Matasci & Gessler, 1997).

Platanus orientalis L. is locally known as 'Chinar' or 'Boiun' in Kashmir. It is a deep-rooting plant with roots extending the crown area. Chinar tree normally gains a height of about 25 meters with girth exceeding 50 feet in some cases. The bark is grey-brown, flaking and scaly. Leaves are arranged alternately, deeply 3, 5 or 7 lobed, 12-20 cm in length, and palmate with long stalks. Petiole

lengths vary from 3 to 8 cm. Flowers are dense, unisexual spherical heads. Fruits are shaped like spheres, about 2 cm in width and are located on the leafstalk. The fruits still stay over on the trees late until the spring. The buds are large, green and protruding. The flowering begins during March-April. It grows in sunny places without continuous shade toleration. It is fit for soils such as sandy, loamy and clay and can tolerate pH from neutral to strongly alkaline. It prefers moist soil but can withstand drought, but not exposure to marine conditions. It can also withstand air-pollution. As per IUCN Red list, it is recognized as endangered in parts of its range due to the expansion of agriculture and irrigation schemes (Anonymous, 2008).

P.orientalis L. possibly resulted from accumulation of genetic changes during intercontinental disjunctions and other impediments in geological time (Sert *et al*., 2008; Pilotti *et al*., 2009). *P.orientalis* L. occurs naturally in almost every forest, streams and water basins of Turkey. It is commonly used in Turkey's landscape design and there are many reports of these trees being preserved as monumental trees (Zencirkiran, 2010; Zencirkiran and Erken, 2012). Differently, natural standings of *P. orientalis* L. are found in the Mediterranean region of Southern Europe and South-West Asia particularly in Iran and Turkey.

Chinar trees characteristically grow in Western Himalayas. They spread uniformly over an area of cool climate with enough water. Chinar trees were originally found only in Greece. With the passage of time, however, they entered Asia where the West Himalayan region of India was most favourable place for them to grow (Sharma, 2008).

Platanus orientalis L. is the only species of Platanaceae family found in India and its growth is confined to Jammu & Kashmir state (Kozgar and Khan, 2011). The notion that the Mughals brought Chinar trees into the state was denied by Wadoo (2007), according to whom there are many references to the presence of the tree in the state in the historical accounts.

The Chinar tree is living heritage of Kashmir. It is a majestic tree that can be found throughout the landscape of valley, hillsides and cities. Kashmir houses the largest and oldest Chinar in Asia, which is 700 years old, situated at Chattergam in Budgam district. The tree is 31.85 meters in girth at ground level and 14.78 meters high. Syed Qasim sahib planted the tree. This tree replaced previous largest one, located at Bijbehara, which had a width of 19.70 meters and height of 13.30 meters (Sharma, 2008).

In Kashmir, the Chinar tree is at its peak beauty and exuberance during autumn. Over time, the large hollow trunks of the trees were used for contemplation, and were thus considered sacred and usually planted in places of worship. It remained a significant garden and landscape tree throughout the Mughal period, and still dominates many historical gardens of the valley (Kozgar and Khan, 2011).

Chinar tree has a noteworthy cultural significance and is a common emblem of Kashmir heritage seen in various art and craft designs, embellishment of shawls, wood carving etc. As a very large, wide tree with broad, thick leaves that appear to be horizontally oriented, it is particularly appreciated for its shade and coolness it provides during the summer season. A paste made from the leaves and seeds is applied on eyes for treating ophthalmic disorder. Bark when boiled in vinegar acts as a cure for hernia, toothaches, dysentery and diarrhea. A fabric dye is manufactured from the branches and roots. The wood, called the lace wood, is used for making delicate furniture, ornamentally carved doors, fancy lacquered articles mallets, interior finish, for chopping and dressing of meat as well as fuel wood (Wadoo, 2007).

Given the government restrictions such as J & K Preservation of Specific Trees Act 1967, Land Revenue Act S36 and Chinar rules on the felling of Chinar trees in the valley in the past, the tree population has declined over the years, suffering much damage due to negligence and human greed. Chinar the ‘king of trees’ has been under the axe of smugglers. Their number decreased to more than

half, from 42000 in 1970 to less than 27000 in the valley (Kozgar and Khan, 2011). However, it is heartening to note that the authorities are making honest efforts to stop the unlawful felling of this majestic tree of Kashmir and declared 15th of March as "The Chinar Plantation Day". Chinars, once abundant, are gradually becoming a rare sight, and thus need immediate efforts for their conservation and propagation.

The literature scanned indicates that the propagation of chinar through seed is poor (seed germination is 30-40%), however, the seed sown after stratification shows better germination (Anonymous, 2003) and the vegetative propagation of the species is effected by various environmental factors and part of the part of the mother plant used for the propagation (Guoqiang *et al*., 2003).

As such realizing the immense economic and aesthetic importance of the species this study programme entitled **"Variability in germination parameters and effect of growth hormones on propagation of Chinar *(Platanus orientalis* L.) through branch cuttings"** has been undertaken to standardize its propagation through seed as well as cuttings under the following objectives:

1. To determine the variability in germination parameters of *Platanus orientalis* L. seed.
2. To standardize optimum concentration of growth hormones for rooting of *Platanus orientalis* L. cuttings.
3. To determine best section of branches for rooting of *Platanus orientalis* L. cuttings.

Chapter -2

REVIEW OF LITERATURE

The selection of any research problem and the methods of solving it are often based on the review of the available literature on that problem. It is a well-established fact that the relevant literature is checked and analysed in order to create a sound basis for framing research needs and to learn about the problem's explored and unexplored aspects. In this context, efforts were made to review the literature related to the current investigation entitled **"Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings"**. *Platanus orientalis* L. is the "Heritage Tree" and counted among one of the important trees of the Kashmir, but very few scientific studies on the propagation of this multipurpose tree species have been carried out. Since the literature relating to the *Platanus orientalis* L. was not adequate to illustrate the research findings of this investigation, the literature available from other species have been, therefore, taken into account. Attempts have been made to compile the available literature under the following specific headings:

2.1 Propagation through seeds

2.2 Propagation through cuttings

2.1 Propagation through seeds

Mass propagation through seeds is an effective and economical way of propagating plants. Seeds play a crucial role in establishment of new individuals and their expansion thus resulting in the establishment and founding of new population (Rees, 1996). However, the dormancy of the seed halts this process (Schmidt, 2000). There are several factors such as seed coat, embryo or inhibitors that result in the dormancy of seed which, in turn, influences the germination rate of the seed (Agrawal and Dadlani, 1995). Seed dormancy is a stage in which growth cessation occurs that, at its crucial stage, has problems maintaining a

growth potential without the cessation of its biological probity (Amen, 1968).This process often results in the failure of germination of seeds although the conditions for germination are apparently favourable (Rolston, 1978).

There are no set rules for classification of dormancy globally and has been classified in different ways. Dormancy on the basis of development has been divided in three groups: 1. Innate dormancy which results at the time of seed dispersal 2. Induced dormancy which evolves in response to environmental conditions and 3. Enforced dormancy which results because of external conditions (Harper, 1977). Seed that fails to germinate because of environmental stimulus are commonly called as inactive (Villiers, 1971), while innate and induced dormancies are referred as primary and secondary dormancies respectively.

The other way of classification in vogue involves the parts of seeds responsible for inducing dormancy as criteria. Embryo dormancy results because of under developed embryo or due to chemical inhibition of embryo collectively known as endogenous dormancy. Another form is seed coat dormancy, also known as exogenous dormancy, which may result due to mechanical resistance, impermeability and light sensitivity. Seed coat dormancy may involve endocarp or the whole pericarp.

The combination of two or more forms of dormancy in the same seed is referred as double dormancy or combined dormancy. This is mostly reported in fleshy fruits and results in combination with chemical inhibitors or may result by combination of immature embryo with other forms of dormancy.

The place and severity of dormancy can be experimentally discovered by removal and treatment of various sections of the fruit and seed. For example if dormant seeds germinate by removing their seed-coat, it can be inferred that the seed-coat is the site of dormancy.

2.1.1 Pre- sowing/ Pre-germination treatment

Pre-germination treatments are important to speed up the germination (William, 1985).There are many factors such as maturity of seeds and severity of drought which influences the dormancy so dormancy differs from species to species. Therefore, pre-treatment for breaking the dormancy should be modified taking these factors into the consideration (Amen, 1968; Rees, 1996). The purpose of any seed treatment is intended to achieve rapid and uniform seed germination (Azad *et al.,* 2006). Stratification, such as moist chilling or cold stratification is commonly employed to break the dormancy of several species (Wang and Berjak, 2000). Appropriate pre-sowing treatments may increase rate of germination and overall processes (Koirala *et al*., 2000; Alamgir and Hossain, 2005; Azad *et al.,* 2006).

2.1.2 Moist or cold stratification

The purpose of stratification is to meet out the requirements of embryo to initiate the germination and this process has been tried in several species (Karam and Al-Salem, 2001; Falleri, 2004; Gebre and Karam, 2004; Smiris *et al*., 2006). Stratification has been reported to enhance the activity of growth hormone gibberellic acid (GA) (Powell, 1987). With the progress of stratification the activity of abscisic acid (ABA), a dormancy hormone (Tillberg, 1983), diminishes and the activity of GA increases (Diaz and Martin, 1972).

GA speeds up the process of germination by releasing the hydrolytic enzymes (Mozer, 1980) and through mediation of cell plasticity (Taylor and Cosgrove, 1989). These changes through stratification result in the promotion of growth of embryo. ABA plays a critical role in the induction and maintenance of dormancy (Bewley, 1997; Kucera *et al*., 2005) while GA plays a role in releasing the dormancy and accelerating the germination (Nicolas *et al*., 1996). Therefore, the levels of GA and ABA determine the dormancy and germination of the seed. Stratification and low temperature significantly alters the activity of ABA and

GA, thereby promotes the germination (Frankland and Wareing, 1966; Rudnicki, 1969; Copeland and McDonald, 1985 and Le page-Degivry *et al*., 1997).

Amin and Shahsavar (2018) performed an experiment to study the impact of stratification on the germination of seeds of *Diospyros* lotus. The result showed that maximum germination was observed for stratification of 70 days.

Lu *et al.* (2016) after examining the performance and growth of seedlings and seed germination of native subtropical tree species in South China have recommended 17 species for forest restoration.

Kumar (2016) studied the impact of pre-sowing treatments on various parameters of growth and germination of *Terminalia bellirica* and found all pre-sowing treatments such as moist stratification, 24-hour water soaking, and 48-hour water soaking have a significant impact on growth attributes and production of biomass in *Terminalia bellirica.*

Parvin *et al*. (2015) conducted an experiment with the objective to find out the best treatment for breaking dormancy of Eastern black walnut where in the results showed that combination of chilling stratification and GA_3 proved to be effective in breaking the dormancy.

Fetouh and Hassan (2014) carried an investigation to study the impact of cold stratification on seed germination and seedling growth of *Magnolia grandiflora* L. In this experiment the seeds were subjected to 0, 30, 60, 90 and 120 days cold stratification at 5^{o}C. Length of root, number of lateral roots, length of shoot, vigour index, fresh weight of shoot and root and leaf area were measured at the end of the experiment. The results obtained clearly indicated germination parameters as well as seedling characteristics were improved by increasing cold stratification period. They observed that the most effective stratification period was 90 days followed by 120 days. They recommended that treatment of seeds with 90 or 120 days of cold stratification improved the germination and seedling growth parameters.

Pandey and Tamta (2013) after applying different treatments for germination of *Quercus serrata* and *Quercus semecarpifolia* reported that both stratification and scarification are successful in breaking dormancy in comparison to control.

Aboutalebi *et al*. (2012) conducted an experiment to determine the impact of various pre-treatments (control, 24 hours soaking in tap water, digested seeds, scarification with sulphuric acid for 30, 60 and 120 minutes, gravel sand and stratification for 1, 3 and 6 weeks) on the different parameters of seed germination of Wild Ziziphus (*Ziziphus spina-christi*). Based on the results, the highest and lowest percentages of germination were observed in 1 and 3 weeks of stratification respectively. They concluded that 3 week stratification at a temperature between 4-5^{o}C as the best treatment for improving seed germination characteristics of Ziziphus.

Merou *et al*. (2012) performed an investigation to see the impact of various treatments on germination of fresh *Carpinus orientalis* seeds. It was observed that the cold stratification for three months at 5°C proved to be adequate to release dormancy and allow germination of almost all viable seeds.

Vahdati *et al*. (2012) reported that stratification for 6-8 weeks succeeded in breaking the dormancy and to get good germination rate, percentage and to avoid dwarfing after treating five Persian walnut genotypes with stratification, chilling and heat treatment.

Pipinis *et al*. (2012) conducted an investigation to determine the impact of warm and cold stratification on the germination of seeds of *Carpinus betulus* and *Carpinus orientalis*. No germination was observed in both species, in seeds subjected to only warm or cold stratification for 1 or 2 months. The seeds that were given warm stratification for 1 or 2 months ahead of cold stratification germinated to higher ($P \leq 0.05$) percentages than those subjected to only cold

stratification. In contrast, in *C. orientalis* seeds the similar treatment resulted in a significant reduction ($P \leq 0.05$) in germination percentage.

Sillero *et al*. (2012) reported better growth performance, improvement in emergence, early vigorous progenies and germination of five cultivars of Olive after using three stratification treatments.

Zare *et al.* (2011) investigated the effect of various treatments on seed germination and dormancy breaking in *Ferula ass-foetida* L. and concluded that the combined treatments of chilling (4^oC) and duration of 30 and 60 days were most effective in breaking the dormancy of *Ferula assa- foetida* seeds.

Draghici and Abdrudan (2011) conducted a study to know the effect of different stratification methods on the germination of *Acer platanoides* seeds. Four stratifications were used: cold (3^oC), warm (20^oC), with and without sand-peat media. Highest germination (54.75%) was recorded when stratified at 3^oC.

Tylkoskwi (2010) found that the seeds of *Hippophae rhamnoides* do not germinate or germinate slowly at lower temperatures (3-20^oC), but stratification for 4-6 weeks at 3^oC resulted in increased germination rate upto 90-100% within 2-3 weeks.

Offiong *et al*. (2010) investigated impact of pre-treatments on *Tectona grandis* and concluded that pre-sowing can significantly influence the seedling height and leaf production.

Al-Absi (2010) carried out an experiment to study the impact of various pre-sowing treatments on dormancy in *Prunus mahaleb* L. seeds. He observed that stratification for 60 or more days along with GA_3 at 1000ppm resulted in better germination and reduced germination period.

Ghadikolaee *et al*. (2010) revealed that the cold stratification of walnut (*Juglans regia* L.) kernels showed germination up to 61.00%. They also revealed that metabolism of amino acids involved in germination works efficiently in low temperatures during stratification.

Mughal and Raja (2010) revealed that *Fraxinus floribunda* seed has intermediate physiological dormancy and the same can be overcome by cold stratification for a period of 4 weeks. After 4 weeks of stratification, the germination percent, germination value and mean germination time were 78.00%, 26.00 and 16.42 days respectively.

Ajiboye *et al.* (2009) studied the effect of pre-sowing treatments on germination in *Tamarindus indica, Prosopis africana, Parkia biglobossa and Albizzia lebbeck* and concluded that the five weeks cold storage treatments at $4^{o}C$ gave 80 percent germination in *Albizzia* and 70 percent in *Tamarindus.*

Malik *et al.* (2008) reported that the seeds of *Pinus gerardiana* are highly dormant when freshly harvested. To end dormancy, six stratification periods and four stratification temperatures were used to enhance the germination of the seeds. Treatment of seeds for 45 days in moist sand enhanced the germination behaviour of the species.

While performing an experiment on the impact of stratification on *Pterocarya fraxinifolia* seed germination, Cicek and Tilki (2008) concluded that five weeks of cold stratification was sufficient to optimize seed germination percent and rate.

Esen *et al.* (2007) reported that many angiosperms and gymnosperms showed better germination and seedling growth with stratification. Similar findings have been reported in *Solamun nigrum* by Suthar *et al*. (2009), *Prunus webii* and *Prunus scorparia* by Heidari *et al*. (2008).

Ghasemi and Khosh-khui (2007) investigated the impact of stratification on seed germination and seedling growth of *Quercus ilex* L. They stratified seeds for 0, 1, 2, 3 and 4 months. They found that stratification for 1 to 2 months at $5^{o}C$ resulted in better seed emergence and faster shoot growth.

Bhan and Sharma (2007) in an experiment on wild apricot reported that seed stratification resulted in significant germination (80.13%) compared to control (74.54%) in wild apricot (*Prunus armeniaca* L.).

Smiris *et al.* (2006), Falleri (2004) and Gebre and Karam (2004) reported that stratification was applied to several species viz., *Arbutus unedo* L., *Podocytisus caramanicus*, *Cornus sanguine*, *Cercissili quastrum*, *Arbutus rachne* L. in order to satisfy the requirements of embryo for the purpose of stimulating germination.

Rouhi (2006) has demonstrated that cold stratification plays a critical role in initiating germination. In his experiment, he observed significant variation with various stratification timings to induce germination in *Prunus scoporia.* He observed that cold treatment at 9-10^{o}C resulted in better germination percentage, physiological activities and seedling growth. He also noted that stratification (moist Chilling) at 7^{o}C without the inclusion of gibberellic acid showed better results compared to higher temperature of 22^{o}C. For commercial purposes, he recommended moist chilling in absence of gibberellic acid.

Koyuncu (2005) demonstrated the impact of cold stratification on black mulberry (*Morus nigra* L.). For 100 days of stratification, seeds showed 88 % germination. The study revealed that the cold stratification had a major impact on the germination of seeds in black mulberry (*Morus nigra* L.).

Hossain *et al*. (2005) demonstrated that pre-sowing treatment of *Terminalia chebula* seeds resulted in the improvement of shoot length, root length, collar diameter, leaf number, shoot, root and total seedling dry weight.

Romero *et al.,* (2005) revealed cold stratified for four weeks enhanced germination and germination rate in seeds of *Echinacea angustifolia, Echinacea purpurea, Echinacea palli*.

Dosmann *et al*. (2000) studied the effect of stratification on seed germination of *Ceridiphyllum japonicum* and *Ceridiphyllum magnificum* for 21

days at 25°C. The results showed that in both species, stratification was not required for germination but increased germination percentage (from 42.00% to 75.00% in case of *Ceridiphyllum japonicum* and from 12.00% to 24.00% in *Ceridiphyllum magnificum*.

Qaiser *et al.* (1997) subjected *Celtris australis* seeds to nine different pre-sowing treatments in order to enhance the germination and seedling growth. They concluded that maximal germination resulted after stratifying seeds for 1 month at 5±1°C.

Robison *et al.* (1997) performed studies on direct seeding of Black walnut which revealed that success is most dependent on adequate germination. They recommended that in addition to the intensive site preparation, weed control and possibly nitrogen fertilization, stratified or pre-germinated seed could lead to more successful plantings of *Juglans nigra*.

Williams (1971) and Von Althen (1971) while stratifying walnut seed under refrigeration and in outdoor pits to prepare nuts for spring planting concluded that the length of stratification is important with at least 60 days needed to allow germination.

Wang (1960) conducted a study to establish a suitable pre-treatment to test the germination of the grand fir- *Abies grandis* (Doughlas ex D.Don) Lindl seed. The findings revealed that stratification have a greater impact on the rate of germination of the species than on the germination capacity.

