EFFECT OF SEED PRIMING ON GERMINATION AND SEEDLING GROWTH IN AMLOOK (*Diospyros lotus* L.)

Thesis

by

REVA JARYAL
(H-2018-31-M)

submitted to

Dr. YASHWANT SINGH PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY SOLAN (NAUNI) HP - 173 230 INDIA

in

partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE) SEED SCIENCE AND TECHNOLOGY

DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY
COLLEGE OF HORTICULTURE

2020

Dr C L Sharma
Scientist
(Fruit Science)

Department of Seed Science and Technology
College of Horticulture
Dr. Yashwant Singh Parmar University of Horticulture and Forestry (Nauni) Solan (HP) - 173 230 India

CERTIFICATE-I

This is to certify that the thesis titled **"Effect of seed priming on germination and seedling growth in amlook (*Diospyros lotus* L.)"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture) Seed Science and Technology** in the discipline of **Plant Sciences** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173 230 is a bonafide research work carried out by **Ms. Reva Jaryal (H-2018-31-M)** daughter of Shri Santosh Kumar Jaryal under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

Place Nauni (Solan)
Dated

Dr C L Sharma
Chairman
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis titled, **"Effect of seed priming on germination and seedling growth in amlook (*Diospyros lotus* L.)"** submitted by **Ms. Reva Jaryal (H-2018-31-M)** daughter of Shri Santosh Kumar Jaryal to the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173 230 India in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture) Seed Science and Technology** in the discipline of **Plant Sciences** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an Internal Examiner.

Dr C L Sharma
(Major Advisor)
Scientist
Dept. of Seed Science and Technology

Dr Manisha Thakur
(Internal Examiner)
Associate Professor
Dept. of Biotechnology

Dr Devina Vaidya
(Dean's Nominee)
Professor
Dept. of Food Science and Technology

Members of Advisory Committee

1. **Dr Manish K Sharma**
   Professor and Head
   Dept. of Seed Science and Technology

2. **Dr B S Dilta**
   Principal Scientist
   Dept. of Seed Science and Technology

3. **Dr D P Sharma**
   Principal Scientist & Head
   HRTS & KVK, Solan at Kandaghat

Professor and Head
Dept. of Seed Science and Technology

Dean
College of Horticulture

ACKNOWLEDGEMENTS

At this juncture, while writing acknowledgements myriads of thoughts are rushing up to my mind. But before divulging anything out let me first express my solemn reverence to the Supreme Power of the universe ***God the Almighty*** *for bestowing me all these endowment which are required to accomplish, the venture like this.*

First and foremost, my utmost gratitude to chairman of my advisory committee ***Dr CL Sharma*** *(Scientist, Department of Seed Science and Technology) for his invaluable advice, constructive comments, suggestions, guidance, motivation and for sharing his broad knowledge. He has been very generous in providing the necessary resources to carry out my research. Your advice on research has been priceless. He was always beside me during the happy and hard moments to motivate me.*

Almighty! The Supreme Being has showered his love by blessing me with the parents like you. It is with a personal touch of emotions that I seize this rare opportunity to express my gratitude to my beloved parents ***Mr. Santosh Kumar Jaryal*** *and* ***Mrs. Savita Jaryal*** *Brother* ***Akshay Jaryal,*** *my respected grandparents* ***Shri. Duni Chand Jaryal*** *and* ***Smt. Mahesho Devi,*** *uncle* ***Mr. Vijay Jaryal,*** *aunt* ***Mrs. Reena Jaryal*** *and cousins* ***Jiya*** *and* ***Kanishk*** *and other family members for their oceans of love and moral support. I am overwhelmed to their everlasting love, innumerable sacrifices, endless support, selfless care, constant inspiration and blessings which have always pushed me move ahead.*

I am greatfulness to my advisory committee members viz. ***Dr Manish K Sharma*** *(Professor and Head, Department of Seed Science and Tecnhology),* ***Dr BS Dilta*** *(Principal Scientist, Department of Seed Science and Technology) and* ***Dr DP Sharma*** *(Principal Scientist and Head, HRTS and KVK, Solan at Kandaghat) for their suggestions and help during my study period and research work. I also wish to thank* ***Dr RS Rana, Dr Narender K Bharat*** *and* ***Dr Rajender Sharma*** *for their guidance during the discourse of my academic pursuits.*