2.2 Propagation through cuttings

Vegetative propagation (also referred as vegetative reproduction) is an asexual reproductive process which results in the growth of new plant from the parent plant either at a fragment or on a specialised reproductive structure (Swingle, 1996). It is the most convenient, effective and economical way of growing superior stock of some valuable crops (Hartman *et al.,* 1993). The boon of vegetative propagation is well known for yielding true-to-type plants and

achieving early and fast flowering and fruiting of species (Venkateswarlu and Mukhopadhaya, 1999; Verma and Joshi, 2006). The merits of vegetative propagation are (a) no dependency on seed (b) rapid growth rate (c) true-to-type character and (d) abundant matching of clone site, promising increase in the production of wood volume (Ooyama and Toyoshima 1965; Fielding, 1969; Kleinschmit, 1985; Thatoi *et al*., 2000).

Vegetative propagation techniques have been used to mitigate and overcome the problems which hinder the multiplication of economically important tree species of the forest (Libby and Rauter, 1984). It provides a feasible substitute to the customary seedling dependant forestry (Hussey, 1986; Longman and Jenik, 1990; Ali and El-Tigani, 2003).

Shoot cuttings are an important means of vegetative propagation, providing a fast and easy tool for superior/ rare clonal replication. During this process a part of branch or leaf after obtaining from the parent plant is kept in favourable environment to induce the germination of root and shoot to produce a new plant. There are various records on the rooting behaviour of shoot cuttings in many forest tree species (Puri and Shamet, 1988; Hill and Libby, 1970; Sargento and Baker, 1978; Nanda and Kochhar, 1985).

The success of plants raised through stem cuttings depends on regeneration of roots by them.

Rooting potential of cuttings is regulated by optimization of several endogenous as well as exogenous factors (Zsuffa *et al*., 1977; Densmore and Zasada, 1978). The endogenous factors that influence the rooting potential of cuttings include maturity of the donor, cutting position, time of collection, pre-conditioning and size of the cutting etc (Nautiyal *et al*., 2007; Ramesh and Khurana, 2007). The exogenous factors that influence the rooting potential of cuttings include rooting medium, humidity, temperature, length of day period and the intensity of light together with other treatments. Hence, it can be said that the

potential of cuttings for rooting is influenced by a variety of factors that may function individually or in combination to determine the rooting potential of cuttings.

The other factors determining the success of rooting potential of cuttings are age of cuttings, selection of desired traits and the environment (Klass, 1984; Leaky *et al*., 1990; Ali and El-Tigani, 2003). The rooting potential of cuttings from woody trees has been reported to be influenced by lignifications in vascular tissues (Ali, 1986).

The energy requirement of cuttings to initiate rooting plays a crucial role in plant species (Went and Thimann, 1938). Several workers have demonstrated the need for balance between nutrition and auxin in different plant species (Nanda *et al*., 1970; Nanda, 1979). It has been documented that glucose, sucrose, fructose, ribose or sorbose can be given, but their effectiveness varies considerably (Nanda and Jain, 1972).

Many attempts have been made to promote the rooting potential of cuttings through different substances such as growth promoters, carbohydrates and many more (Doud and Carlson, 1972; Couvillon, 1988). Among different growth promoters IBA have proved its potential by promoting the root initiation and decreased plant mortality (Soni, 1970). Because of its efficacy in wide variety of plant species and its non-toxic behaviour, IBA has turned out to be the best root-promoting chemical (Sadhu, 1999). In many tree species, IBA has been documented as rooting promoter (Gurumurti and Bandari, 1988; Chandra and Verma, 1989; Pal, 1992; Nautiyal and Rawat, 1994). However, effectiveness varies with season, concentration, chemical nature and the mode of treatment (Nanda, 1979). Other factors such as treatment, duration, moisture tension and depth of dipping also influence rooting response of cuttings (Howard, 1972).

Age of the donor plant has a major impact on the rooting in various tree species (Hitchcock and Zimmerman, 1939; Pal, 1989). Many researchers have

recorded diminished regeneration of adventitious roots with advanced age in tree species (Thimann and Delisle, 1939).

Propagation using rooted cuttings has been the subject of considerable interest to researchers for a long time for commercially important species. The multiplication of plants with desirable traits by cuttings is an old practice followed since time immemorial. Since then considerable amount of literature dealing with different aspects of rooting has accumulated and revealed that rooting potential of plant species varies considerably (Fadl and Hartmann, 1967).

Rashied *et al.* (2018) reported that IBA treatment on rooting and seedling growth of G*inko biloba* L. with 3000ppm resulted in maximum sprouting (91.18%), rooting (74.77%), shoot length (21.07 cm) and collar diameter (5.93 mm).

Tomar and Kumar (2018) conducted an experiment to study propagation of *Ulmus wallichiana* from divergent sources of North India. Among all the germplasm collections and IBA concentrations, the maximum rooting was 41.30% recorded with 6000ppm IBA for Mukteshwar (Nainital) and with 7000ppm IBA for Munsyari (Pithoragarh) while the minimum rooting, excluding control, was 26.30 percent for Bijoriya (Bageshwar) at 4000ppm IBA. Without IBA, the rooting success was 0 to 2.50 percent.

Krishan-Kumar (2018) reported that treating mulberry stem cuttings (*Morus nigra*), with various treatments of IBA concentration (1000ppm & 2000ppm) resulted in maximum sprouting (7.11%), survival (71.11%), rooting (70.00%) and number of primary roots (10.77) with 2000ppm.

Uchoi *et al.* (2018) has documented that propagation in tea tree (*Melaleuca alternifolia* L.). Vegetative propagation done by using different types of cuttings with 1500ppm resulted in maximum sprouting (49.45%) and highest number of sprouts per cutting (8.78) in comparison to Control.

Pallavi *et al.* (2018) after conducting a research trial on the impact of different concentrations of IBA and NAA on rooting and growth of mulberry cuttings, observed maximum number of roots (20.97) and root length (22.12 cm) with 2000ppm IBA.

Gehlot (2017) performed an experiment for multiplication of *Azadirachta indica* through semi-hardwood cuttings under the influence of different auxin concentrations. Data revealed significant impact ($p \leq 0.5$) on different rooting parameters. He recorded 65.00% rooting with 3.00 number of sprouts, 32.38 number of roots with 5.77 cm root length and 4.92 number of leaves with 500ppm IBA treatment.

Zahra *et al*. (2017) reported that 4000mg/L among different concentrations of IBA (zero, 1000, 2000, 4000, 6000 mg/L) during different time periods resulted in highest number of rooting percentage and root length in *Magnolia soulangeana* in June.

Hussain *et al.* (2016) conducted experiment to visualise the effect of growth hormones IBA, IAA and NAA on rooting response of *Ulmus villosa* cuttings. The cuttings treated with IBA@2000ppm and IBA@1000ppm had a sprouting rate of 80.00% and 95.00%, followed by NAA@2000ppm with 65.00%, IAA@2000ppm with 60.00% and highest survival was recorded IBA@ 2000ppm and 1000ppm which showed 100% survival rate, followed by IAA@2000ppm 90.00%, NAA@2000ppm with 89.00%. Among all of these plant growth regulators IBA@2000ppm and IBA@1000 showed the best results.

Nasri *et al*. (2015) after conducting an experiment on rooting of 12 wild genotypes of (Kurdistan 1-12) of *Rosa damascene* Mill. with different concentrations of IBA reported 79.56% rooting, 69.08% callus formation, 361.80 g fresh and 244.74 g dry root weight in Kurdistan 5 with 1000mg /L IBA.

Dhiman and Gupta (2013) conducted a study to standardise the season and auxin concentration in *Wendlandia exserta*. Cuttings collected and planted in

spring exhibited better sprouting and rooting than those planted in rainy season. Non- apical cuttings produced better sprouting and root length in apical portion in the spring. The highest rooting was only 10.00%.

Sajad *et al*. (2014) revealed that in *Bauhinia purpurea* L., maximum rooting 87.50% was recorded in untreated cuttings (control) while, 65.00 percent in cuttings treated with IBA 2000ppm followed by 65.00 percent in IBA 4000ppm and IBA 6000ppm. The trend noted was Control >IBA 2000ppm >IBA 4000ppm > IBA 6000ppm. Moreover, maximum number of roots and root length were also recorded in untreated cuttings.

Mishra *et al*. (2010) reported that IBA (100ppm) treated cuttings of *Tinospora cardifolia* were found to be best for maximum plant length (364.73 cm) and number of branches (3.42) after 6 months of the transfer of plants in the field.

Akwatulira *et al.* (2011) reported that vegetative propagation of *Warburgia ugandensis* through stem cuttings can be appropriately achieved by treating the cuttings with 0.80% w/w IBA hormone using milled pine bark as a growth medium.

Qaisar *et al.* (2010) conducted experiment to see the effect of growth hormones IBA, IAA and NAA on rooting response of Branch cuttings of *Morus alba* var. gosherami. Different concentrations used were IBA, IAA and NAA with concentrations 100, 200, 300 & 400ppm respectively. Distilled water was used as control. IBA (100ppm), IAA (100ppm) and NAA (100 & 200ppm) resulted in maximum rooting of 93.33%. Maximum root length was observed in IBA (200ppm) as 127.30 cm, however, maximum number of roots (22.00) per cutting was recorded in NAA (100ppm)**.**

Khan and Qaiser (2009) conducted an experiment on vegetative propagation of *Morus alba* var. Kanva through branch cuttings. Under different concentrations of growth hormones, IBA 100, 200, 300 & 400ppm, IAA 100, 200, 300 & 400ppm and NAA 100, 200, 300 & 400ppm besides Control (distilled

water). Maximum rooting of 93.33% was recorded in IBA (100ppm) & IAA (100ppm) where as minimum rooting (20.00%) was recorded in Control (distilled water).

Gangoo *et al.* (2009) reported about the vegetative propagation of four timber yielding species of Kashmir with success rates of 62.13% rooting from stem cuttings of *Cedrus deodara* (Deodar) with IBA 4,000ppm+ NAA 4000ppm, 88.00% rooting from stem cuttings of *Pinus wallichiana* (Blue pine) with IBA 2000 + NAA 2000ppm, 85.00% rooting from stem cuttings of *Taxus baccata* (Yew) with IBA 2000ppm + NAA 3000ppm and 90.00% rooting from stem cuttings of *Cupressus torulosa* (Himalayan cypress) with IBA 3000ppm under intermittent mist conditions.

Amri *et al.* (2009) revealed that the cuttings treated with IBA produced higher rooting, root number and length as compared to untreated cuttings, which demonstrated the significant impact of IBA on the rooting ability of stem cuttings of *Dalbergia melanxylon.*

Majeed *et al.* (2009) reported about the vegetative propagation of *Aesculus indica* through stem cuttings treated with plant growth regulators and observed that the highest rooting rate (50.00%) was recorded in the cuttings with the application of IBA@4000ppm. The cuttings treated with IBA@2000ppm had 25.00% rooting rate. All other treatments along with control (talc powder) failed to induce rooting. Further, they recorded that IBA@4000ppm was a better-applied concentration for vegetative propagation of *Aesculus indica* under Kashmir conditions.

Purohit *et al.* (2009) studied rooting of stem cuttings of G*inkgo biloba* and reported maximum rooting of 50.00 percent in male cuttings at 500µM concentration of IBA. Further, they observed highest number of roots (7.50 per male cutting) in 500µM IBA while 5.00 roots per female cuttings in 100µM IBA treatment.

Madhwal *et al*. (2008) reported better rooting response 55.00% with 4000ppm IBA, 35.00% with 3000ppm IBA and IAA in juvenile shoot cuttings of *Terminalia chebula*.

Gangoo *et al.* (2007), in order to enhance rooting in hardwood cuttings of *Buxus wallichiana,* tested the efficacy of rooting hormone. The findings revealed that, compared to individual doses of 500 and 1000ppm, the mixture of IBA and NAA produced better rooting and also no positive impact on rooting percentage was noticed with increase in the sole doses of IBA and NAA.

Aslam *et al.* (2007) reported that out of three auxins: IAA, IBA and NAA, IBA 5000ppm worked best in rooting the cuttings of *Taxux baccata* (76.66%), whereas control produced a minimum rooting of 8.00% only. Lower concentrations (5000ppm) of all the three auxins were found to be better than their higher concentrations.

Singh (2007) reported maximum rooting (88.88%) in cuttings of *Taxus wallichiana* when treated with 500ppm IBA, while those treated with 1000ppm of IAA+IBA+ NAA reported minimum rooting percentage (22.22%) under field conditions.

Shahraji *et al*. (2007) during a study on *Ulmus glabra*, recorded that highest rooting success of 21.10 percent for hardwood and 71.00 percent for semi-hardwood cuttings with 8000ppm IBA and planted in mixed media.

Bhat *et al.* (2007) reported that vegetative propagation of *Ulmus wallichiana* by cuttings showed that the 200ppm of IBA is the best growth regulator to be used under existing conditions. However, softwood cuttings did not respond to the plant growth regulators treatment.

Luna and Kumar (2006) examined the effect of 1000, 2000 and 3000ppm of IBA, IAA and NAA on various parameters of juvenile shoot cuttings of *Melia composite* under mist conditions and reported that IBA 3000ppm gave best results in 45-50 days with 57.14% rooting, 3.92 roots per cutting and 4.31 cm root length.

Handa *et al*. (2005) conducted a study to standardize the vegetative propagation of *Albizia lebbek* species through stem cuttings and to study the biochemical changes occurring within the cuttings during different stages of rooting and its ultimate impact on rooting success of the species. IBA was found to be more successful in inducing rooting in this species than NAA and maximum rooting was produced by IBA 400ppm (71.66%).

Singh and Chander (2001) after conducting a study on performance of auxins on rooting behaviour of Neem cuttings stated root was absent in all types of branch cuttings under control conditions. Root emergence was observed in IBA treated softwood cuttings (500 and 1000ppm).

Rao *et al*. (1999) recorded that IBA 4000ppm increased rooting percentage in *Wrightia tinctoria* from 10.00 percent to 62.50 percent, which was more than six times the control.

Bhardwaj and Mishra (1998) reported significant improvements in rooting percentage, number, length and dry matter over control in Maple with application of IBA 5000ppm.

Palaniswamy and Kumar (1997) observed that 8000ppm IBA induced significant rooting in *Pongamia pinnata* during March whereas there was no rooting during July. This may be attributed to dormant period of cambium or low level of endogenous auxins or absence of auxin synergists.

Shinde (1996) reported that hard wood cuttings obtained from wounded pomegranate after treatment with 3000 and 4500ppm showed better rooting and survival of 83.33% and 86.77% respectively.

Badola *et al*. (1993) documented that *Perilla frutescens* after treatment with IBA 1000ppm induced 100% rooting in leafy cuttings compared to 80.00% in control, while as 1000ppm IBA recorded 52.00% rooting in non-leafy shoot cuttings against 40.00% to control.

Kanwar *et al.* (1996) tested one year old branches of twenty five year old trees under nursery conditions, under the effect of auxin, season and cuttings position for rooting potential of *Ulmus lavigata*. Maximum rooting (63.30%) was recorded when cuttings prepared from basal portions were treated with 1.5% IBA formulation during winter (February). In the rainy season best rooting was achieved when cuttings from basal portions were treated with 0.50% NAA + 1.00% IBA. In rooting characteristics (except mean root length), basal portions in winter and the rainy season were quite effective in enhancing the root quality.

Surendran (1990) documented in G*melia arbora* 60.00% rooting was recorded by exogenous application of IBA 1000ppm, followed by 53.30% in Seradix compared to control (26.70%).

Panda and Das (1990) reported highest rooting percentage, root length and number of roots per cutting after dipping hard wood cuttings of pomegranate in 5000ppm of IBA.

Mukhopadhyay and Jain (1983) reported that for *Eugeni formosa* 5000ppm IBA proved to be a better treatment while for *Sterculia alata* var. Diversifolia 10000ppm was the most successful treatment for root cuttings.

Verma *et al.* (1966) studied the influence of IBA and NAA on rooting of *Azadirachta indica*. Treatments used were 100, 500 and 1000ppm. Findings revealed that all the treatments of IBA and NAA stimulated rooting and sprouting, while control cuttings neither rooted nor sprouted. The 100ppm dosage worked best for both IBA and NAA, but IBA was more effective than NAA at all dosages.

Chapter-3

MATERIALS AND METHODS

The present study entitled "Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings" was conducted in the experimental field of Division of Forest Biology and Tree Improvement, Faculty of Forestry, Benhama during the years 2018 and 2019. A comprehensive description of the experimental details is listed below

3.1 Experimental sites

3.2 Methodology adopted and observations recorded

3.3 Statistical analysis

3.1 Experimental sites

3.1.1 Location and physiography

The Kashmir Valley is located in India's north western extremity, between 33^{o}North latitude and 75^{o} East longitude. The valley is situated in the country's northern latitude, occupying nearly central position on the Asian continent. The average altitude of valley ranges from 1,500 to 2,300 m from mean sea level. Kashmir's geographical expanse is 15, 948.00 sq km (excluding the part under Pakistan).

The experimental field where study was conducted is located at 34°16' 4" North and 74^{o}46' 31" East longitude on the southern aspect. The study area is situated above mean sea level at an elevation of 1,783 m (5850 feet). The area is hilly, has ups and downs and visible elevations and lowered topography and a slope in the direction of south-eastern aspect.

3.1.2 Climate

The climate in the Kashmir valley is temperate with four clearly established seasons: a harsh winter (December to February), a pleasant spring (March to May), a moderate summer (June to August) and a nice fall (September to November). The average precipitation is 690 mm, much of which is obtained in the form of rain and snow, during December to April. The temperature ranges between -8^{o}C in winters to an average summer temperature of 33^{o}C.

3.2 Methodology adopted and observations recorded

3.2.1 Objective number 1 "To determine the variability in germination parameters of *Platanus orientalis* L. seed" was fulfilled by conducting following experiment

3.2.1.1 Selection of trees for seed collection

Ten phenotypically superior trees located in the District Ganderbal of the valley were selected randomly and used for collection of seeds. The seeds were collected manually from their mother trees during the month of January.

3.2.1.2 Pre-sowing treatment

Cold stratification treatment: After collection seeds were given a moist chilling treatment by keeping in a wet muslin cloth bag at 0 to 4±1^{o}C for different time periods of 10 days, 20 days, 30 days, 40 days, 50 days and 60 days.

Stratification:

P_0	**:**	Control (no stratification)
P_1	**:**	10 days
P_2	**:**	20 days
P_3	**:**	30 days
P_4	**:**	40 days
P_5	**:**	50 days
P_6	**:**	60 days

No. of replications : 03

Design : Completely Randomized Design (Factorial)

3.2.1.3 Preparation of growing media

Potting mixture

Sieved soil, sand and FYM were used as a medium of growth. The trays were filled with potting media which included the mixture of sand, soil and FYM in the ratio of 1:2:1.The treated seeds were sown on 26th of March, 2019 simultaneously in these trays in three replicates per chilling treatment per tree in polyhouse and the design followed was the CRD (Factorial) with ten treatments (10 trees). Daily observation of germination was taken until no further germination could be observed for about a week and the following parameters were recorded.

Tree characters

1. Tree height (m)

The height of ten selected trees was measured with the help of Clinometer and recorded in meters**.**

2. Tree DBH (m)

The diameter at breast height (1.37 m) was measured for ten selected trees using a diameter tape and recorded in meters.

Seed and germination characters

3. 1000 seed weight (g)

One thousand seeds were selected randomly in three replicates and weighed to get the mean weight in each tree as per the guidelines of International Rules for Seed Testing (ISTA, 1966).

4. Germination percent (%)

Germination percent is the total number of seeds that germinate from a sample expressed as percentage. Germination percent was calculated after 28 days of sowing as per the guidelines of international Rules for Seed Testing (ISTA, 1966). For the present study, the number of seeds sown for each treatment was 300. Total germination was calculated for different treatments using the formula suggested by Bonner (1983).

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

5. Germination energy (GE)

It is the percent, by number, of seeds that germinated upto the peak of germination and was determined by the formula of Williams (1985).

$$\text{Germination energy} = \frac{\textit{Seeds germinated upto peak germination}}{\textit{Number of seeds sown in all replications}} \times 100$$

6. Mean daily germination (MDG)

Mean daily germination was computed by the following formula given by Czabator (1962).

$$\text{MDG} = \frac{\textit{Cumulative percent of seed germinated at the end of test}}{\textit{Days since sowing to the end of test}}$$

7. Peak value (PV)

Peak value is defined as the maximum mean daily germination reached at any time during the period. It was calculated using the formula given by Czabator (1962).

$$\text{Peak Value} = \frac{\textit{Cumulative germination percent}}{\textit{Days since sowing}}$$

8. Germination value (GV)

It is the combined measurement of speed and declined point of germination represented by a single figure and was determined by the formula provided by Czabator (1962).

Germination value = final MDG ×PV

Where,

MDG = Mean daily germination

PV= Peak value**.**

9. Germination speed (GS)

Germination speed expresses the rate of germination in terms of the total number of seeds that germinate in a time interval. It was computed using the following formula given by Allan *et al.,* (1962).

$$GS = \sum_{i=1}^{n} (n/t)$$

Where,

n = number of newly germinated seeds at time t

t = number of days since sowing

10. Vigour index

It reflects the health of the seedling produced. It takes into account the germination percent and the total length of seedling. It was calculated by the procedure given by Abdul Baki and Anderson (1973).

Vigour index (VI) = Germination percent × Total mean seedling length

Seedling growth characteristics

11. Length of shoot (cm)

It was calculated from the collar region to the tip of shoot and was measured for three randomly selected seedlings from each replication for each treatment using a measuring scale at the end of growing season in October.

12. Length of root (cm)

It was calculated from the cut base to the tip of taproot with the help of a measuring scale. Three seedlings were randomly selected in each replication for each treatment on a final count after 7 months and were measured.

Genetic parameters

13. Phenotypic coefficient of variation (PCV)

Phenotypic variance is the total variance observed in a character partly attributable to genotypic variance and partly to environmental effect and was computed through PCV by the formula provided by Johnson *et al*. (1955).

$$PCV = \sqrt{\sigma^2 p / x} \times 100$$

Where,

$\sigma^2 p$ = Phenotypic variance

x = General mean

14. Genotypic coefficient of variation (GCV)

Genotypic variance is the magnitude of phenotypic variance for a given trait in a population attributable to differences in genotype among individuals and was determined by GCV as per the formula of Jhonson *et al*. (1955)

$$GCV = \sqrt{\sigma^2 g / x} \times 100$$

Where,

$\sigma^2 g$ = Genotypic variance

x= General mean

15. Heritability (Broad sense, H^2)

Broad sense heritability is defined as the proportion of trait variance that is due to all the genetic factors including dominance and gene- gene interactions. Broad sense heritability of all traits was calculated using the following formula given by Burton and Devane (1953).

$$H^2 = [(\sigma^2 g)/ (\sigma^2 p)] \times 100$$

Where,

H^2 = Heritability in broad sense

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

16. Genetic advance (GA)

Improvement in the mean genotypic value of selected plants over the parental population is called genetic advance. Genetic advance was determined by the following formula given by Jhonson *et al*. (1955).

$$GA = K. \sqrt{\sigma^2 p} . H^2$$

Where,

K= Selection differential (K= 2.06 at 5% selection intensity)

$\sqrt{\sigma^2 p}$ = Phenotypic variance

H^2 = Heritability in broad sense

Analysis of all the genetic parameters was done using the software Window Stat.

3.2.2 Objective 2nd "To standardize optimum concentration of growth hormones for rooting of *Platanus orientalis* L. cuttings" and 3rd "To determine best section of branches for rooting of Platanus orientalis L. cuttings" was fulfilled by conducting following experiment:

3.2.2.1 Collection and preparation of cuttings

The cuttings were collected from different sections (upper, lower and middle) of branches from one available *Platanus orientalis* L. tree located in the vicinity of the campus on 28th of January, 2019. The collected cuttings were dumped in soil till planting on 14th of March, 2019.

The cuttings, from each section possessing minimum 2-3 nodes and 15-20 cm long were made. A horizontal cut at the base and a slant cut at the top with the help of a scateur was given to each cutting.

3.2.2.2 Preparation of rooting hormone IBA

A known amount of IBA was dissolved in 10-15 ml of alcohol with constant stirring by a glass rod to prevent precipitation and homogenous solution was made. To this distilled water was added to achieve the stock solution of desired concentration (12000ppm). From stock solution working solution was obtained by adding distilled water. Each time, cuttings were treated with fresh working solutions.

3.2.2.3 Application of rooting hormone

The cuttings after receiving horizontal cut beneath the bud at the basal end and a slanting cut above the bud towards apical side were bundled. Before planting, a quick dip method for each set of cutting was given IBA formulations for 60 seconds from the basal end.

3.2.2.4 Planting operation

The cuttings were planted 6-8 cm deep. The soil mixture surrounding the cuttings was smoothly pressed to keep them firm but not tight, in order to provide

proper aeration to root area. Cuttings were irrigated twice in a day, in the morning and in the evening, daily. Weeding was done as and when needed. The details of the treatment are given below:

Treatments	IBA Concentrations
I_0	**Control**
I_1	**1000ppm**
I_2	**2000ppm**
I_3	**3000ppm**
I_4	**4000ppm**
I_5	**5000ppm**
I_6	**6000ppm**
I_7	**7000ppm**
I_8	**8000ppm**
I_9	**9000ppm**
I_{10}	**10000ppm**
I_{11}	**11000ppm**
I_{12}	**12000ppm**

Section of Cutting

S_1	Apical (tip) Section
S_2	Middle Section
S_3	Basal section

Treatment Combinations

T_1	:	S_1I_0	T_{14}	:	S_2I_0	T_{27}	:	S_3I_0
T_2	:	S_1I_1	T_{15}	:	S_2I_1	T_{28}	:	S_3I_1
T_3	:	S_1I_2	T_{16}	:	S_2I_2	T_{29}	:	S_3I_2
T_4	:	S_1I_3	T_{17}	:	S_2I_3	T_{30}	:	S_3I_3
T_5	:	S_1I_4	T_{18}	:	S_2I_4	T_{31}	:	S_3I_4
T_6	:	S_1I_5	T_{19}	:	S_2I_5	T_{32}	:	S_3I_5
T_7	:	S_1I_6	T_{20}	:	S_2I_6	T_{33}	:	S_3I_6
T_8	:	S_1I_7	T_{21}	:	S_2I_7	T_{34}	:	S_3I_7
T_9	:	S_1I_8	T_{22}	:	S_2I_8	T_{35}	:	S_3I_8
T_{10}	:	S_1I_9	T_{23}	:	S_2I_9	T_{36}	:	S_3I_9
T_{11}	:	S_1I_{10}	T_{24}	:	S_2I_{10}	T_{37}	:	S_3I_{10}
T_{12}	:	S_1I_{11}	T_{25}	:	S_2I_{11}	T_{38}	:	S_3I_{11}
T_{13}	:	S_1I_{12}	T_{26}	:	S_2I_{12}	T_{39}	:	S_3I_{12}

No. of cuttings/treatment : 10

No. of replications **:** 03

Design **:** Completely Randomized Design (Factorial)

Observations Recorded:

1. Sprouting percent

The number of cuttings sprouted under each treatment was counted and the sprouting percent was worked out.

2. Rooting/ survival percent

The number of cuttings in each treatment that survived up to uprooting of cuttings was expressed as rooting/survival percent after counting.

3. Root length (cm)

It was calculated at the end of growing season, for the longest root arising from the cutting base and was measured for three randomly selected cuttings from each replication within each treatment using a measuring scale.

4. Average number of roots per plant

To expose the region, the basal portion of cutting was gently washed. The roots which emerged directly from the base and were ≥ 1mm were then counted for three cuttings from each replication within each treatment and their average number per treatment was tabulated.

5. Shoot length (cm)

It was calculated at the end of growing season, from the cut base to the tip of shoot and was measured for three randomly selected cuttings from each replication for each treatment using a measuring scale.

6. Average number of branches per plant

The three cuttings from each replication within each treatment were selected for counting and average number of branches per treatment was tabulated.

7. Leaf area (cm^2)

Three leaves were taken randomly from each primary branch separately for each replication within each treatment and calculated as cm^2 with leaf area meter (Portable leaf area meter model C-1-203).

8. Collar diameter (mm)

It was measured for three randomly selected rooted cuttings from each replication within each treatment, at the end of growing season, with the help of digital calliper and expressed in millimetre.

9. Fresh shoot biomass (g)

It was measured for three randomly selected cuttings from each replication within each treatment using digital weighing pan and expressed in gram.

10. Dry shoot biomass (g)

It was assayed for three cuttings from each replication within each treatment after drying in an oven at 60^{o}C for 24 hours and mean value was calculated for each treatment.

11. Fresh root biomass (g)

It assayed for three randomly selected rooted cuttings from each replication within each treatment using a digital weighing pan and then treatment average was calculated.

12. Dry root biomass (g)

It was assayed for three cuttings from each replication within each treatment after drying them in an oven at 60^{o}C for 24 hours and after that mean value for each treatment was calculated.

3.4 Statistical analysis

The whole data was subjected to statistical analysis using Completely Randomised Design for propagation by seeds as well as for propagation by cuttings. For each parameter, Statistical analysis was performed on mean values using the software OP-STAT.

Chapter- 4

EXPERIMENTAL FINDINGS

The present investigation entitled "Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings" was carried out at the experimental field of Division of Forest Biology and Tree Improvement, Faculty of Forestry, Benhama during the years 2018 and 2019. The results obtained from the present investigation have been presented objective wise in this chapter**.** The objectives were:

4.1 To determine the variability in germination parameters of *Platanus orientalis* L. seed.

4.2 To standardize optimum concentration of growth hormones for rooting of *Platanus orientalis* L. cuttings.

4.3 To determine best section of branches for rooting of *Platanus orientalis L.* cuttings.

4.1 To determine the variability in germination parameters of *Platanus orientalis* L. seed.

The results of the parameters which were recorded in order to fulfil this objective are presented as:

4.1.1 Tree height, DBH and 1000 seed weight

Table-1 represents the tree height (m), DBH (m) and 1000 seed weight (g) of the selected ten *Platanus orientalis* L. trees. The tree height ranged from 16 m to 30 m. Height was recorded maximum (30 m) for the tree (T_5) located at Tulmulla, followed by (28 m) for the tree (T_7) located at Lar, while as minimum height (16 m) was recorded for the tree (T_2) located at Duderhama. DBH was also recorded maximum (4.99 m) for the tree (T_5) of Tulmulla, followed by (4.27 m) for the tree (T_7) present in Lar, whereas the minimum DBH (2.28 m) was recorded for the tree (T_2) located in Duderhama**.**

Average seed weight for 1000 seeds was recorded maximum (5.51 g) for the seeds collected from the tree (T_5) located at Tulmulla, followed by (4.65 g) for the tree (T_7) of Lar, while the average seed weight was recorded minimum (4.07 g) for the seeds collected from the tree (T_2) located at Duderhama, which was stastically at par with (4.17 g) recorded for the tree (T_1) located at Harran.

Table1: Height, DBH and average seed weight of ten different *Platanus orientalis* L. trees

Trees	Tree height (m)	DBH (m)	Average seed weight (g)
T_1	20.00	2.88	4.17
T_2	16.00	2.28	4.07
T_3	20.50	3.65	4.24
T_4	25.00	3.98	4.41
T_5	30.00	4.99	5.51
T_6	27.00	4.08	4.62
T_7	28.00	4.27	4.65
T_8	21.00	3.65	4.31
T_9	23.00	3.79	4.39
T_{10}	18.00	2.57	4.11

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla, T_6:Saloora, T_7:Lar, T_8:Gadoor, T_9:Sehpora, T_{10}:Arch

C.D. (P≤0.05): 0.12 (For seed weight).

4.1.2 Germination percent

The data regarding the germination percent of *Platanus orientalis* L. seeds is presented in table-2.

4.1.2.1 Effect of stratification period

It is evident from the data presented in table-2 that stratification period had a significant impact on seed germination. Stratification for a period of 60 days (P_6) reported significantly maximum seed germination (73.07%), followed by (67.46%) for a stratification period of 50 days (P_5). Minimum seed germination (34.63%) was reported in Control (P_0), followed by (46.07%) for a stratification period of 10 days (P_{10}).

4.1.2.2 Effect of tree

From table-2, it is evident that the seeds collected from tree (T_5) located at Tulmulla recorded maximum germination (61.35%). This was followed by (59.37%) for the seeds collected from the tree (T_7) located at Lar, which was stastically at par with (58.57%) recorded for the seeds collected from the tree (T_6) located at Saloora. Minimum germination (51.43%) was recorded in seeds collected from the tree (T_2) located at Duderhama.

4.1.2.3 Interaction effects of stratification period and trees

Interaction effects of stratification period and trees was significant. Maximum (78.28%) germination was recorded in P_6T_5 (Stratification for 60 days $\times$ T_5) and the minimum (30.00%) germination was recorded in P_0T_2 (Control $\times$ T_2).

4.1.3 Germination energy

The results recorded for germination energy are shown in table-3.

4.1.3.1 Effect of stratification period

The data presented in table-3 clearly indicates that maximum germination energy (29.60) was recorded in seeds stratified for 60 days (P_6), followed by (27.37) for the seeds stratified for 50 days (P_5). Minimum germination energy (14.77) was recorded in Control (P_0), followed by (18.50) for seeds stratified for 10 days (P_1).

4.1.3.2 Effect of tree

As evident from table-3, seeds collected from the tree (T_5) located at Tulmulla recorded the maximum germination energy (32.19), followed by (28.90) for the seeds collected from the tree (T_7) located at Lar, while the minimum germination energy (15.43) was observed in seeds collected from the tree (T_2) located at Duderhama.

4.1.3.3 Interaction effects of stratification period and trees

Interaction effects of stratification period and trees was found to be significant. Maximum germination energy (41.00) was recorded in P_6T_5 (Stratification for 60 days × T_5) and the minimum (4.67) was recorded in P_0T_2 (Control × T_2).

4.1.4 Mean daily germination (MDG)

The data regarding the mean daily germination of *Platanus orientalis* L. seeds is presented in table-4.

4.1.4.1 Effect of stratification period

As evident from the data presented in table-4, stratification for a period of 60 days (P_6) recorded the maximum mean daily germination (2.85), followed by (2.61) for a stratification period of 50 days (P_5), while the minimum (0.73) was observed in Control (P_0).

4.1.4.2 Effect of tree

As evident from table-4, seeds collected from the tree (T_5) located at Tulmulla recorded the maximum mean daily germination (2.43), followed by (2.23) for the seeds collected from the tree (T_7) located at Lar while the minimum (1.59) was recorded for the seeds collected from the tree (T_2) located at Duderhama.

4.1.4.3 Interaction effects of stratification period and trees

Interaction effects of stratification period and trees was found to be significant. Maximum mean daily germination (3.73) was recorded in P_6T_5 (Stratification for 60 days × T_5) and the minimum mean daily germination (0.63) was recorded in P_0T_2 (Control × T_2).

4.1.5 Peak value (PV)

The analysed data for peak value is presented in table-5.

4.1.5.1 Effect of stratification period

As evident from the data in table-5, maximum peak value (4.03) was recorded for seeds stratified for a period of 60 days (P_6), followed by (2.93) for the seeds stratified for 50 days (P_5) while the minimum (0.95) was observed in Control (P_0).

4.1.5.2 Effect of tree

As clearly evident from table-5, maximum peak value (3.21) was recorded for the seeds collected from tree (T_5) located at Tulmulla, followed by (2.92) for the seeds collected from tree (T_7) located at Lar, while the minimum peak value (1.83) was observed for seeds collected from tree (T_2) located at Duderhama.

4.1.5.3 Interaction effects of stratification period and trees

Interaction effects of stratification period and trees was found to be significant. Maximum peak value (6.33) was recorded in P_6T_5 (Stratification for 60 days × T_5) and the minimum peak value (0.84) was recorded in P_0T_2 (Control × T_2).