Life would have been incomplete and colourless without my 'The Best Buddies' Thankyou ***Bhag Singh, Ashima, Juby, Nikhil, Divesh, Komal, Kiran, Mohini, Vipul, Priya, Deepak, Bharti.***

Rewinding my life that I spent in Nauni, I would like to affectionately remember the company of my friends ***Yukti, Pavitra, Diksha, Aarzoo, Anu, Shivani, Shikha, Shree, Akwal, Bhisham, Ankush, Lalit, Nitesh, Shreya, Shailja, Shabnam, Akhilesh, Walia Sir, Vinay, Arushi.*** *I express my immense and whole hearted thanks to* ***Garima Verma*** *very encouraging and supportive senior, who helped me during the course of study and research.*

I cordially acknowledge the assistance extended by office, lab and field staff of Department of Seed Science and Technology, especially Vinay uncle, Roop Singh Uncle and Inder Uncle for timely and sincere help during the course of examination. Last but not the least, I am thankful for direct and indirect help received from various quarters but not mentioned here because of slip of mind and pen.

Needless to say Errors and Omissions are mine.

Place Nauni, Solan
Dated __/__/2020

(Reva Jaryal)

CONTENTS

ABBREVIATIONS USED

%	:	Per cent
&	:	And
*	:	Significant
/	:	Per
@	:	At the rate
+	:	Plus
=	:	Equal to
>	:	Greater than
×	:	Multiplication
ABA	:	Abscisic acid
ANOVA	:	Analysis of Variance
BA	:	Benzyl adenine
CD	:	Critical Difference
cm	:	Centimetre
cm^2	:	Square centimetre
cv.	:	Cultivar
DAS	:	Days after sowing
df	:	Degree of freedom
DMSO	:	Dimethyl sulphoxide
DNA	:	Deoxyribo nucleic acid
ed.	:	Edition
eds.	:	Editors
et al.	:	Co-workers
etc.	:	Et cetera
F-cal	:	F-calculated
Fig.	:	Figure
FYM	:	Farm yard manure
g	:	Gram
GA_3	:	Gibberellic acid
ha	:	Hectare
HP	:	Himachal Pradesh
hrs	:	Hours
i.e.	:	That is

IAA	:	Indole-3-Acetic Acid
kg	:	Kilogram
KNO_3	:	Potassium nitrate
L	:	Litre
m	:	Metre
m^2	:	Square metre
mg	:	Milligram
ml	:	Millilitre
mm	:	Millimeter
NAA	:	1-Naphthalene acetic acid
$^{\circ}C$	:	Degree Celsius
OD	:	Optical density
PBZ	:	Paclobutrazol
pH	:	Pouvoir Hydrogen
ppm	:	Parts per million
PSB	:	Phosphate solubilising bacteria
RBD	:	Randomized Block Design
RH	:	Relative Humidity
SE	:	Standard Error
UHF	:	University of Horticulture and Forestry
VAM	:	Vesicular arbuscular mycorrhizae
var.	:	Variety
viz.	:	Videlicet (namely)
α	:	Alpha

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

Chapter-1

INTRODUCTION

Amlook (*Diospyros lotus* L.) is commonly used as a rootstock for raising cultivated persimmon because of its high grafting affinity and strong resistance to drought and low winter temperatures. Persimmon belongs to the family Ebenaceae, is the most economic species of the genus *Diospyros*. In India, persimmon is locally called Japaniphal or the Japanese fruit. It is a deciduous fruit tree adapted to warm temperature and sub-tropical climate. At present, the commercial plantings of persimmon exist in Japan, Korea, Australia, USA, Brazil, Italy, Israel and New Zealand. Persimmons are high in vitamin A and C containing 2710 IU of vitamin A per 100 grams of fruit and 11 mg of ascorbic acid per 100 grams of fruit (Griffith *et al*., 1982).