Table 2: Effect of different stratification periods and trees on germination percent of *Platanus orientalis* L. seeds

Trees / Stratification period	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Mean
P_0 (Control)	31.67 (34.22)	30.00 (33.11)	33.33 (35.24)	36.00 (36.85)	40.00 (39.21)	37.33 (37.64)	38.67 (38.43)	34.00 (35.65)	34.33 (35.84)	31.00 (33.81)	34.63 (36.01)
P_1 (10 days)	43.00 (40.96)	42.00 (40.38)	44.33 (41.73)	47.00 (43.26)	50.67 (45.36)	49.33 (44.60)	50.00 (44.99)	45.33 (42.30)	46.67 (43.07)	42.33 (40.57)	46.07 (42.72)
P_2 (20 days)	49.67 (44.79)	47.33 (43.45)	50.33 (45.17)	53.67 (47.09)	56.33 (48.63)	54.33 (47.47)	54.67 (47.66)	51.33 (45.75)	51.67 (45.94)	47.67 (43.64)	51.70 (45.96)
P_3 (30 days)	54.00 (47.28)	52.67 (46.51)	56.33 (48.62)	58.00 (49.59)	63.67 (52.92)	59.67 (50.56)	60.00 (50.76)	56.67 (48.82)	57.33 (49.20)	53.33 (46.90)	57.17 (49.11)
P_4 (40 days)	60.33 (50.95)	57.33 (49.20)	60.67 (51.14)	63.00 (52.52)	68.67 (55.96)	63.33 (52.72)	65.57 (54.12)	61.33 (51.53)	62.33 (52.13)	58.67 (49.98)	62.12 (52.03)
P_5 (50 days)	65.16 (53.93)	63.67 (52.98)	65.33 (53.91)	69.33 (56.36)	71.83 (58.06)	69.67 (56.56)	70.00 (56.77)	66.67 (54.73)	68.00 (55.54)	64.95 (53.73)	67.46 (55.25)
P6 (60 days)	70.37 (57.02)	67.00 (54.93)	71.67 (57.84)	75.33 (60.22)	78.28 (62.24)	76.33 (60.89)	76.67 (61.10)	72.33 (58.26)	74.33 (59.56)	68.33 (55.78)	73.07 (58.78)
Mean	53.46 (47.02)	51.43 (45.80)	54.57 (47.66)	57.48 (49.41)	61.35 (51.77)	58.57 (50.06)	59.37 (50.55)	55.38 (48.15)	56.38 (48.75)	52.33 (46.34)	

Figures in parenthesis are sine transformed values

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla,T_6:Saloora, T_7:Lar, T_8:Gadoora, T_9:Sehpora, T_{10}:Arch

C.D. ($P \leq 0.05$)

Tree (T) : 0.95
Stratification (S) : 0.79
T×S : 1.03

Table 3: Effect of different stratification periods and trees on germination energy of *Platanus orientalis* L. seeds

Trees / Stratification period	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Mean
P_0 (Control)	6.33	4.67	7.67	9.67	25.00	20.67	21.67	17.67	19.00	15.33	14.77
P_1 (10 days)	15.67	14.33	16.33	19.33	25.00	20.67	21.67	17.67	19.00	15.33	18.50
P_2 (20 days)	17.67	15.67	20.00	24.67	28.67	25.33	25.67	21.00	22.33	17.00	21.80
P_3 (30 days)	18.33	16.67	20.67	25.33	32.33	27.67	28.33	21.33	23.67	17.67	23.20
P_4 (40 days)	18.67	17.33	21.33	27.00	35.67	29.33	31.33	22.67	25.33	18.00	24.67
P_5 (50 days)	23.67	18.67	24.33	28.33	37.67	32.67	34.33	25.33	26.67	22.00	27.37
P_6 (60 days)	24.33	20.67	25.00	30.67	41.00	37.00	39.33	26.00	28.33	23.67	29.60
Mean	17.81	15.43	19.33	23.57	32.19	27.62	28.90	21.67	23.48	18.43	

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla,T_6:Saloora, T_7:Lar, T_8:Gadoora, T_9:Sehpora, T_{10}:Arch

C.D. ($P \leq 0.05$)

Tree (T) : 0.14
Stratification (S) : 0.11
T×S : 0.36

Table 4: Effect of different stratification periods and trees on mean daily germination of *Platanus orientalis* L. seeds

Trees / Stratification period	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Mean
P_0 (Control)	0.66	0.63	0.71	0.76	0.86	0.81	0.81	0.71	0.72	0.65	0.73
P_1 (10 days)	1.04	1.02	1.13	1.18	1.69	1.23	1.21	1.13	1.17	1.02	1.18
P_2 (20 days)	1.35	1.21	1.49	1.79	1.88	1.81	1.82	1.48	1.78	1.34	1.60
P_3 (30 days)	1.66	1.57	1.69	2.07	2.12	2.06	2.14	1.71	1.95	1.54	1.85
P_4 (40 days)	2.05	2.05	2.17	2.42	3.27	2.75	2.98	2.10	2.23	2.02	2.40
P_5 (50 days)	2.26	2.27	2.33	2.67	3.43	3.03	3.18	2.38	2.34	2.24	2.61
P_6 (60 days)	2.44	2.39	2.47	2.90	3.73	3.32	3.48	2.58	2.75	2.44	2.85
Mean	1.64	1.59	1.71	1.97	2.43	2.14	2.23	1.73	1.85	1.61	

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla,T_6:Saloora, T_7:Lar, T_8:Gadoora, T_9:Sehpora, T_{10}:Arch

C.D. ($P \leq 0.05$)

Tree (T) : 0.02
Stratification (S) : 0.02
T×S : 0.06

Table 5: Effect of different stratification periods and trees on peak value of *Platanus orientalis* L. seeds

Trees / Stratification period	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Mean
P_0 (Control)	0.88	0.84	0.93	1.00	1.06	1.03	1.03	0.94	0.95	0.85	0.95
P_1 (10 days)	1.28	1.23	1.44	1.55	2.23	1.68	1.71	1.48	1.54	1.22	1.54
P_2 (20 days)	1.55	1.35	1.70	2.22	2.53	2.25	2.27	2.02	2.12	1.50	1.95
P_3 (30 days)	1.93	1.83	2.02	2.44	2.82	2.54	2.58	2.06	2.24	1.88	2.23
P_4 (40 days)	2.41	2.29	2.39	2.70	3.65	3.11	3.24	2.38	2.60	2.33	2.71
P_5 (50 days)	2.63	2.50	2.67	2.95	3.81	3.23	3.45	2.73	2.74	2.60	2.93
P_6 (60 days)	2.91	2.78	2.98	4.45	6.33	4.85	6.15	3.04	4.02	2.80	4.03
Mean	1.94	1.83	2.02	2.47	3.21	2.67	2.92	2.09	2.32	1.88	

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla,T_6:Saloora, T_7:Lar, T_8:Gadoora, T_9:Sehpora, T_{10}:Arch

C.D. ($P \leq 0.05$)

Tree (T) : 0.03
Stratification (S) : 0.03
T×S : 0.68

4.1.6 Germination value

Table-6 represents the data pertaining to the germination value of *Platanus orientalis* L. seeds.

4.1.6.1 Effect of stratification period

The data in table-6 clearly indicates that stratification period of 60 days (P_6) resulted in maximum germination value (12.08), followed by (7.83) for the stratification period of 50 days (P_5), while the minimum germination value (0.70) was recorded in Control (P_0), followed by (1.95) for the stratification period of 10 days (P_{10}).

4.1.6.2 Effect of tree

As it is obvious from the table-6 that seeds collected from the tree (T_5) located at Tulmulla recorded the maximum germination value (9.15), followed by (7.95) for the tree (T_7) located at Lar (T_7), while the minimum (3.20) was recorded for the tree (T_2) located at Duderhama. This was stastically at par with (3.37) recorded for the seeds collected from tree (T_{10}) located at Arch.

4.1.6.3 Interaction effects of stratification period and trees

Interaction effects of stratification period and trees was found to be significant. Maximum germination value (23.62) was recorded in P_6T_5 (Stratification for 60 days × T_5) and the minimum germination value (0.53) was recorded in P_0T_2 (Control × T_2).

4.1.7 Germination speed (GS)

Analysed data regarding the germination speed is presented in table-7.

4.1.7.1 Effect of stratification period

The data in table-7 clearly indicates that maximum germination speed (18.90) was recorded when seeds were stratified for a period of 60 days (P_6), followed by (15.13) for the stratification period of 50 days (P_5), while the

minimum germination speed (6.66) was recorded in Control (P_0), followed by (9.43) for the stratification period of 10 days (P_1).

4.1.7.2 Effect of tree

As it is obvious from the table-7 that seeds collected from the tree (T_5) located at Tulmulla recorded maximum germination speed (15.00), followed by (14.55) for the seeds collected from the tree (T_7) located at Lar, while the minimum germination speed (10.05) was observed in seeds collected from tree (T_2) located at Duderhama.

4.1.7.3 Interaction effects of stratification period and trees

Interaction effects of stratification period and trees was found to be significant. Maximum germination speed (26.08) was recorded in P_6T_5 (Stratification for 60 days × T_5) and the minimum (5.51) was recorded in P_0T_2 (Control × T_2).

4.1.8 Vigour index

The analysed data for seedling vigour index is given in table-8.

4.1.8.1 Effect of stratification period

As evident from table-8, maximum vigour index (5568.77) was recorded for the seeds which were stratified for 60 days (P_6), followed by (4653.99) for the seeds stratified for 50 days (P_5). Minimum (1004.76) was recorded in Control (P_0), followed by (1783.69) for the seeds stratified for 10 days (P_1).

4.1.8.2 Effect of tree

From table-8, it is evident that maximum vigour index (3939.39) was recorded in seedlings of Tulmulla (T_5), followed by (3718.75) for the seedlings of Lar (T_7) while the minimum (2445.92) was recorded in seedlings of Duderhama (T_2).

4.1.8.3 Interaction effects of stratification period and trees

Interaction effects of stratification period and trees was found to be significant. Maximum vigour index (6539.90) was recorded in P_6T_5 (Stratification for 60 days × T_5) and the minimum (594.46) was recorded in P_0T_2 (Control × T_2).

4.1.9 Length of shoot (cm)

Analysed data regarding the shoot length (cm) has been presented in table-9.

4.1.9.1 Effect of stratification period

The data presented in table-9 clearly indicates that stratification had a significant impact on shoot length of seedlings. Seeds stratified for 60 days (P_6) reported significantly maximum shoot length (42.22 cm), followed by (39.96 cm) for the seeds stratified for 50 days (P_5). Minimum shoot length (19.40 cm) was recorded in Control (P_0), followed by (25.05 cm) for the seeds stratified for 10 days (P_{10}).

4.1.9.2 Effect of tree

From table-9, it is evident that the seedlings of Tulmulla (T_5) recorded the maximum shoot length (37.19 cm), which was stastically at par with (36.29 cm) recorded for the seedlings of Lar (T_7). Minimum (26.69 cm) was observed in seedlings of Duderhama (T_2), which was found to be stastically at par with (27.82 cm) for the seedlings of Arch (T_{10}).

4.1.9.3 Interaction effects of stratification period and trees

Interaction effects of stratification period and trees was found to be significant. Maximum shoot length (46.70 cm) was recorded in P_6T_5 (Stratification for 60 days × T_5) and the minimum (13.40 cm) was recorded in P_0T_2 (Control × T_2).

Table 6: Effect of different stratification periods and trees on germination value of *Platanus orientalis* L. seeds

Trees / Stratification period	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Mean
P_0 (Control)	0.58	0.53	0.66	0.76	0.91	0.83	0.87	0.66	0.68	0.55	0.70
P_1 (10 days)	1.27	1.19	1.62	1.82	3.77	2.07	3.02	1.67	1.79	1.24	1.95
P_2 (20 days)	2.86	1.63	2.51	3.98	4.74	4.08	4.14	3.40	7.78	1.99	3.31
P_3 (30 days)	2.90	2.10	2.89	5.05	5.99	5.23	5.53	3.53	4.38	2.40	4.00
P_4 (40 days)	4.93	4.68	4.98	6.54	11.93	8.57	9.66	5.00	5.79	4.72	6.68
P_5 (50 days)	5.96	5.65	6.22	7.87	13.08	9.79	10.98	6.42	6.51	5.83	7.83
P_6 (60 days)	7.10	6.65	7.37	12.90	23.62	16.08	21.44	7.70	11.07	6.85	12.08
Mean	3.66	3.20	3.75	5.56	9.15	6.66	7.95	4.06	4.86	3.37	

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla,T_6:Saloora, T_7:Lar, T_8:Gadoora, T_9:Sehpora, T_{10}:Arch

C.D. ($P \leq 0.05$)

Tree (T) : 0.27
Stratification (S) : 0.23
T×S : 0.72

Table 7: Effect of different stratification periods and trees on germination speed of *Platanus orientalis* L. seeds

Trees / Stratification period	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Mean
P_0 (Control)	5.96	5.51	6.37	7.10	7.87	7.39	7.59	6.48	6.59	5.70	6.66
P_1 (10 days)	8.18	7.70	9.27	9.96	10.75	10.57	10.72	9.50	9.88	7.79	9.43
P_2 (20 days)	9.23	8.61	9.40	10.56	12.18	10.69	10.76	9.64	9.96	8.94	10.00
P_3 (30 days)	10.15	8.61	11.01	11.90	13.76	12.60	12.59	11.12	10.74	9.86	11.23
P_4 (40 days)	12.48	12.01	12.64	13.97	16.74	16.05	16.65	12.07	13.60	12.38	13.86
P_5 (50 days)	13.78	13.32	13.80	15.72	17.58	17.00	18.01	14.27	14.16	13.70	15.13
P_6 (60 days)	15.51	14.56	15.62	20.80	26.08	22.49	25.53	15.13	18.46	14.79	18.90
Mean	10.76	10.05	11.16	12.86	15.00	13.83	14.55	11.17	11.91	10.45	

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla,T_6:Saloora, T_7:Lar, T_8:Gadoora, T_9:Sehpora, T_{10}:Arch

C.D. ($P \leq 0.05$)

Tree (T) : 0.10
Stratification (S) : 0.08

T×S : 0.27

Table 8: Effect of different stratification periods and trees on vigour index of *Platanus orientalis* L. seeds

Trees / Stratification period	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Mean
P_0 (Control)	738.47	594.46	876.80	1101.58	1515.01	1182.53	1387.70	976.30	1009.11	665.66	1004.76
P_1 (10 days)	1448.48	1206.83	1650.24	1897.03	2313.39	2036.13	2281.74	1750.33	1845.60	1355.19	1783.69
P_2 (20 days)	1994.27	1690.68	2165.67	2605.22	2886.45	2691.71	2757.48	2436.22	2478.88	1891.57	2359.82
P_3 (30 days)	2682.28	2470.93	2911.05	3368.05	3988.27	3518.36	3569.11	3174.69	3230.40	2600.67	3151.38
P_4 (40 days)	3504.74	3001.41	3733.28	4054.07	4793.25	4184.18	4407.99	3819.03	3988.24	3163.60	3864.98
P_5 (50 days)	4188.44	3743.41	4422.89	4926.64	5487.51	5076.65	5260.98	4681.65	4791.39	3960.32	4653.99
P_6 (60 days)	4946.97	4413.71	5354.60	5992.35	6539.90	6102.61	6366.22	5579.52	5836.55	4555.30	5568.77
Mean	2786.24	2445.92	3016.36	3420.71	3939.39	3541.74	3718.75	3202.54	3311.45	2598.90	

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla,T_6:Saloora, T_7:Lar, T_8:Gadoora, T_9:Sehpora, T_{10}:Arch

C.D. ($P \leq 0.05$)

Tree (T) : 144.41
Stratification (S) : 120.82
T×S : 141.04

Table 9: Effect of different stratification periods and trees on shoot length (cm) of *Platanus orientalis* L. seedlings

Trees / Stratification period	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Mean
P_0 (Control)	16.23	13.40	17.37	21.07	25.73	21.63	24.31	19.83	19.89	14.53	19.40
P_1 (10 days)	21.49	19.13	24.01	26.50	30.03	27.03	30.00	25.23	26.00	21.03	25.05
P_2 (20 days)	25.45	23.10	27.77	31.23	33.10	31.83	32.47	30.33	30.87	25.30	29.15
P_3 (30 days)	30.30	28.50	31.83	35.53	37.93	36.13	36.30	34.57	34.63	29.53	33.53
P_4 (40 days)	34.90	32.20	36.83	38.67	42.13	40.10	40.70	37.17	38.63	32.22	37.36
P_5 (50 days)	37.21	34.00	38.53	41.67	44.67	42.73	43.86	40.88	41.14	34.89	39.96
P_6 (60 days)	39.27	36.47	41.03	44.27	46.70	44.63	46.40	42.67	43.57	37.23	42.22
Mean	29.26	26.69	31.05	34.13	37.19	34.87	36.29	32.95	33.53	27.82	

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla,T_6:Saloora, T_7:Lar, T_8:Gadoora, T_9:Sehpora, T_{10}:Arch

C.D. ($P \leq 0.05$)

Tree (T) : 1.36
Stratification (S) : 1.14
T×S : 2.37

4.1.10 Length of root (cm)

Table-10 represents the data pertaining to the root length (cm) of *Platanus orientalis* L. seedlings.

4.1.10.1 Effect of stratification period

The data presented in table-10 clearly indicates that stratification significantly impacted root length of seedlings. Maximum root length (33.68 cm) was recorded for the stratification period of 60 days (P_6). This was followed by (28.84 cm) for stratification period of 50 days (P_5). Minimum root length (9.08 cm) was recorded in Control (P_0), followed by (13.35 cm) for the stratification period of 10 days (P_{10}).

4.1.10.2 Effect of tree

From table-10, it is evident that seedlings of Tulmulla (T_5) recorded the maximum root length (24.04 cm), which was stastically at par with (23.25 cm) and (22.30 cm) for seedlings of Lar (T_7) and Saloora (T_6) respectively. Minimum root length (17.36 cm) was observed in seedlings of Duderhama (T_2).

4.1.10.3 Interaction effects of stratification period and trees

Interaction effects of stratification period and trees was found to be significant. Maximum root length (36.85 cm) was recorded in P_6T_5 (Stratification for 60 days × T_5) and the minimum root length (6.38 cm) was recorded in P_0T_2 (Control × T_2).

Table 10: Effect of different stratification periods and trees on root length (cm) of *Platanus orientalis* L. seedlings

Trees / Stratification period	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	Mean
P_0 (Control)	7.00	6.38	8.86	9.58	12.03	9.97	11.65	9.03	9.57	6.75	9.08
P_1 (10 days)	12.18	9.69	13.17	13.94	16.76	14.15	15.49	13.45	13.59	11.09	13.35
P_2 (20 days)	14.74	12.57	15.22	17.36	18.34	17.70	18.00	16.99	17.21	14.29	16.24
P_3 (30 days)	19.18	18.49	19.82	22.53	24.66	22.75	23.14	21.46	21.68	19.11	21.28
P_4 (40 days)	23.18	20.16	24.73	25.71	27.81	26.09	26.58	25.14	25.40	21.71	24.65
P_5 (50 days)	27.04	24.88	29.15	29.38	31.85	30.10	31.27	29.33	29.34	26.10	28.84
P_6 (60 days)	30.99	29.38	33.66	35.22	36.85	35.31	36.61	34.37	34.93	29.44	33.68
Mean	19.19	17.36	20.66	21.96	24.04	22.30	23.25	21.40	21.67	18.36	

T_1:Harran, T_2:Duderhama, T_3:Hakim Gund, T_4:Serch, T_5:Tulmulla,T_6:Saloora, T_7:Lar, T_8:Gadoora, T_9:Sehpora, T_{10}:Arch

C.D. ($P \leq 0.05$)

Tree (T) : 0.98
Stratification (S) : 0.82
T×S : 2.29

4.1.11 Genetic parameters

Variability for different germination and seedling growth characters was estimated in terms of genotypic and phenotypic coefficient of variation. Genetic parameters were also worked out with regard to heritability (broad sense) and genetic advance. The results obtained are presented in table-11.

The results revealed that highest PCV was recorded for vigour index (49.81), followed by length of root (40.57), germination energy (31.77), germination value (26.68), length of shoot (26.59), germination speed (18.98), germination percent (12.05), mean daily germination (11.99), seed weight (9.55) while as peak value exhibited lowest PCV (9.01). Genotypic coefficient of variation also showed the same trend. The highest GCV was recorded for vigour index (49.30), followed by length of root (39.90), germination energy (31.76), germination value (25.92), length of shoot (25.78), germination speed (18.44), germination percent (11.82), mean daily germination (10.31), 1000 seed weight (9.42) while as peak value exhibited lowest GCV (7.68).

Heritability estimates were recorded highest for germination energy (99.90%), followed by vigour index (97.90%), 1000 seed weight (97.24%), length of root (96.70%), germination percent (96.10%), germination speed (94.34%), germination value (94.30%), length of shoot (94.00%) , mean daily germination (73.89%), while as peak value recorded minimum heritability (72.71%) as compared to other characters.

Genetic advance was recorded highest for vigour index (100.49), followed by 1000 seed weight (85.10), length of root (80.82), germination energy (65.39), germination value (51.85), length of shoot (51.49), germination speed (25.83), germination percent (23.87), mean daily germination (13.32) while peak value recorded minimum genetic advance (12.82) as compared to other characters.

Table 11: Estimation of coefficient of variance for various germination and seedling growth characters of *Platanus orientalis* L.

Parameters	GCV (%)	PCV (%)	Heritability (%)	Genetic advance
1000 seed weight	9.42	9.55	97.24	85.10
Germination percent	11.82	12.05	96.10	23.87
Germination energy	31.76	31.77	99.90	65.39
Mean daily germination	10.31	11.99	73.89	13.32
Peak value	7.68	9.01	72.71	12.82
Germination value	25.92	26.68	94.30	51.85
Germination speed	18.44	18.98	94.34	25.83
Vigour index	49.30	49.81	97.90	100.50
Length of shoot	25.78	26.59	94.00	51.49
Length of root	39.90	40.57	96.70	80.82

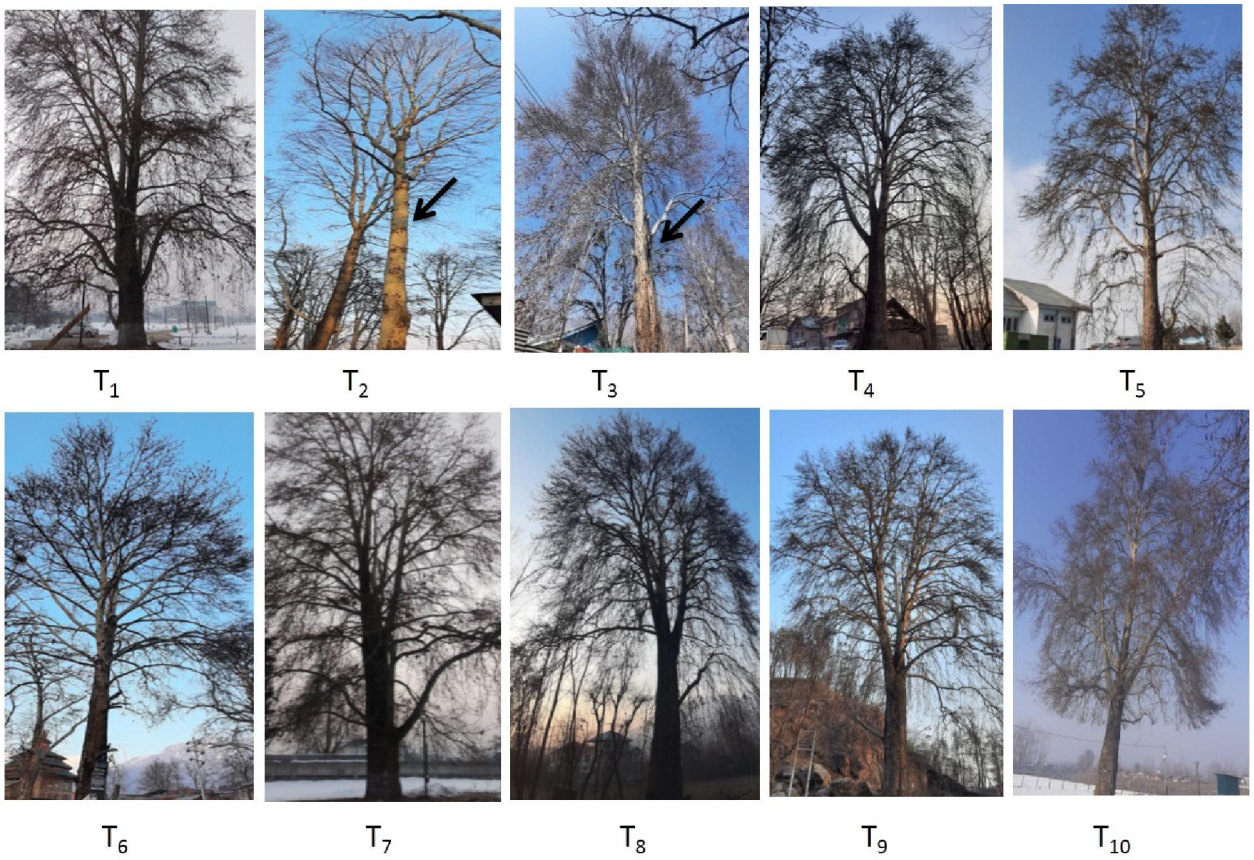


Plate 1: Ten selected trees of *Platanus orientalis* L.

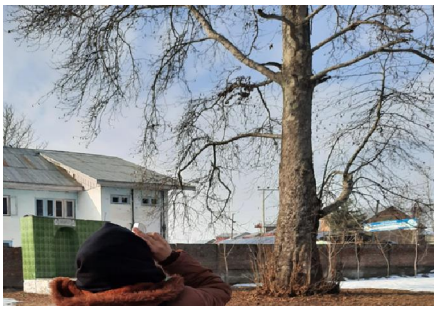
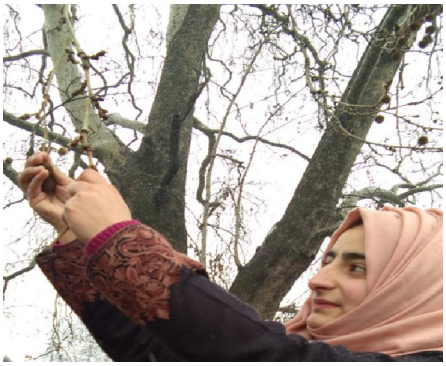


Plate 2: Height measurement

Plate 3: DBH measurement



(a)

Plate 4a: Seed collection

(b)

Plate 4b: Seeds of *Platanus orientalis* L.

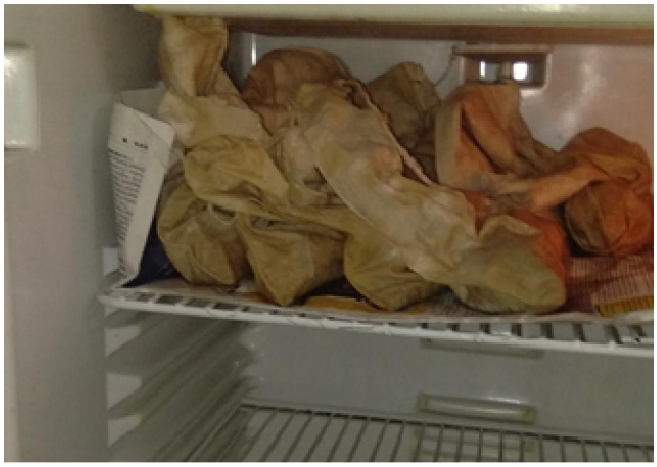


Plate 5: Stratification at 4 ±1°C

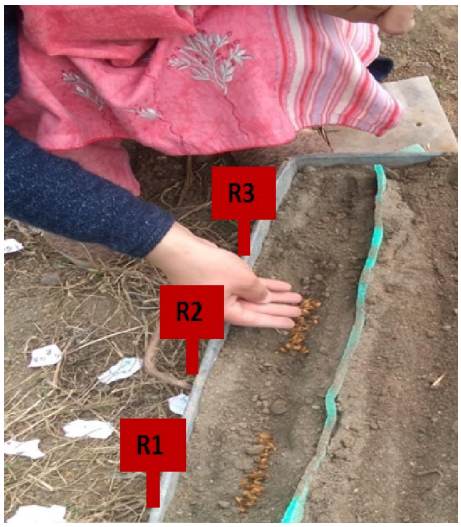


Plate 6: Seed sowing in trays

Plate 7: Seed germination after 33 days of sowing

Plate 8: Seedlings after 55 days of growth

Plate 9: Shoot length measurement

4.2 To standardize optimum concentration of growth hormones for rooting of *Platanus orientalis* L. cuttings, and To determine best section of branches for rooting of *Platanus orientalis* L. cuttings

The results of the parameters which were recorded in order to fulfil these objectives are presented as:

4.2.1 Sprouting percent

Analysed data regarding the sprouting percent is presented in table-12.

4.2.1.1 Effect of IBA

It is obvious from the data presented in table-12 that IBA has a significant influence on sprouting percent. Among various concentrations of IBA, IBA@ 6000ppm (T_7) reported the maximum sprouting (98.89%), followed by (97.78%) for the IBA@7000ppm (T_6). Minimum sprouting (72.22%) was reported in Control (T_1), followed by (76.67%) for the IBA@1000ppm (T_2). The data recorded also revealed that sprouting percent increased with increase in IBA concentration up to 6000ppm but at higher concentrations (beyond 6000ppm), sprouting percent declined sharply.

4.2.1.2 Effect of cutting section

From table-12, it is evident that the apical cuttings recorded maximum sprouting (89.67%), which was significantly superior over the middle (85.38%) and basal (82.31%) cutting sections.

4.2.1.3 Interaction effects of cutting sections and IBA

Interaction between cutting section and IBA concentration was found to be non- significant. However, maximum sprouting percent (100.00) was recorded in S_1T_6 (apical cutting × 6000ppm), S_2T_7 (middle × 7000ppm) and S_3T_7 (basal × 6000ppm), while the minimum sprouting (63.33) was recorded in S_3T_1 (basal cutting without any treatment).

Table 12: Effect of IBA and different types of cutting sections on sprouting percent of *Platanus orientalis* L.

Sprouting percent				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	80.00 (8.95)	73.33 (8.59)	63.33 (8.02)	72.22 (8.52)
T_2 (1000ppm)	80.00 (9.00)	76.67 (8.78)	73.33 (8.62)	76.67 (8.80)
T_3 (2000ppm)	86.67 (9.36)	80.00 (9.00)	76.67 (8.81)	81.11 (9.06)
T_4 (3000ppm)	90.00 (9.53)	80.00 (8.99)	83.33 (9.18)	84.44 (9.23)
T_5 (4000ppm)	90.00 (9.53)	83.33 (9.18)	86.67 (9.36)	86.67 (9.36)
T_6 (5000ppm)	100.00 (10.05)	93.33 (9.70)	93.33 (9.71)	95.56 (9.82)
T_7 (6000ppm)	96.67 (9.88)	100.00 (10.05)	100.00 (10.05)	98.89 (9.99)
T_8 (7000ppm)	93.33 (9.71)	100.00 (10.05)	100.00 (10.05)	97.78 (9.94)
T_9 (8000ppm)	90.00 (9.53)	93.33 (9.70)	86.67 (9.36)	90.00 (9.53)
T_{10} (9000ppm)	90.00 (9.54)	86.67 (9.35)	83.33 (9.18)	86.67 (9.36)
T_{11} (10000ppm)	83.33 (9.18)	86.67 (9.36)	76.67 (8.81)	82.22 (9.12)
T_{12} (11000ppm)	83.33 (9.18)	80.00 (8.99)	73.33 (8.62)	78.89 (8.93)
T_{13} (12000ppm)	83.33 (9.18)	76.67 (8.80)	73.33 (8.62)	77.78 (8.87)
Mean	89.67 (9.43)	85.38 (9.27)	82.31 (9.11)	

Figures in parentheses are square root transformed values

C.D. ($P \leq 0.05$)

IBA concentration (T) : 0.41
Cutting section (S) : 0.20
T×S : N.S

4.2.2 Rooting/ survival percent

The analysed data regarding the rooting/survival percent is presented in table-13.

4.2.2.1 Effect of IBA

As indicated by data presented in table-13, the maximum rooting/survival (41.33%) was noted in IBA@6000ppm (T_7), followed by (40.22%) for IBA@7000ppm (T_8) while the minimum (29.39%) was noted in Control (T_1).

4.2.2.2 Effect of cutting section

The data in table-13 clearly indicated that the basal cuttings of *Platanus orientalis* L. recorded maximum rooting/survival (45.18%), which was superior over the middle (34.03%) and apical (26.38%) cutting sections.

4.2.2.3 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration with respect to rooting/survival was found to be significant. Maximum rooting/survival (55.00) was recorded in S_3T_7 (basal × 6000ppm), while the minimum rooting/survival (24.00) was recorded in S_1T_1 (apical cutting without any treatment).

4.2.3 Length of root (cm)

Statically analysed data regarding the root length (cm) is presented in table-14

4.2.3.1 Effect of IBA

The data in table-14 clearly indicated that the IBA@6000ppm (T_7) produced the maximum root length (26.48 cm), which was significantly superior to all other IBA concentrations. This was followed by IBA@7000ppm (T_8) which produced a root length of (24.86 cm), being stastically at par (24.70 cm) with IBA@5000pm (T_6). It is evident from the data that the concentration of IBA upto 6000ppm increased root length. But, further increase in the concentration of IBA

reduced the root length. Minimum root length (13.07 cm) was recorded Control (T_1).

4.2.3.2 Effect of cutting section

As evident from the data presented in table-14, basal cuttings recorded the maximum root length (24.59 cm), which was significantly superior over the middle (19.05 cm) and apical (15.73 cm) cutting sections.

4.2.3.3 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration was found to be significant. Maximum root length (32.42 cm) was recorded in S_3T_7 (basal × 6000ppm), while the minimum (11.33 cm) was recorded in S_1T_1 (apical cutting without any treatment).

Table 13: Effect of IBA and different types of cutting sections on rooting/survival percent of *Platanus orientalis* L.

Rooting/Survival percent				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	24.00 (4.98)	29.33 (5.49)	34.83 (6.00)	29.39 (5.49)
T_2 (1000ppm)	24.00 (5.00)	30.67 (5.61)	40.33 (6.45)	31.67 (5.69)
T_3 (2000ppm)	26.00 (5.19)	32.00 (5.75)	42.17 (6.58)	33.39 (5.84)
T_4 (3000ppm)	27.00 (5.29)	32.00 (5.74)	45.83 (6.85)	34.94 (5.96)
T_5 (4000ppm)	27.00 (5.29)	33.33 (5.86)	47.67 (7.00)	36.00 (6.05)
T_6 (5000ppm)	30.00 (5.57)	37.33 (6.18)	51.33 (7.26)	39.56 (6.34)
T_7 (6000ppm)	29.00 (5.48)	40.00 (6.40)	55.00 (7.48)	41.33 (6.45)
T_8 (7000ppm)	28.00 (5.39)	38.33 (6.27)	54.33 (7.44)	40.22 (6.36)
T_9 (8000ppm)	27.00 (5.29)	37.33 (6.18)	47.67 (7.00)	37.33 (6.16)
T_{10} (9000ppm)	26.67 (5.26)	34.67 (5.96)	45.83 (6.85)	35.72 (6.03)
T_{11} (10000ppm)	25.00 (5.10)	34.67 (5.97)	42.17 (6.58)	33.94 (5.88)
T_{12} (11000ppm)	25.00 (5.10)	32.00 (5.74)	40.33 (6.45)	32.44 (5.76)
T_{13} (12000ppm)	24.33 (5.03)	30.67 (5.62)	39.83 (6.40)	31.61 (5.68)
Mean	26.38 (5.23)	34.03 (5.91)	45.18 (6.80)	

Figures in parentheses are square root transformed values

C.D. ($P \leq 0.05$)

IBA concentration (T) : 0.26
Cutting section (S) : 0.12
T×S : 0.40

Table 14: Effect of IBA and different types of cutting sections on root length of *Platanus orientalis* L.

Root length (cm)				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	11.33	12.92	14.96	13.07
T_2 (1000ppm)	12.54	13.77	17.87	14.73
T_3 (2000ppm)	14.95	15.73	21.48	17.39
T_4 (3000ppm)	15.44	16.04	21.96	17.81
T_5 (4000ppm)	17.10	18.56	25.89	20.52
T_6 (5000ppm)	22.14	22.37	29.61	24.70
T_7 (6000ppm)	20.14	26.88	32.42	26.48
T_8 (7000ppm)	18.53	25.64	30.41	24.86
T_9 (8000ppm)	16.80	21.22	28.83	22.29
T_{10} (9000ppm)	14.94	20.99	27.10	21.01
T_{11} (10000ppm)	14.57	20.92	26.55	20.68
T_{12} (11000ppm)	13.48	17.92	23.40	18.27
T_{13} (12000ppm)	12.46	14.64	19.21	15.43
Mean	15.73	19.05	24.59	

C.D. ($P \leq 0.05$)

IBA concentration (T) : 0.69
Cutting section (S) : 0.33
T×S : 1.20

4.2.4 Average number of roots per plant

The data pertaining to the average number of roots per plant is presented in table-15.

4.2.4.1 Effect of IBA

As evident from table-15, IBA influenced average number of roots per plant. The average number of roots per plant was recorded maximum (8.56) for IBA@6000ppm (T_7), followed by (7.78) for IBA@7000ppm (T_8). Average number of roots per plant increased upto the concentration of IBA@6000ppm (T_7). However, further increase in the concentration of IBA reduced the average number of roots. Average number of roots per plant was recorded minimum (3.67) for Control (T_1).

4.2.4.2 Effect of cutting section

The data in table-15 clearly indicated that average number of roots per plant was recorded maximum (7.77) in basal cuttings, which was superior over the middle (5.74) and apical (4.56) cutting sections.

4.2.4.3 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration was found to be significant. Maximum average number of roots per plant (10.67) was recorded in S_3T_7 (basal × 6000ppm), while the minimum (3.00) was recorded in S_1T_1 (apical cutting without any treatment).

4.2.5 Length of shoot (cm)

Statically analysed data of shoot length (cm) has been presented in table-16.

4.2.5.1 Effect of IBA

From the data (table-16), it is clearly evident that shoot length was significantly affected by IBA. The data revealed that the IBA@6000ppm (T_7)

reported the maximum shoot length (35.38 cm), which was significantly superior to all other IBA concentrations. The next superior shoot length (33.29 cm) was recorded for IBA@7000ppm (T_8), while the minimum shoot length (17.66 cm) was observed Control (T_1).

4.2.5.2 Effect of cutting section

From table-16, it is evident that the basal cuttings recorded the maximum shoot length (33.32 cm) which was significantly superior over the middle (25.81 cm) and apical (21.29 cm) cutting sections.

4.2.5.3 Interaction effects of cutting section and IBA

Interaction between cutting section and IBA concentration was found to be significant. Maximum shoot length (43.33 cm) was recorded in S_3T_7 (basal × 6000ppm), while the minimum (15.31 cm) was recorded in S_1T_1 (apical cutting without any treatment).

4.2.6 Average number of branches per plant

The analysed data regarding the average number of branches per plant is presented in table-17.

4.2.6.1 Effect of IBA

The average number of branches was recorded maximum (2.67) for IBA@6000ppm (T_7) and IBA@7000ppm (T_8), while the minimum (1.00) was recorded in Control (T_1).

4.2.6.2 Effect of cutting section

As evident from the data (table-17), basal cuttings of *Platanus orientalis* L. recorded the maximum average number of branches (2.54), which was significantly superior over the middle (1.85) and apical (1.38) cutting sections.

4.2.6.3 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration was found to be significant. . Maximum average number of branches (3.00) was recorded in S_3T_7 (basal × 6000ppm), S_3T_8 (basal × 7000ppm), S_2T_7 (middle × 6000ppm) and S_2T_8 (middle× 7000ppm), while the minimum (1.00) was recorded in S_1T_1 (apical cutting without any treatment), S_1T_2 (apical × 1000ppm), S_2T_1 (middle cutting without any treatment), S_3T_1 (basal cutting without any treatment) and S_2T_2 (middle× 1000ppm).

4.2.7 Leaf area (cm^2)

The analysed data regarding the leaf area is presented in table-18.

4.2.7.1 Effect of IBA

As clearly evident from table-18, the maximum leaf area (44.67 cm^2) was recorded for IBA@6000ppm (T_7), which was significantly superior over other treatments. This was followed by (41.79 cm^2) for the IBA@7000ppm (T_8), which was statically at par with (41.61 cm^2) and (40.83 cm^2) recorded in IBA@5000ppm (T_6) and IBA@8000ppm (T_9) respectively. The minimum leaf area (20.62 cm^2) was recorded in Control (T_1).

4.2.7.2 Effect of cutting section

As evident from the data presented in table-18, basal cuttings of *Platanus orientalis* L. recorded the maximum leaf area (39.04 cm^2), which was significantly superior over the middle (36.03 cm^2) and apical (31.45 cm^2) cutting sections.