In India, persimmon is grown on a semi-commercial scale in the states like Himachal Pradesh, Jammu and Kashmir, Uttarakhand and Tamil Nadu and as a scattered plantation in some parts of North East and Nilgiri Hills in South India. In Himachal Pradesh, it was introduced in Kullu valley by Capt. A.N. Lee in 1921 and has since been found to grow successfully at elevations ranging from 500 to 900 m above mean sea level.

Although, persimmon offers great potential for successful cultivation in the low and mid- hill regions of Himachal Pradesh, yet it is cultivated only in a limited scale mostly in Kullu, Mandi, Solan, Kangra and Shimla districts of the state. The total area under persimmon cultivation in Himachal Pradesh was 523 hectares with a production of 877 MT (Anonymous, 2019).

Persimmon is hard to propagate by cuttings. Thus, producing rootstocks from seeds for grafting is critically required. Persimmon is commercially propagated by grafting the desired variety on seedling rootstocks. Hard seed coat affects seed germination through inhibiting and mechanically restricting the embryo growth (Taha, 1987). Therefore, persimmon seeds are hard to germinate and need additional treatments to break dormancy and to have uniform germination. Such germinated seeds are used as rootstocks for grafting with suitable variety.

Due to low germination of seeds, there is a need to enhance the germination through stratification and treatment of the seeds with certain chemicals, so as to increase the production of quality seedlings of persimmon for rootstock purpose (Peche *et al*., 2016). The plant hormones play an important role in the growth and development of plants. Progressive increase in the vegetative characteristics like plant height, seedlings diameter, leaf area, number of leaves and scion-stock girth is generally influenced with the exogenous applications of growth regulators in many plants (Srivastava and Singh, 1967).

Many investigators have studied the effect of exogenous growth regulators on seed germination in many fruit crops including persimmon. It is well documented fact that gibberellins are known to substitute the chilling requirements of peach and apple seeds and ultimately increase their germination (Mehanna *et al*., 1985).

Breaking seed dormancy to enhance germination is controlled by some physical factors like light, temperature, moisture and by the endogenous growth regulating hormones (GA and ABA). Gibberellins stimulate the seed germination whereas, ABA is involved in the establishment and maintenance of dormancy (Debeaujon and Koornneef, 2000).

Gibberellic acid in seed exerts its influence in two manners, first by increasing the growth potential of embryo and second by inducing hydrolytic enzymes. During seed germination, embryonic gibberellic acid is released that triggers the weakness of seed cover by stimulating gene expression involved in cell expansion (Finkelstein *et al*., 2008). Gibberellins represent a natural regulator of the processes involved in seed germination to stimulate the production of hydrolytic enzymes i.e., α-amylase in the aleurone layer of germinating seed grains.

Gibberellic acid has been reported to increase cell division (Sachs *et al*., 1959) and cell enlargement (Haber and Leopold, 1960; Haber *et al*., 1969). Gibberellins stimulate cell elongation by altering the rheological properties of the cell wall. As a consequence, the water potential of the cell wall is lowered allowing for water uptake and therefore an increase in cell volume (Jones and Kaufman, 1983).

Certain chemicals like thiourea and potassium nitrate are widely used to break seed dormanacy (Agrawal and Dadlani, 1995). During recent years, thiourea has been widely used for enhancing plant growth, stress tolerance and crop yield. However, thiourea overcomes

certain types of dormancy, such as the seed-coat inhibiting effect of deep embryo-dormant seeds (Hartmann *et al*., 1997). These chemicals are also used to improve the seed germination. Thiourea improve the germination as it has a strong neutralizing effect on inhibitors present in seed or may be due to variation in characteristic of thiourea (Hore and Sen, 1994). The use of potassium nitrate has also been an important seed treatment for promoting germination. Potassium nitrate has been known as suitable chemical approach for promoting germination in various plant species and generally as a halo-priming agent for germination (Shim *et al*. 2008).