4.2.7.3 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration was found to be significant. Maximum leaf area (50.65 cm^2) was recorded in S_3T_7 (basal × 6000ppm), while the minimum leaf area (18.22 cm^2) was recorded in S_1T_1 (apical cutting without any treatment).

Table 15: Effect of IBA and different types of cutting sections on average number of roots per plant of *Platanus orientalis* L.

Average number of roots per plant				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	3.00 (2.12)	3.67 (2.27)	4.33 (2.41)	3.67 (2.27)
T_2 (1000ppm)	3.33 (2.20)	4.00 (2.31)	5.33 (2.61)	4.22 (2.37)
T_3 (2000ppm)	4.33 (2.41)	4.33 (2.41)	6.67 (2.88)	5.11 (2.56)
T_4 (3000ppm)	4.33 (2.41)	4.33 (2.41)	7.00 (2.92)	5.33 (2.60)
T_5 (4000ppm)	5.00 (2.55)	6.00 (2.74)	8.00 (3.08)	6.33 (2.79)
T_6 (5000ppm)	7.00 (2.92)	7.00 (2.96)	9.67 (3.34)	7.89 (3.06)
T_7 (6000ppm)	6.33 (2.80)	8.67 (3.19)	10.67 (3.49)	8.56 (3.16)
T_8 (7000ppm)	5.67 (2.68)	8.00 (3.08)	9.67 (3.34)	7.78 (3.03)
T_9 (8000ppm)	5.00 (2.55)	6.33 (2.80)	9.33 (3.29)	6.89 (2.88)
T_{10} (9000ppm)	4.33 (2.41)	6.33 (2.80)	8.67 (3.19)	6.44 (2.80)
T_{11} (10000ppm)	4.00 (2.35)	6.33 (2.80)	8.67 (3.19)	6.33 (2.78)
T_{12} (11000ppm)	3.67 (2.27)	5.33 (2.61)	7.00 (2.92)	5.33 (2.60)
T_{13} (12000ppm)	3.33 (2.20)	4.00 (2.34)	6.00 (2.74)	4.44 (2.42)
Mean	4.56 (2.45)	5.74 (2.67)	7.77 (3.03)	

Since the count was less than 10, the original values were square root transformed as √ (original value) + 1.5

C.D. (P≤0.05)

IBA concentration (T) : 0.04
Cutting section (S) : 0.09
T×S : 0.15

Table 16: Effect of IBA and different types of cutting sections on shoot length of *Platanus orientalis* L.

Length of shoot (cm)				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	15.31	17.46	20.21	17.66
T_2 (1000ppm)	17.91	19.67	25.54	21.04
T_3 (2000ppm)	19.35	20.36	28.42	22.71
T_4 (3000ppm)	21.66	22.49	30.11	24.75
T_5 (4000ppm)	22.33	24.23	33.78	26.78
T_6 (5000ppm)	28.33	28.61	37.88	31.61
T_7 (6000ppm)	26.91	35.91	43.33	35.38
T_8 (7000ppm)	24.83	34.33	40.72	33.29
T_9 (8000ppm)	23.27	29.41	39.95	30.88
T_{10} (9000ppm)	20.66	29.01	36.71	28.79
T_{11} (10000ppm)	19.35	27.77	35.97	27.69
T_{12} (11000ppm)	18.89	25.11	32.81	25.60
T_{13} (12000ppm)	18.00	21.17	27.77	22.31
Mean	21.29	25.81	33.32	

C.D. ($P \leq 0.05$)

IBA concentration (T) : 0.79

Cutting section (S) : 0.38

T×S : 1.37

Table17: Effect of IBA and different types of cutting sections on average number of branches per plant of *Platanus orientalis* L.

Average number of branches per plant				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	1.00 (1.58)	1.00 (1.58)	1.00 (1.58)	1.00 (1.58)
T_2 (1000ppm)	1.00 (1.58)	1.00 (1.58)	2.00 (1.87)	1.33 (1.68)
T_3 (2000ppm)	1.00 (1.58)	1.00 (1.58)	2.00 (1.87)	1.33 (1.68)
T_4 (3000ppm)	1.33 (1.68)	2.00 (1.87)	2.00 (1.87)	1.78 (1.81)
T_5 (4000ppm)	1.67 (1.77)	2.00 (1.87)	3.00 (2.12)	2.22 (1.92)
T_6 (5000ppm)	2.00 (1.87)	2.00 (1.87)	3.00 (2.12)	2.33 (1.95)
T_7 (6000ppm)	2.00 (1.87)	3.00 (2.12)	3.00 (2.12)	2.67 (2.04)
T_8 (7000ppm)	2.00 (1.87)	3.00 (2.12)	3.00 (2.12)	2.67 (2.04)
T_9 (8000ppm)	2.00 (1.87)	2.00 (1.87)	3.00 (2.12)	2.33 (1.95)
T_{10} (9000ppm)	1.00 (1.58)	2.00 (1.87)	3.00 (2.12)	2.00 (1.86)
T_{11} (10000ppm)	1.00 (1.58)	2.00 (1.87)	3.00 (2.12)	2.00 (1.86)
T_{12} (11000ppm)	1.00 (1.58)	2.00 (1.87)	3.00 (2.12)	2.00 (1.86)
T_{13} (12000ppm)	1.00 (1.58)	1.00 (1.58)	2.00 (1.87)	1.33 (1.68)
Mean	1.38 (1.69)	1.85 (1.82)	2.54 (2.00)	

Since the count was less than 10, the original values were square root transformed as √ (original value) + 1.5

C.D. (P≤0.05)

IBA concentration (T) : 0.04
Cutting section (S) : 0.02
T×S : 0.06

Table 18: Effect of IBA and different types of cutting sections on leaf area of *Platanus orientalis* L.

Leaf area (cm^2)				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	18.22	20.23	23.41	20.62
T_2 (1000ppm)	24.56	26.61	28.63	26.60
T_3 (2000ppm)	25.64	29.53	32.71	29.29
T_4(3000ppm)	30.74	33.41	36.53	33.56
T_5 (4000ppm)	34.68	36.71	39.88	37.09
T_6 (5000ppm)	34.61	42.42	45.72	41.61
T_7 (6000ppm)	37.84	45.51	50.65	44.67
T_8 (7000ppm)	39.97	40.88	44.53	41.79
T_9 (8000ppm)	34.61	42.42	45.45	40.83
T_{10} (9000ppm)	33.54	40.72	42.82	39.03
T_{11} (10000ppm)	31.85	38.66	41.91	37.47
T_{12} (11000ppm)	31.55	36.83	38.77	35.72
T_{13}(12000ppm)	29.89	33.46	36.56	33.31
Mean	31.45	36.03	39.04	

C.D. ($P \leq 0.05$)

IBA concentration (T) : 1.49

Cutting section (S) : 0.72

T×S : 2.58

4.2.8 Collar diameter (mm)

The analysed data regarding the collar diameter (mm) is presented in table-19.

4.2.8.1 Effect of IBA

From the table-19, it is clearly evident that collar diameter was significantly affected by IBA. The data revealed that IBA@6000ppm (T_7) reported the maximum collar diameter (6.45 mm), which was significantly superior to all other IBA concentrations. The next superior collar diameter (6.18 mm) was recorded for IBA@7000ppm (T_8), while the minimum (4.10 mm) was recorded in Control (T_1).

4.2.8.2 Effect of cutting section

As evident from table-19, basal cuttings of *Platanus orientalis* L. recorded the maximum collar diameter (6.18 mm), which was significantly superior over the middle (5.18 mm) and apical (4.59 mm) cutting sections.

4.2.8.3 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration was found to be significant. Maximum collar diameter (7.51 mm) was recorded in S_3T_7 (basal × 6000ppm), while the minimum collar diameter (3.79 mm) was recorded in S_1T_1 (apical cutting without any treatment).

4.2.9 Above ground biomass

The analysed data regarding the above ground biomass is presented in table-20 and 21.

4.2.9.1 Effect of IBA

As evident from table-20, IBA@6000ppm (T_7) recorded the maximum fresh biomass of shoot (21.57 g), which was significantly superior over all other treatments. This was followed by (19.86 g) for IBA@7000ppm (T_8), being

statically at par with (19.31 g) recorded in IBA@5000ppm (T_6). The minimum fresh biomass of shoot (10.07 g) was recorded for Control (T_1).

4.2.9.2 Effect of cutting section

Table-20 indicated that basal cuttings recorded the maximum fresh biomass of shoot (21.67 g), which was significantly superior middle (14.92 g) and apical (11.68 g) cutting sections.

4.2.9.3 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration with respect to fresh biomass of shoot was found to be significant. Maximum fresh biomass of shoot (30.18 g) was recorded in S_3T_7 (basal × 6000ppm), while the minimum (7.87 g) was recorded in S_1T_1 (apical cutting without any treatment).

4.2.9.4 Effect of IBA

As evident from table 21, IBA@6000ppm (T_7) recorded the maximum dry biomass of shoot (9.44 g), which was followed by (9.06 g) for IBA@7000ppm (T_8). Minimum (4.52 g) was recorded in Control (T_1).

4.2.9.5 Effect of cutting section

Table-21 indicated that basal cuttings recorded maximum dry biomass of shoot (7.96 g), which was significantly superior middle (6.25 g) and apical (5.33 g) cutting sections.

4.2.9.6 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration with respect to dry biomass of shoot was found to be significant. Maximum dry biomass of shoot (13.20 g) was recorded in S_3T_7 (basal × 6000ppm), while the minimum (3.53 g) was recorded in S_1T_1 (apical cutting without any treatment).

Table 19: Effect of IBA and different types of cutting sections on collar diameter of *Platanus orientalis* L.

Collar diameter (mm)				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	3.79	4.08	4.44	4.10
T_2 (1000ppm)	4.14	4.37	5.15	4.55
T_3 (2000ppm)	4.33	4.46	5.53	4.77
T_4 (3000ppm)	4.63	4.75	5.75	5.04
T_5 (4000ppm)	4.72	4.97	6.24	5.31
T_6 (5000ppm)	5.52	5.55	6.78	5.95
T_7 (6000ppm)	5.33	6.52	7.51	6.45
T_8 (7000ppm)	5.05	6.31	7.16	6.18
T_9 (8000ppm)	4.85	5.66	7.06	5.86
T_{10} (9000ppm)	4.50	5.61	6.63	5.58
T_{11} (10000ppm)	4.33	5.44	6.53	5.43
T_{12} (11000ppm)	4.26	5.09	6.11	5.16
T_{13} (12000ppm)	4.15	4.57	5.44	4.72
Mean	4.59	5.18	6.18	

C.D. ($P \leq 0.05$)

IBA concentration (T) : 0.10

Cutting section (S) : 0.05

T×S : 0.18

Table 20: Effect of IBA and different types of cutting sections on above ground biomass of *Platanus orientalis* L.

Fresh shoot biomass (g)				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	7.87	9.23	13.12	10.07
T_2 (1000ppm)	9.53	11.62	16.39	12.51
T_3 (2000ppm)	10.77	13.42	17.45	13.88
T_4 (3000ppm)	13.00	14.87	19.33	15.73
T_5 (4000ppm)	13.23	15.98	22.29	17.17
T_6 (5000ppm)	15.04	17.44	25.46	19.31
T_7 (6000ppm)	14.29	20.24	30.18	21.57
T_8 (7000ppm)	13.10	18.11	28.38	19.86
T_9 (8000ppm)	12.77	17.01	27.25	19.01
T_{10} (9000ppm)	12.37	16.85	24.45	17.89
T_{11} (10000ppm)	11.13	14.59	23.20	16.31
T_{12} (11000ppm)	9.84	13.23	19.64	14.24
T_{13} (12000ppm)	8.91	11.39	14.59	11.63
Mean	11.68	14.92	21.67	

C.D. ($P \leq 0.05$)

IBA concentration (T) : 0.81

Cutting section (S) : 0.37

T×S : 1.40

Table 21: Effect of IBA and different types of cutting sections on above ground biomass of *Platanus orientalis* L.

Dry shoot biomass (g)				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	3.53	4.14	5.90	4.52
T_2 (1000ppm)	4.45	5.42	6.05	5.31
T_3 (2000ppm)	5.10	6.05	6.25	5.80
T_4 (3000ppm)	6.05	6.25	7.66	6.65
T_5 (4000ppm)	6.25	6.35	8.26	6.95
T_6 (5000ppm)	6.36	7.20	10.77	8.11
T_7 (6000ppm)	6.25	8.86	13.20	9.44
T_8 (7000ppm)	5.98	8.26	12.95	9.06
T_9 (8000ppm)	5.88	6.02	8.93	6.94
T_{10} (9000ppm)	5.37	6.02	6.94	6.11
T_{11} (10000ppm)	5.33	5.88	5.88	5.70
T_{12} (11000ppm)	4.48	5.42	5.37	5.09
T_{13} (12000ppm)	4.24	5.38	5.33	4.99
Mean	5.33	6.25	7.96	

C.D. ($P \leq 0.05$)

IBA concentration (T) : 0.39

Cutting section (S) : 0.19

T×S : 0.67

4.2.10 Below ground biomass

The analysed data regarding the below ground biomass is presented in table-22 and 23.

4.2.10.1 Effect of IBA

As evident from table-22, IBA@6000ppm (T_7) recorded the maximum fresh biomass of root (15.49 g), which was superior over all other treatments. This was followed by (14.33 g) for IBA@7000ppm (T_8), being stastically at par with (14.22 g) recorded for IBA@5000ppm (T_6). The minimum fresh biomass of root (6.01 g) was recorded in Control (T_1).

4.2.10.2 Effect of cutting section

As clearly indicated by Table 22, basal cuttings recorded the maximum fresh biomass of root (14.14g), which was significantly superior middle (10.21g) and apical (7.82g) cutting sections.

4.2.10.3 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration with respect to fresh biomass of root was found to be significant. Maximum fresh biomass of root (19.73g) was recorded in S_3T7 (basal × 6000ppm), while the minimum fresh biomass of root (4.69g) was recorded in S_1T1 (apical cutting without any treatment).

4.2.10.4 Effect of IBA

As evident from table-23, IBA@6000ppm (T_7) recorded the maximum dry biomass of root (5.11 g) which was superior over all other treatments. The minimum (1.98 g) was recorded for Control (T_1).

4.2.10.5 Effect of cutting section

As clearly indicated by table-23, basal cuttings recorded the maximum dry biomass of root (4.67 g), which was significantly superior middle (3.37 g) and apical (2.58 g) cutting sections.

4.2.10.6 Interaction effect of cutting section and IBA

Interaction between cutting section and IBA concentration with respect to dry biomass of root was found to be significant. Maximum dry biomass of root (6.51 g) was recorded in S_3T_7 (basal × 6000ppm), while the minimum dry biomass of root (1.55 g) was recorded in S_1T_1 (apical cutting without any treatment).

Table 22: Effect of IBA and different types of cutting sections on below ground biomass of *Platanus orientalis* L.

Fresh root biomass (g)				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	4.69	6.06	7.27	6.01
T_2 (1000ppm)	5.55	6.51	9.35	7.14
T_3 (2000ppm)	7.27	7.83	11.92	9.01
T_4 (3000ppm)	7.62	8.05	12.26	9.31
T_5 (4000ppm)	8.80	9.84	15.07	11.24
T_6 (5000ppm)	12.39	12.55	17.72	14.22
T_7 (6000ppm)	10.97	15.77	19.73	15.49
T_8 (7000ppm)	9.82	14.89	18.29	14.33
T_9 (8000ppm)	8.59	11.74	17.17	12.50
T_{10} (9000ppm)	7.26	11.57	15.93	11.59
T_{11} (10000ppm)	7.00	11.52	15.54	11.35
T_{12} (11000ppm)	6.22	9.38	13.29	9.63
T_{13} (12000ppm)	5.49	7.05	10.30	7.61
Mean	7.82	10.21	14.14	

C.D. ($P \leq 0.05$)

IBA concentration (T) : 0.49
Cutting section (S) : 0.24
T×S : 0.85

Table 23: Effect of IBA and different types of cutting sections on below ground biomass of *Platanus orientalis* L.

Dry root biomass (g)				
Cutting section / Treatment	S_1 (Apical)	S_2 (Middle)	S_3 (Basal)	Mean
T_1 (Control)	1.55	2.00	2.40	1.98
T_2 (1000ppm)	1.83	2.15	3.08	2.35
T_3 (2000ppm)	2.40	2.58	3.94	2.97
T_4 (3000ppm)	2.51	2.65	4.05	3.07
T_5 (4000ppm)	2.91	3.25	4.97	3.71
T_6 (5000ppm)	4.09	4.91	5.85	4.95
T_7 (6000ppm)	3.62	5.20	6.51	5.11
T_8 (7000ppm)	3.24	4.14	6.04	4.47
T_9 (8000ppm)	2.83	3.88	5.66	4.12
T_{10} (9000ppm)	2.40	3.82	5.26	3.83
T_{11} (10000ppm)	2.31	3.80	5.13	3.75
T_{12} (11000ppm)	2.05	3.09	4.39	3.18
T_{13} (12000ppm)	1.81	2.33	3.40	2.51
Mean	2.58	3.37	4.67	

C.D. ($P \leq 0.05$)

IBA concentration (T) : 0.08

Cutting section (S) : 0.16

T×S : 0.28

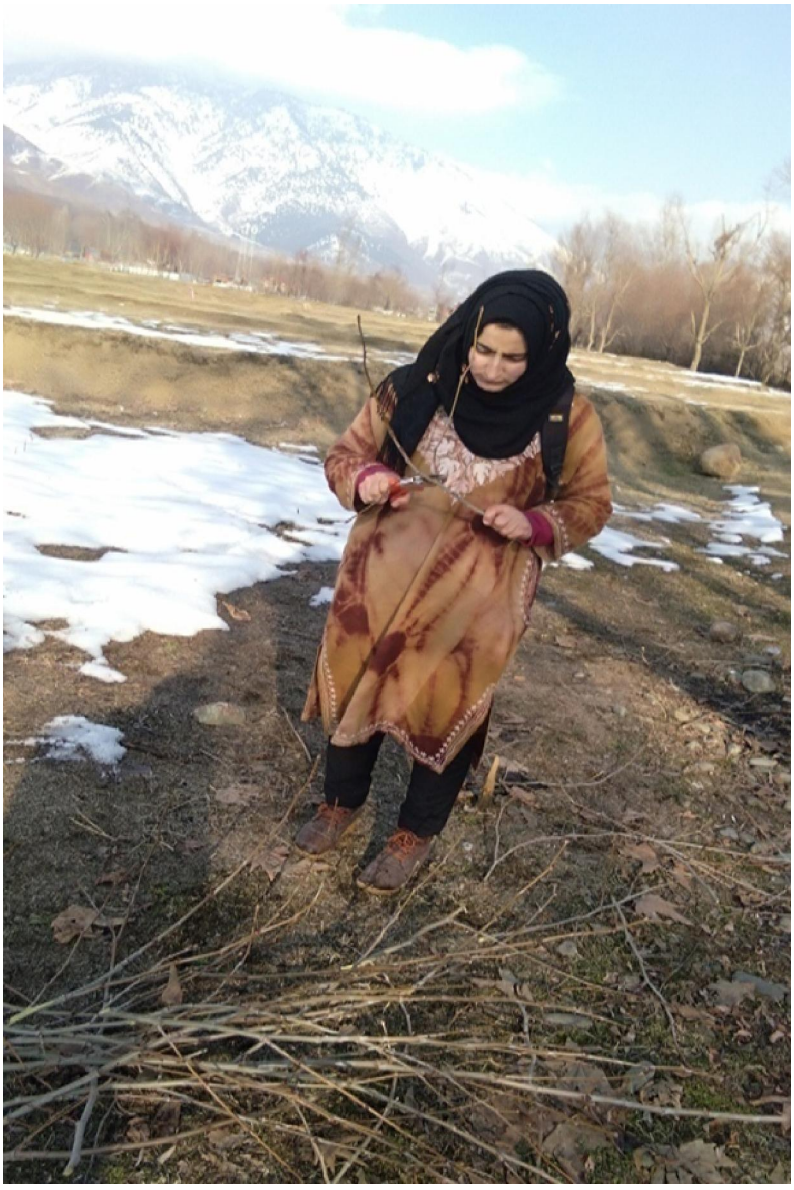
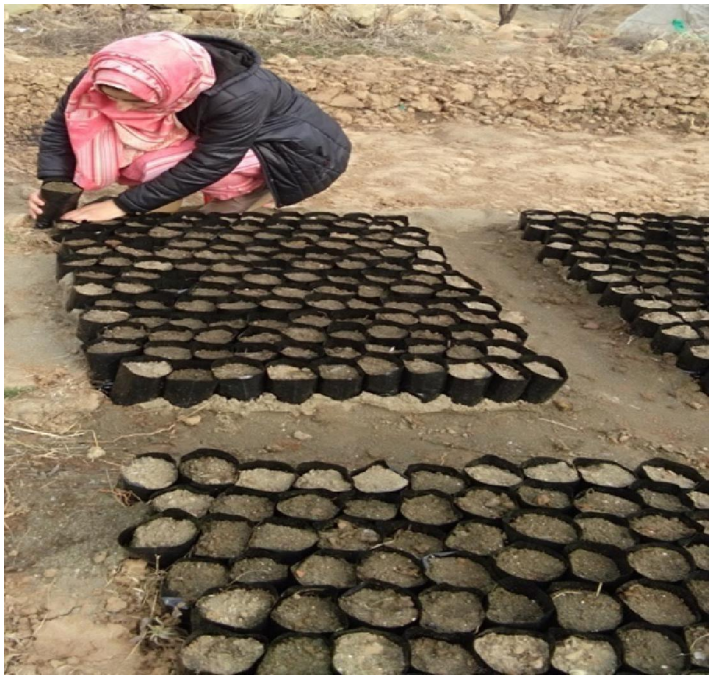


Plate 10: Collection of cuttings



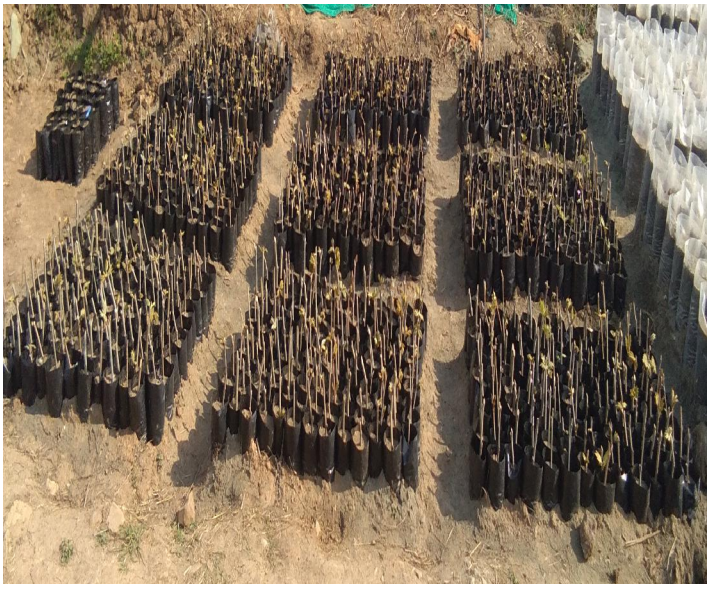


Plate 11: Laying of trial

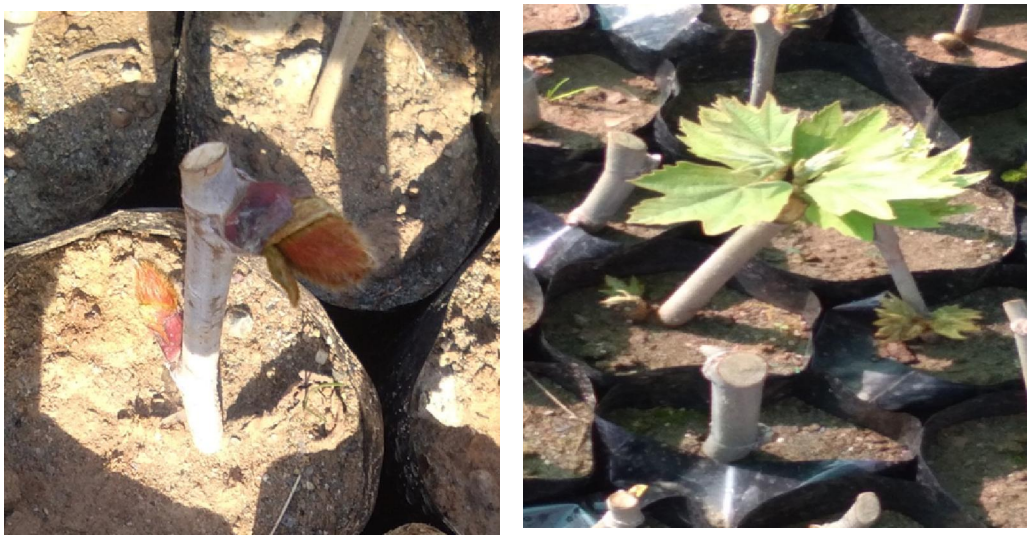


Plate 12: A view of sprouting and leaf formation in field

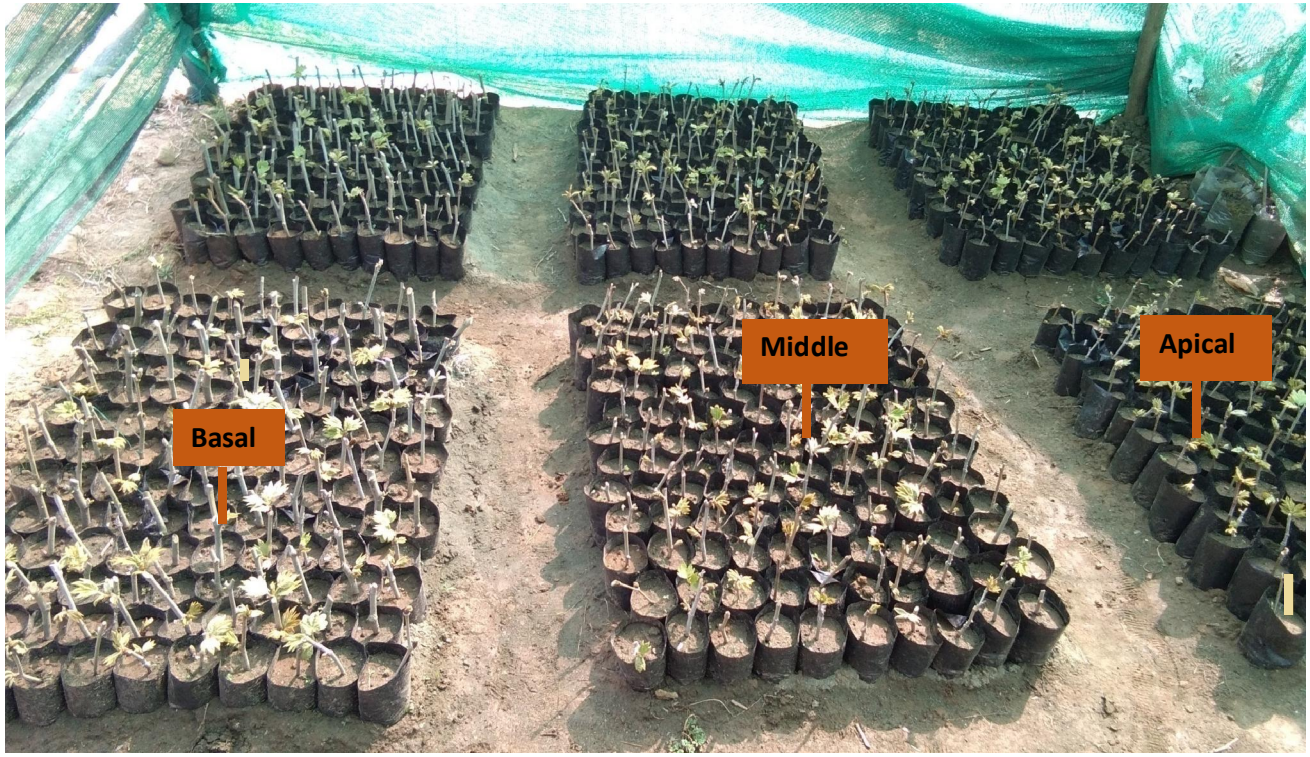


Plate 13: Sprouting in different cutting sections

Apical **Middle** **Basal**

Plate 14: Comparative shoot and root lengths of different cutting sections

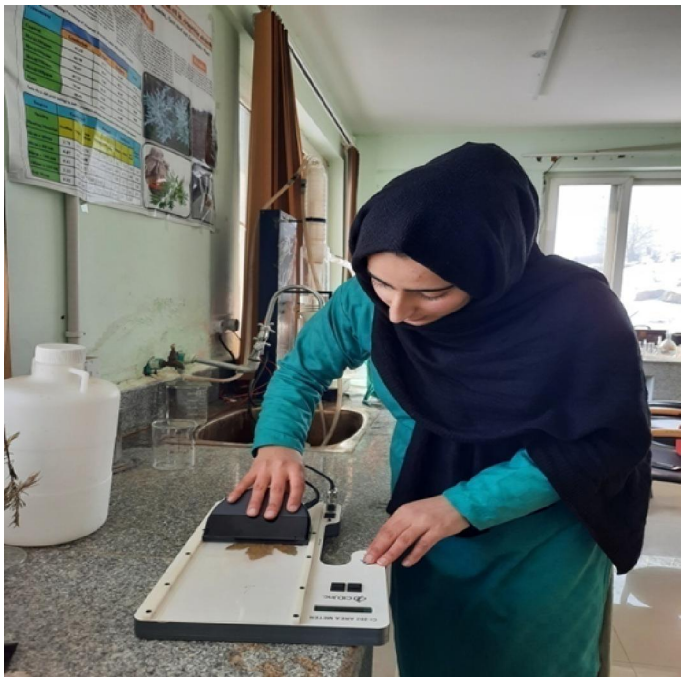


Plate 15: Leaf area measurement

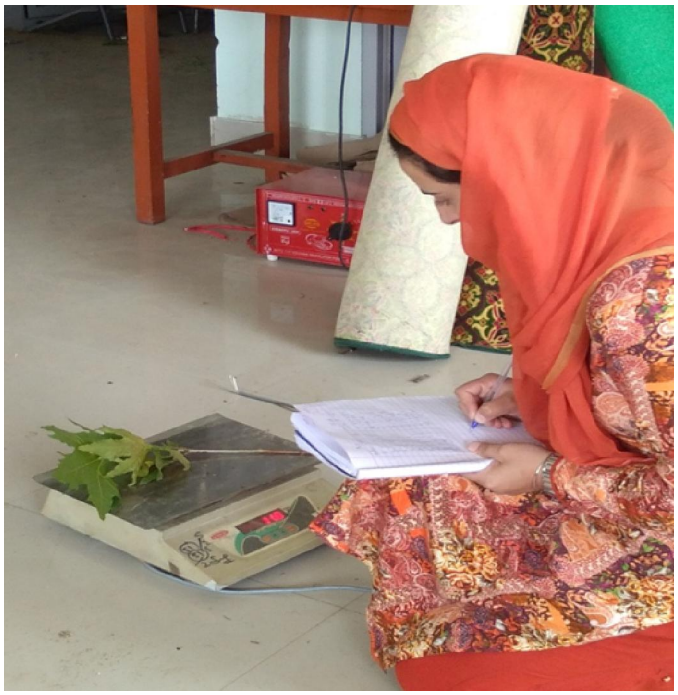


Plate 16: Biomass measurement

Chapter- 5

DISCUSSION

In this chapter, the results of experiment entitled as **"Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings"** have been evaluated with the help of probable justification and opinions published by various scientists for a clear understanding of the occurrences. The findings obtained are discussed under the following headings:

5.1 Determination of variability in germination parameters of *Platanus orientalis* L. seed

5.2 Standardization of optimum concentration of growth hormones for rooting of *Platanus orientalis* L. cuttings, and

5.3 Determination of best section of branches for rooting of *Platanus orientalis* L. cuttings

5.1 Determination of variability in germination parameters of *Platanus orientalis* L. seed.

5.1.1 Tree height and DBH (m)

Tree height was measured for ten randomly selected trees and it ranged from 16 m to 30 m, highest (30 m) being recorded for the tree (T_1) selected from Tulmulla. Also, the range of DBH among the selected trees was from 4.99 m to 2.28 m, the maximum (4.99 m) being recorded for the tree (T_5) of Tulmulla. Also, average seed weight for 1000 seeds was recorded maximum (5.51 g) for the seeds collected from the tree (T_5) located at Tulmulla. Similar results were reported by Yadav *et al.* (2005) in *Dalbergia sissoo* Roxb., Vyas and Bansal (2007) in *Bombax ceiba,* Dhillon *et al.* (2007) in *Azadirachta indica,* Kaushik *et al.* (2011) in *Pongamia pinnata* (L.) Pierre and Daneva *et al.* (2018) in *Ailanthus excelsa*.

5.1.2 Effect of stratification period (P)

5.1.2.1 Effect of stratification period on germination and seedling growth characteristics

In present study, seeds of *Platanus orientalis* L. were stratified for 0 (P_0), 10 (P_1), 20 (P_2), 30 (P_3), 40 (P_4), 50 (P_5) and 60 (P_6) days to know its effect on various germination parameters like germination percent (GP), germination energy (GE), mean daily germination (MDG), peak value (PV), germination value (GV), germination speed (GS), vigour index (VI) and seedling growth parameters viz., length of shoot (cm) and length of root (cm). It was observed that with increase in stratification periods from 0 to 60 days, there was an increase in all the germination parameters as well as growth characteristics. Results revealed significantly maximum values for germination (73.07%), germination energy (29.60), mean daily germination (2.85), peak value (4.03), germination value (12.08), germination speed (18.90), vigour index (5568.77), length of shoot (42.22 cm) and length of root (33.68 cm) when seeds were stratified for 60 days as compared to control. The study, thus, showed that there was an enhancement in germination and seedling performance with increase in stratification period.

Basically, seed dormancy involves the interaction between the plant growth regulators. These regulators may be either inhibitors or promoters and act together to influence the net result of germination or dormancy. During the process of stratification, (a) enzyme systems are triggered (b) stored food material is converted into soluble forms (c) balance of promoter/inhibitor is changed.

These results are consistent with the findings of Kumar (2013), who revealed that germination and seedling growth of *Pinus gerardiana* have increased with increase in stratification period. Similarly, Koyuncu (2005) found that increase in stratification period from 0 to 100 days resulted in an increase of 116% in the germination of dormant *Morus nigra* seeds. Moreover, same findings were reported by Kumar (2014) in *Acer acuminatum,* Farhadi *et al.* (2013) in *Acer*

velutinum, Dogra (2003) in *Picea smithiana* and *Abies pindrow*, Sofi and Bhardwaj (2007) in *Cedrus deodara*.

These studies and our findings indicate that stratification is beneficial in breaking dormancy of seeds, although the treatment period can differ with species.

5.1.3 Effect of tree (T)

5.1.3.1 Effect of tree on germination and seedling growth characteristics

Among ten selected trees, maximum germination (61.35%), germination energy (32.19), mean daily germination (2.43), peak value (3.21), germination value (9.15), germination speed (15.00), vigour index (3939.39), length of shoot (37.19 cm) and length of root (24.04 cm) was recorded was for the seeds collected from Tulmulla and seedlings raised thereafter. Germination and seedling growth characteristics delineated consistent differences among all the ten trees and this might reflect the true genetic variation. Similar results were reported by Stephen (1974) in *Pinus strobus,* Bey (1979) in *Juglans nigra* and Vakshaya *et al.* (1992) in *Dalbergia sisoo*.

5.1.4 Genetic variability

The results clearly indicated that the phenotypic coefficient of variation (PCV) for all the characters was higher than the corresponding genotypic coefficient of variation (GCV) which clearly indicated that majority of characters were under genetic control. Highest PCV was recorded for vigour index (49.81), followed by length of root (40.57), germination energy (31.77), germination value (26.68), length of shoot (26.59), germination speed (18.98), germination percent (12.05), mean daily germination (11.99), 1000 seed weight (9.55) while as peak value exhibited lowest PCV (9.01). Genotypic coefficient of variation also showed the same trend, therefore, indicating close correspondence between the estimates of PCV and GCV. The highest GCV was recorded for vigour index (49.30), followed by length of root (39.90), germination energy (31.76), germination value (25.92), length of shoot (25.78), germination speed (18.44),

germination percent (11.82), mean daily germination (10.31), 1000 seed weight (9.42) while as peak value exhibited lowest GCV (7.68). These findings draw support from the findings of Gera *et al.* (2000) in *Acacia nilotica* Willd., Mukherjee *et al.* (2004) in *Pinus roxburghii* Sarg. and Selvan and Guleria (2012) in *Acacia catechu* Willd.

Heritability (broad sense) was categorized as low (below 30%), medium (30-60%) and high (above 60%) by *Jhonson et al.* (1995). Heritability in broad sense was high for all the characters. Heritability estimates were recorded highest for germination energy (99.90), followed by vigour index (97.90), 1000 seed weight (97.24), length of root (96.70), germination percent (96.10), germination speed (94.34), germination value (94.30), length of shoot (94.00), mean daily germination (73.89), while as peak value (72.71) recorded minimum heritability as compared to other characters. These findings are in line with those of Hooda and Raj Bahadur (1993) in *Leucaena leucocephala*, Mukherjee (2005) in *Pinus roxburghii*, Rawat and Bakshi (2011) in *Pinus wallichiana* and Singh *et al.* (2020) in *Acacia catechu* Willd.

Genetic advance was classified as low (0-10%), moderate (10-20%) and high (≥20%) as suggested by Jhonson *et al.* (1995). Genetic advance was recorded highest for vigour index (100.50), followed by 1000 seed weight (85.10), length of root (80.82), germination energy (65.39), germination value (51.85), length of shoot (51.49), germination speed (25.83), germination percent (23.87), whereas moderate genetic advance was recorded for mean daily germination (13.32) and peak value (12.82). These results were corroborated by Jayaprakash *et al.* (2010) in *Acacia nilotica* (Var. Indica), Milatovic *et al.* (2010) in Peach, Rawat and Bakshi (2011) in *Pinus wallichiana* and Singh *et al.* (2020) in *Acacia catechu* Willd.