Therefore, keeping in view the above facts, the present studies have been carried out with the following objective:

- To study the effect of seed priming with $GA_{3,}$ Thiourea and KNO_3 on seed germination, seedling growth and quality parameters in amlook

Chapter-2

REVIEW OF LITERATURE

Seed priming play an important role in seed germination and enhancing subsequent seedling growth of horticultural crops. In the present chapter, efforts have been made to review the work done by other workers in India and abroad on propagation of persimmon and other fruit plants. The brief resumes of the studies conducted by several workers and their findings related to this study are presented under the following heads:

2.1 INFLUENCE OF GA_3, THIOUREA AND KNO_3 ON SEED GERMINATION

Hore and Sen (1994) studied the effect of pre-sowing seed treatment on germination, seedling growth and longevity of ber (*Zizyphus mauritiana* Lam.) seeds. Maximum germination was obtained with seeds pre-treated with 200 ppm GA_3 whereas, the germination was faster with 1 per cent thiourea. Gibberellic acid separately and in combination with nutrient (composed of 1 % Microshakti and 1000 ppm K_2HPO_4) caused maximum seedling growth.

Ak *et al.* (1995) performed the studies on the rate of germination, plant height and lengths of internodiums in the GA_3 treated seeds of Siirt pistachio variety. The seeds were soaked in different doses (0, 125, 250, 500 and 1000 ppm) of GA_3 solutions for either 24 or 48 hours. The results indicated the highest germination rate with the seed treatment of 125 ppm GA_3 and 48 hours soaking.

Pawshe *et al.* (1997) conducted the investigations on pre-germination seed treatment in aonla (*Emblica officinalis* Garten.) seeds. The seeds were treated with gibberellic acid (50 and 100 ppm), water soaking (24 hrs) and hot water soaking at 60°C (5 min). The results revealed that the seed treatment with GA_3 (50 and 100 ppm) increased the germination of seeds. However, the seed treatment with GA_3 @ 100 ppm and soaked for 24 hours was found to be effective in producing the tallest plants.

Verma *et al.* (1998) investigated the effect of GA_3 on seed germination of kiwifruit cultivars (Abbot, Allison, Bruno, Hayward, Monty). The extracted seeds were soaked in water as well as in 10, 20, 30 or 40 ppm solution of GA_3 for 24 hours and sown in pots

containing sand. The studies revealed the highest seed germination with GA_3 at 30 ppm with soaking period of 24 hours.

Ono (2000) conducted the studies on the effects of storage time and exogenous GA_3 treatment on lychee (*Litchi chinensis*) seed germination. The seeds were removed from ripe fruits, washed, dried, stored at 8°C for 0, 15 and 30 days and then soaked for 24 hours in water and GA_3 at 50, 100 and 200 mg/L solutions. It was found that as the storage period increased, the germination capacity decreased and seeds had a short germinability after 30-days of storage period. However, Gibberellic acid had no significant effect on enhancing both the germination percentage and rate.

Rahemi and Baninasab (2000) performed the experiment on beneh (*Pistacia mutica*) and kolkhong (*Pistacia khinjuk* Stock) the wild species of pistachio to study the effect of GA_3 (100, 250, 500, 750 and 1000 mg/litre) on seedling growth. It was observed that GA_3 application during and after stratification, significantly improved the length, trunk diameter, internodal length, leaf area and fresh and dry weight of seedlings of both species. Application of GA_3 after stratification was found to be more effective on seedling growth of beneh. Further, it was observed that the GA_3 applied at higher concentrations (500 and 750 mg/litre) increased the rate of seedling growth.

Ratan and Reddy (2003) studied the influence of KNO_3 on germination and seedling growth of custard apple (*Annona squamosa* L.). Seeds were soaked in 0.5 or 1 per cent potassium nitrate for 12 or 24 hours before sowing in raised beds. Seed germination was highest with seed soaking at 1 per cent potassium nitrate for 24 hours. Stem diameter and weight, and root weight increased with increasing seed soaking time and were found highest with seed soaking at 0.5 per cent potassium nitrate for 24 hours.

Ratan and Reddy (2004) studied the effect of gibberellic acid on seed germination and seedling growth of custard apple (*Annona squamosa* L.). Seeds were soaked in different concentrations of GA_3 i.e. 200, 400 and 600 ppm for 12 and 24 hours. The results revealed that GA_3 @ 400 ppm for 12 hours gave the highest seed germination percentage, plant height, root length and dry weight of stems and roots.

Koyunchu (2005) performed the studies on seed dormancy treatments in black mulberry (*Morus nigr*a L.) through cold stratification and gibberellic acid (250, 500, 1000

and 2000 mg/L). It was observed that the combined treatment of GA_3 @ 250 mg/L and stratification for 100 days possessed the highest seed germination. However, the seed treatment with GA_3 @ 1000 mg/L, when used individually was more effective than the other concentrations of GA_3.

Purbey and Meghwal (2005) performed the investigations on pre-sowing seed treatment with various concentrations of KNO_3 and GA_3 to improve the germination percentage and vigour of the aonla (*Emblica officinalis*) seedlings. The results revealed that maximum seed germination, root length and root diameter were observed in the seeds treated with 1 per cent KNO_3 for 18 hours. Besides, seedling height, number of leaflets and survival of the 100 days old seedlings were also significantly more in 1 per cent KNO_3 treatment.

Rao and Reddy (2005) observed that soaking of mango stones in GA_3 @ 100, 200 and 300 ppm, KNO_3 @ 1, 2 and 3 per cent and water for 12 hours increased the germination percentage and enhanced the rate of germination. It was concluded that GA_3 at 200 ppm for 12 hours was the best treatment, which exhibited the maximum germination percentage compared to other treatments.

Kumar *et al*. (2008) investigated the effect of pre-soaking treatments on germination, growth and graft take in mango. It was concluded that all the treatments promoted significantly earlier germination as compared to control. Mango stones pre-treated with 3 per cent panchagavya significantly took lower number of days for the initiation of germination, completion of germination, maximum germination percentage, rootstock diameter, number of leaves, graft success, graft survival percentage, sprout height and number of leaves per graft. GA_3 at 100 ppm showed the highest germination index and rootstock height and was at par with KNO_3 and water soaking.

Shinde *et al*. (2008) conducted the studies on the effect of pre-sowing seed treatments on seed germination, growth rate and survival percentage of Rangpur lime (*Citrus limonia*).The seeds were treated with distilled water (control), GA_3 (40, 60 and 80 ppm), NAA (40, 60 and 80 ppm), thiourea (1.0, 1.5 and 2.0 %), KNO_3 (1.0, 1.5 and 2.0 %), cow urine and cow dung paste. The result revealed that GA_3 at 80 ppm recorded 93.33 per cent seed germination followed by 90.00 per cent and 86.66 per cent seed germination with the application of NAA at 80 ppm and cow dung paste treatments, respectively.

Dhaka and Pal (2009) laid an experiment with three concentrations of GA_3 i.e. 450, 500 and 550 ppm and applied these by long dip method for 30, 35 and 40 hours to lime seeds. In the month of July, seeds were sown in pots after long dipping. It was observed that GA_3 at 500 ppm with seed soaking period of 40 hours resulted in better germination, growth and survival compared to other treatments.

Ahmad (2010) treated the seeds of two kiwi fruit varieties i.e. Bruno and Hayward with different concentrations of GA_3 (500, 1000, 1500, 2000 ppm) for a duration of 20 hours and stratified at 4.4ºC for 6, 8, 10 weeks and sown directly in open field conditions. Maximum seed germination (67.25 and 53 %) was observed with the application of GA_3 @ 2000 ppm in Bruno and Hayward, respectively.

Pawar *et al*. (2010) investigated the effect of gibberellic acid on seed germination and growth of *Jatropha curcas* L. Highest seed germination was obtained with treatment GA_3 @ 300 ppm for 4 hours, followed by minimum seed germination with GA_3 @ 300 ppm for 8 hours as compared to control. Similarly, maximum height, average number of leaves per plant, maximum diameter of stem of seedlings and maximum fresh weight of shoot and root was recorded in treatment of GA_3 at 300 ppm for 8 hours as against control. However, maximum dry weight of shoot was also recorded with GA_3 @ 300 ppm for 8 hours followed by GA_3 300 ppm for 6 hours, while the treatment GA_3 @ 300 ppm 8 hours produced maximum dry weight of root as compared to control.