High heritability coupled with high genetic advance was obtained for vigour index, 1000 seed weight, length of root, germination energy, germination value, length of shoot, germination speed and germination percent, which

indicates the predominance of additive gene action for controlling this trait, which means that this character can be improved simply through selection. High heritability coupled with low or moderate genetic advance was obtained for mean daily germination and peak value, which indicated non-additive gene action for expression of these traits and hence, selection for these traits may not be rewarding. These findings draw support from the findings of Milatovic *et al.* (2010) in Peach, Jayaprakash *et al.* (2010) in *Acacia nilotica* (Var. Indica), Islam *et al.* (2015) in Rice and Taneva *et al.* (2019) in Wheat

5.2 Standardization of optimum concentration of growth hormones for rooting of *Platanus orientalis* L. cuttings, and

5.3 Determination of best section of branches for rooting of *Platanus orientalis* L. cuttings.

Propagating plants by using different vegetative methods is an age-old practice in order to get true-to-type and early planting material. Among the various vegetative methods, the most common are cutting, grafting, layering and budding. There are many plant species which can be propagated by cuttings, but cuttings do not root easily. In such cases, cuttings are made to produce roots with the aid of auxins. IBA, NAA and IAA are the growth hormones that are selected for this purpose.

When placed in a favourable environment, it is the rooting ability of cutting that determines the success of vegetative propagation. Occasionally, root primordia are present on the stem of many plants, but may have to be triggered for producing roots. However, by applying plant growth regulators, the formation of root primordia and root development can be facilitated in many plant species.

The degree of rooting, however, largely depends on the part of the mother plant used. Moreover, stems are normally an excellent planting material since they typically have ample undifferentiated tissue to allow the easy differentiation of root primordia as they have already developed buds as well.

Sound initiation and development of roots, greater success and good root quality have been achieved by judicious application of IBA. Initiation of maximum number of primary and secondary number of roots leads to the increase in the total number of roots, which in turn, can result in manifold success of cuttings.

5.2.1 Effect of IBA (T)

5.2.1.1 Effect of IBA on rooting/survival percent of cuttings

Table-13 represents the data on the rooting/ final survival percent of cuttings. A comparatively higher percentage of rooting/survival was found in IBA-treated cuttings. While the percentage of rooting/survival under treated cuttings was lower.

Maximum rooting/survival (41.33%) was recorded for IBA@6000ppm (T_7). The maximum number of roots with substantial length was induced by this IBA treatment and thus provided a well-developed root system for better establishment of rooted cuttings. Lowest rooting/survival (29.39%) was recorded under untreated cuttings (T_1). The reason behind this might be that the application of IBA may have increased the speed of translocation and movement of carbohydrates to the base of cuttings and consequently triggered rooting (Aminah *et al.*, 1995), as the efficiency of auxins to facilitate adventitious root development in stem cuttings is well known (Ragonezi *et al*., 2010). These results draw support from the findings of Bhattacharjee and Balakrishna (1983) in jasmine, Bhattacharjee and Balakrishna (1991) in *Hiptage madhblota* and Hibiscus, Swamy *et al.* (2002) in *Grewia optiva* and *Robinia pseudoacacia*, Chovatia *et al.* (1995) in Bougainvillea.

5.2.1.2 Effect of IBA on root characters and root biomass

The different concentrations of IBA had a considerable effect on the root characters and root biomass. Root characters such as length of root, average

number of roots per plants and fresh and dry root biomass are shown in table 14, 15, 22 and 23.

All the concentrations of IBA affected root length and number of roots per plant. However, maximum root length (26.48 cm) and number of roots per plant (8.56) was recorded in IBA@6000ppm (T_7), while the minimum root length (13.07 cm) and number of roots (3.67) was recorded in Control (T_1). The reason behind this might be that the application of IBA led to the cell division and cell elongation, which promoted the root length (Abidin and Baker, 1984) or may be PGRs facilitated the hydrolysis and mobilisation of sugars and nutrients to the base of cuttings (Das *et al.,* 1997). Induction of highest number of roots may be attributed to the fact that, growth regulators in many species, stimulate cambial activity involved in root initiation as confirmed in Pea by Digby and Wanerman (1965).These findings are also in agreement with the findings of Mahmood *et al.* (2017) who reported increase in root length and number of roots per plant in *Paulownia tomentosa* on application of Seradix 3. Also, Qaddoury and Amssa (2004) in Date palm, Sharma *et al.* (2009) in *Punica garanatum*, Kurd *et al.* (2010) in Olive and Singh *et al.,* (2014) in *Duranta erecta* reported increase in root length and number of roots on application of IBA.

With respect to fresh and dry biomass of root, the results revealed that among different concentrations of IBA, IBA@6000ppm (T_7) recorded maximum fresh and dry biomass (15.49 g) and (5.11 g) respectively. The minimum fresh and dry biomass (6.01 g) and (1.98 g) was recorded under Control. This can be attributed to the maximum root length and number of roots per plant obtained by this concentration. These findings also draw support from the findings of Gehlot *et al.,* (2014) who confirmed increase in biomass of root system on application of IBA while working on *Azadirachta indica.* Also, Chalfun *et al.* (2003) in *Ficus carica* L., Ingole *et al.* (2015) in *Ficus benjamina* L. and Hussein and Khurshid (2017) in *Olea europaea* L. reported similar findings of increase in biomass of root on application of IBA.

5.2.1.3 Effect of IBA on shoot characters and shoot biomass

The impact of IBA on cuttings varied considerably with respect to above ground i.e., shoot characters in the present study. Shoot characters viz., sprouting percent, length of shoot, average number of branches per plants, leaf area, collar diameter, fresh and dry biomass of shoot are shown in tables 12, 16, 17, 18, 19, 20 and 21 respectively.

The findings showed that in terms of sprouting percent, various IBA levels differed significantly from each other. IBA@6000ppm (T_7) recorded the maximum sprouting (98.89%), which was superior over all the other treatments. The lowest (72.22%) was recorded in Control (T_1). It was also found that a sharp decrease in sprouting percent of cuttings occurred at higher concentrations (beyond 7000ppm). The upsurge in sprouting percent of cuttings treated with IBA may have resulted from the stimulation of hydrolysis of nutrient reserves and their mobilization. Sprouting in control may have occurred due to the already stored carbohydrates in the cuttings. Differences in sprouting between treatments may be caused by the varying levels of auxin absorption by cuttings. Nanda *et al.* (1975) confirmed that the use of auxin contributed to the breakdown of starch into soluble sugars, and most of this was used to produce new sprouts. Pain and Roy (1981) reported substantial sprouting gains due to the use of IBA and other chemicals in *Dalbergia sisoo*. Decline in sprouting at higher concentrations of IBA may be due to super-optimal quantities.

The maximum shoot length (35.38 cm) was found in IBA@6000ppm (T_7), which was superior over all the other treatments, while the lowest (17.66 cm) was found in Control (T_1). However, IBA at higher concentration (beyond 7000ppm) reduced the shoot length. These findings are in line with the findings of Nagaraja *et al.* (1991) in jasmine and Chovatia *et al.* in Bougainvillea (1995). Sarkisova (1964) and Chauhan and Maheshwari (1970) have also documented the ability of IBA to promote shoot growth in Vine and Peach cuttings respectively. Decrease in

shoot length at higher concentrations of IBA may be attributed to the toxic or inhibitory effect of IBA at higher levels.

Significant effects of IBA have been observed on number of branches per plant, collar diameter (mm) and leaf area (cm^2) of cuttings. Maximum number of branches per plant (2.67), collar diameter (6.45 mm) and leaf area (44.67 cm^2) was recorded at IBA@6000ppm (T_7), while the minimum number of branches (1.00), collar diameter (4.10 mm) and leaf area (20.62 cm^2)was recorded in Control (T_1). Zarad and Saleh (1994) confirmed that IBA may cause assistance for the development of root, which in turn leads to the absorption of elements as well as conversion of starch to soluble sugars that are transported, contributing to cell division and elongation, thereby improving the qualitative vegetative growth. These results are in conformity with the findings of Mahmood *et al.* (2017) who reported that the use of Seradix 3 enhanced the length of shoot, number of branches per plant, number of leaves per rooted cutting and collar diameter in *Paulownia tomentosa.* Moreover, Bhat and Tomar (2011) in *Citrus aurantifoliai,* Mehraj *et al.* (2013) in *Bougainvillea spectabilis,* Hussain *et al.* (2016) in *Ulmus villosa* and Kumar *et al.* (2017) in *Punica granatum* L. reported increase in shoot characters on application of IBA.

With respect to fresh and dry biomass of shoot, the results revealed that among different concentrations of IBA, IBA@6000ppm (T_7) recorded maximum fresh and dry biomass (21.56 g) and (9.43 g) respectively. The minimum fresh and dry biomass (10.07 g) and (4.52 g) respectively, was recorded under Control (T_1). This can be attributed to the maximum shoot length, number of branches per plant and collar diameter obtained by this concentration. These findings are in line with the findings of Al-Ma'athid *et al.* (2009) who reported increase in the fresh and dry weight of shoot system on application of Seradix in *Pelaryonium zonale*. Similar findings were reported by Gehlot *et al.* (2014) in *Azadirachta indica,* Hussein and Khurshid (2017) in *Olea europaea* L., Mahmood *et al.* (2017) *Paulownia tomentosa*.

5.2.2 Effect of cutting section (S)

5.2.2.1 Effect of cutting section on rooting/survival percent of cuttings

In present study, three types of cuttings viz., apical (S_1), middle (S_2) and basal (S_3) of *Platanus orientalis* L. were used. Table-13 clearly indicates that there was a significant impact of cutting section on the rooting of cuttings. Among the three types of cuttings, maximum (45.18%) rooting/survival was recorded in basal cuttings (S_3), whereas, apical cuttings (S_1) recorded the minimum rooting/survival (26.38%). The reason behind this may be that apical cuttings are less mature, so it is easy to lose water, dry out and die (Khan *et al.,* 2006) or basal cuttings possess more natural accumulation of endogenous auxin than apical cuttings, which facilitates the initiation and development of roots (Lebrun and Roggemans, 1998). These findings draw support from the findings of Ibironke (2013) who reported that basal cuttings of *Duranta repens* rooted better than apical cuttings. Also, similar findings have been reported by Al-Saqri and Alderson (1996) in *Rosa centifolia* and Soundy *et al.* (2008) in *Lippia javanica* L.

5.2.2.2 Effect of cutting section on root characters and root biomass

Significant effects of cutting sections on the root length and number of roots per plant have been recorded. The results presented in table-14 and 15 indicates that maximum root length (24.59 cm) and number of roots per plant (7.77) was recorded in basal cuttings (S_3), while as minimum root length (15.73 cm) and number of roots per plant (4.56) was recorded in apical cuttings (S_1). These results are consistent with the findings of Ochoa *et al.* (2002) in *Nerium oleander* L. who reported that the basal cuttings produced maximum root length and number of roots as compared to apical cuttings.

With respect to fresh and dry biomass of root, the results presented in table-22 and 23 revealed that among three cutting sections, basal cuttings (S_3) recorded maximum fresh and dry biomass (21.56 g) and (9.43 g) respectively, whereas minimum fresh and dry biomass (10.07 g) and (4.52 g) respectively was

recorded for apical cuttings (S_1). This can be attributed to the maximum root length and number of roots per plant gained by this cutting section (Al- Bebewat, 2011). These results are in conformity with the findings of Zalensy *et al.* (2011) in Populus and Mahmood *et al.* (2017) in *Paulwonia tomentosa.*

5.2.2.3 Effect of cutting section on shoot characters and shoot biomass

The results in table-12 clearly indicate that maximum sprouting (89.67) was recorded for apical cuttings (S_1), whereas basal cuttings recorded minimum sprouting (82.31%). These findings are in line with the findings of Ali *et al.* (2008) who reported that apical cuttings of *Berberis aristata* DC. gave higher sprouting as compared to middle and basal cuttings.

The results presented in table- 16, 17, 18 and 19 indicate that basal cuttings (S_3) recorded maximum shoot length (33.32 cm), average number of branches per plants (2.54), leaf area (39.04 cm^2), collar diameter (6.18 mm) respectively. Minimum values for shoot length (21.29 cm), average number of branches per plants (1.38), leaf area (31.45 cm^2), collar diameter (4.59 mm) was recorded for apical cuttings (S_1). This might be attributed to the fact that different types of cuttings, which differed from one another in the amount of storage nutrient substrates, basal cuttings contain more storage nutrient substrates than intermediate and apical cuttings which contribute to cell division and elongation, leading to the growth and improvement in shoot characters. These results are in line with the findings of Ayan *et al.* (2006) in *Alnus glutinosa*, Ibironke (2013) in *Duranta repens* and Kumar *et al.* (2017) in *Punica granatum.*

Results presented in table-20 and 21 revealed that among three cutting sections, basal cuttings (S_3) recorded maximum fresh and dry biomass (21.67 g) and (7.96 g) respectively, whereas minimum fresh and dry biomass (11.68 g) and (5.33 g) respectively was recorded for apical cuttings (S_1). This can be attributed to the maximum shoot length, average number of branches per plants, leaf area and collar diameter gained by this cutting section (Al- Bebewat, 2011). These findings draw support from the findings of Zalensy *et al.* (2011) in Populus, Kumar *et al.* (2017) in *Punica granatum* and Mahmood *et al.* (2017) in *Paulwonia tomentosa.*

Chapter-6

SUMMARY AND CONCLUSION

The present investigation entitled "Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings" was conducted in the experimental field of Division of Forest Biology and Tree Improvement, Faculty of Forestry, Benhama during the years 2018 and 2019.

The results obtained and observations recorded during the course of study are summarized as under:

6.1 Determination of variability in germination parameters of *Platanus orientalis* L. seed.

The experiment was laid in Completely Randomised Design (Factorial). In all, there were seventy treatment combinations comprising of seven stratification durations (0,10, 20, 30, 40, 50 and 60 days) and ten different trees were selected randomly from different locations of District Ganderbal to study the variability in germination parameters of *Platanus orientalis* L. seed.

The tree characters recorded were tree height, DBH, seed, germination and growth characters recorded were 1000 seed weight, germination percent, germination energy, mean daily germination, peak value, germination value, germination speed, vigour index, length of shoot, length of root and genetic parameters like PCV, GCV, heritability and genetic advance.

In case of stratification periods, maximum germination (73.07%), germination energy (29.60), mean daily germination (2.85), peak value (4.03), germination value (12.08), germination speed (18.90), vigour index (5568.77), length of shoot (42.22 cm) and length of root (33.68 cm) was recorded when seeds were stratified for 60 days.

In case of different trees, tree (T_5) located at Tulmulla gave highest value for all the tree as well as germination and seedling growth parameters viz., tree height (30 m) and DBH (4.99 m), 1000 seed weight (5.51 g), germination percent (61.35%), germination energy (32.19), mean daily germination (2.43), peak value (3.21), germination value (9.15), germination speed (15.00), vigour index (3939.39), length of shoot (37.19 cm) and length of root (24.04 cm) respectively as compared to other trees.

As far as genetic parameters are considered, highest PCV was recorded for vigour index (49.81), followed by length of root (40.57), germination energy (31.77), germination value (26.68), length of shoot (26.59), germination speed (18.98), germination percent (12.05), mean daily germination (11.99), 1000 seed weight (9.55) while as peak value exhibited lowest PCV (9.01). The highest GCV was recorded for vigour index (49.30), followed by length of root (39.90), germination energy (31.76), germination value (25.92), length of shoot (25.78), germination speed (18.44), germination percent (11.82), mean daily germination (10.31), 1000 seed weight (9.42) while as peak value exhibited lowest GCV (7.68).

Heritability estimates were recorded highest for germination energy (99.90), followed by vigour index (97.90), 1000 seed weight (97.24), length of root (96.70), germination percent (96.10), germination speed (94.34), germination value (94.30), length of shoot (94.00), mean daily germination (73.89), while as peak value (72.71) recorded minimum heritability as compared to other characters.

Genetic advance was recorded highest for vigour index (100.49), followed by 1000 seed weight (85.10), length of root (80.82), germination energy (65.39), germination value (51.85), length of shoot (51.49), germination speed (25.83), germination percent (23.87), whereas moderate genetic advance was recorded for mean daily germination (13.32) and peak value (12.82).

6.2 Standardization of optimum concentration of growth hormones for rooting of *Platanus orientalis* L. cuttings, and

6.3 Determination of best section of branches for rooting of *Platanus orientalis* L. cuttings.

The experiment was laid in Completely Randomised Design (Factorial). In all, there were thirty nine treatment combinations comprising of twelve concentrations of IBA (1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000, 11000 and 12000ppm) and Control with three cutting sections (apical, middle and basal) to study the response of IBA and different types of branch cuttings in *Platanus orientalis* L.

The observations recorded were sprouting percent, length of shoot, number of branches per plant, leaf area, collar diameter, fresh and dry biomass of shoot, length of root, number of roots per plant, fresh and dry weight of root and survival percent. Results with respect to all the characters were found significant. In case of IBA concentrations, cuttings of *Platanus orientalis* L. treated with IBA@6000ppm (T_7) yielded best results for all the growth parameters viz., sprouting (98.89%), rooting/survival (41.33%), root length (26.48 cm), average number of roots per plant (8.56), shoot length (35.84 cm), number of branches per plant (2.67), leaf area (44.67 cm^2), collar diameter (6.45 mm), fresh and dry biomass of shoot (21.57 g) and (10.97 g) respectively, fresh and dry biomass of root (15.49 g) and (5.11 g) respectively. In case of cutting sections, basal cuttings (S_3) proved to be superior as they recorded highest results for all the characters like rooting/survival (45.18%), root length (24.59 cm), average number of roots per plant (7.77), shoot length (33.32 cm), number of branches per plant (2.54), leaf area (39.04 cm^2), collar diameter (6.18 mm), fresh and dry biomass of shoot (21.67 g) and (7.96 g) respectively, fresh and dry biomass of root (14.14 g) and (4.67 g) respectively.

Conclusion

From the experimental findings, presented and discussed in the preceding chapters, following conclusions can be drawn

- Out of various stratification periods, stratification for a period of 60 days enhanced seed germination as well as seedling growth characteristics of *Platanus orientalis* L. Hence, seeds of *Platanus orientalis* L. should be stratified for 60 days in order to get fast and uniform germination.
- Among ten different trees, tree located at Tulmulla was found to be superior with respect to all the germination and growth characteristics recorded. The present study, thus, identifies best seed tree for *Platanus orientalis* L. based on seed and seedling traits.
- The best concentration of auxin for vegetative propagation of *Platanus orientalis* L. is IBA@6000ppm since it greatly improved all growth parameters recorded as compared to control.
- IBA@6000ppm was most effective for rooting/survival of *Platanus orientalis* L. cuttings.
- The best section of cutting for vegetative propagation of *Platanus orientalis* L. is basal as it performed better in all characters recorded than apical and middle section of cuttings.
- In order to gain maximum rooting/survival, combination of IBA@6000ppm and basal cuttings should be used.

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C E R T I F I C A T E

Certified that all the corrections/amendments as suggested by External Examiner **Dr. Suheel Ahmad,** Senior Scientist (Forestry) ICAR, IGFRI RRS, Srinagar Viva-Voce examination held on 06-03-2021 have been incorporated in the manuscript entitled **"Variability in germination parameters and effect of growth hormones on propagation of Chinar (*Platanus orientalis* L.) through branch cuttings"** submitted by **Ms. Midhat Bilal (Regd. No. MSF-2018-101**).

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