Gharge *et al.* (2011) conducted the studies on the effect of different concentrations of gibberellic acid and soaking period on seed germination of custard apple. Maximum germination percentage was recorded with GA_3 @ 400 ppm. Regarding duration of soaking, soaking of seeds for 24 to 48 hours gave early, maximum germination percentage of the seedlings. In respect of interaction effect , it was observed that soaking of seeds in GA_3 400 ppm for 12 hours gave maximum germination percentage and seedling height. It was concluded that seed treatment of GA_3 at 400 ppm for 24 to 48 hours was helpful to get higher germination of custard apple seedlings.

Caliskan *et al*. (2012) investigated the influence of pre-sowing treatments (priming with water for 24 hours, GA_3 @ 500 and 1000 ppm for 24 hours, 3 % KNO_3 for 24 hours and stratification at 4°C for 7, 14 and 21 days) on seed germination and emergence of ‘Bursa Siyahi’ and ‘Sarilop’ fig cultivars. The highest germination percentage and emergence was

obtained with GA_3 @ 500 or 1000 ppm in both the cultivars. The application of GA_3 at 500 ppm or 1000 ppm reduced the time to germination and emergence from the seeds of both cultivars.

Al-Hawezy (2013) studied the effect of GA_3 (200, 250 and 300 mg/L) on seed germination and seedling growth of loquat (*Eriobotrya japonica* L.). The seeds were treated at different soaking durations of 12, 24 and 36 hours for production of the quality seedlings. The results revealed that GA_3 @ 250 mg/L increased the seed germination, however, GA_3 @ 300 mg/L increased the shoot and root length of seedlings and vigour index. Further, it was observed that the higher GA_3 concentrations (>250 mg/L) decreased the seed germination rapidly.

Brijwal and Kumar (2013) conducted investigations on the seed germination and subsequent seedling growth of guava. It was noticed that the pre-soaking of guava seeds in HCl acid (10 %) for 2 minutes resulted in maximum seed germination. Scraping of seed coat with sand paper + seeds soaked in GA_3 @ 50 ppm for 24 hours increased the seedling height, stem girth, number of leaves per seedlings and leaf area. However, highest root length was recorded in scraping of seed coat with sand paper + seeds soaked in GA_3 @ 100 ppm for 24 hours. Sowing of seeds without pre-sowing treatments resulted into poor germination and growth parameters.

Kumar and Shahnaz (2013) studied the effect of chemical treatments and stratification on wild apricot (*Prunus armeniaca* L.) seeds. Seeds were treated with different chemicals such as GA_3 (250, 500, 750 ppm), thiourea (0.2, 0.4, 0.6 %) and KNO_3 (0.2, 0.3, 0.4 %) and noticed that the seeds treated with GA_3 @ 500 ppm proved to be the best treatment for enhancing the seed germination and growth of the seedlings of wild apricot.

Kalyani *et al*. (2014) studied the effect of pre-sowing seed treatments like water soaking, gibberellic acid, thiourea, hot water and acid treatments on germination percentage in guava cv. Sardarat. The highest seed germination percentage was recorded with GA_3 1000 ppm and 500 ppm respectively, which were superior to other treatments.

Gurung *et al.* (2014) performed the investigations regarding the effect of chemicals and growth regulators on germination, vigour and growth of passion fruit. The results indicated the maximum seed germination and germination index in seed treatment of thiourea

(1 %) whereas, maximum seedling height and number of leaves were recorded in seed treatment of GA_3 @ 500 ppm at 30, 60 and 90 days.

EL-Dengawy and Hussein (2014) conducted an experiment on the effects of treating persimmon (*Diospyros lotus*) seeds with moist-chilling, GA_3, BA or their combinations on seed germination and subsequent drought resistance of the resulted seedlings. The obtained results indicated that increasing the moist-chilling period from 4 to 8 weeks significantly increased the seed germination percentages and significantly decreased the time to 50 per cent germination.

Jadhav *et al*. (2015) studied the effect of plant growth regulators, chemicals and plant extract on seed germination and seedling growth of custard apple. The results revealed the significant differences with respect to effect of seed soaking in GA_3 @ 50 ppm for 48 hours on days required for germination, germination percentage, seedling height, stem diameter and number of leaves per seedling of custard apple. It was concluded that seed treatment of GA_3 @ 50 ppm for 48 hours was effective to get higher germination and seedling growth of custard apple.

Parvin *et al*. (2015) studied the effect of GA_3 and cold stratification on germination of Eastern black walnut. The treatment consist of seed priming with GA_3 @ 400 and 800 ppm for 24 hours, cold stratification for one month and two months and the combined treatments of cold stratification and GA_3. It was observed that the germination rate for separate application of both concentrations of GA_3 was zero, as no seeds germinated. The highest percentage of seed germination as well as improved growth parameters was recorded with the combined treatment of two months chilling and GA_3 (400 ppm).

Thakur (2015) investigated the effect of growth regulator, scarification and thiourea on seed germination in peach (*Prunus persica* L. Batsch) rootstock 'Flordaguard'. Seeds were sown at 10 days interval on three dates i.e. 15th December, 25th December and 5th January, after stratification, scarification and after soaking in GA_3 (100 and 200 ppm), thiourea (1% and 2 %) and kinetin (100 and 200 mg/l) for 24 hours before sowing. It was observed that seeds sown after scarification exhibited significantly higher percent of seed germination, minimum duration of seed germination and mortality rate. Irrespective of the treatments the maximum seed germination and minimum duration of seed germination was also recorded with seeds sown on 25th December.

Ramteke *et al.* (2015) studied the effect of GA_3 and growing media on germination and seedling growth of papaya. GA_3 @ 200 ppm was found to be superior regarding the seed germination as well as growth of papaya seedlings. Treatment combination of GA_3 @ 200 ppm with growing media soil: sand: cocopeat: vermi-compost (1:1:1:1) exhibited higher seed germination, seed vigour index, leaf area, length of tap root and survival percentage and recommended it as most suitable for growing of papaya nursery.

Samir *et al.* (2015) conducted an experiment on the effect of pre-sowing treatments on seed germination behaviour in khirni (*Manilkara hexandra*). Prior to sowing, seeds were treated with different priming treatments such as GA_3 (100, 200 ppm), thiourea (1, 2 %), potassium nitrate (1, 2 %) and control (without soaking) for 36 hours. Among the different treatments, significantly high germination, germination index, peak value and germination value were recorded for seeds treated with 100 ppm GA_3. Earliest emergence of seedlings was observed in the seeds soaked in 2 per cent KNO_3 whereas, the mean daily germination, seed vigour and germination energy were highest for seeds soaked in 200 ppm GA_3. It was concluded that GA_3 (100 or 200 ppm) may be recommended for improving seed germination of khirni.

Rawat (2016) investigated the influence of seed treatment with GA_3, thiourea, potassium nitrate, sodium thiosulphate and water soaking on germination, seedling vigour and survivability of custard apple (*Annona squamosa*) seedlings. It was observed that the seeds treatment with GA_3 @ 400 ppm proved superior in respect to seed germination, growth parameters *viz*., plant height, plant diameter, number of leaves, shoot and root parameters and survival rate of custard apple seedlings. Similarly, increased Leaf Area Index (LAI), Light Transmission Ratio (LTR), Leaf Area Duration (LAD) and Energy Interception (EI) were also observed under the same treatment.

Qureshi *et al*. (2016) conducted the investigations to know the impact of stratification and gibberellic acid on germination and seedling growth of walnut and found that the treatment of unsoaked + 30-days cold treatment + 100 ppm GA_3 significantly increased the seed germination, sprouting rate and vegetative growth parameters.

Dilip *et al*. (2017) conducted an experiment to study the effect of gibberellic acid on germination and seedling growth of Kagzi lime. It was found that GA_3 @ 80 ppm for 12 hours resulted maximum germination percentage, rate of seed germination, height of plant at

120 days after sowing. Similarly, number of leaves per plant, fresh and dry weight of shoot, length of tap root, number of secondary and fibrous roots, fresh and dry weight of root and survival percentage were also found to be higher under this treatment. Hence, it was concluded that the treatment GA_3 @ 80 ppm possessed the significant effect on the germination and seedling growth of Kagzi lime and may be recommended for obtaining better growth and yield.

Palepad *et al*. (2017) studied the effect of seed treatments on germination, seedling vigour and growth rate of custard apple (*Annona squamosa*). The data revealed that GA_3 @ 1000 ppm minimized the days taken for germination and improved the germination percentage alongwith increased growth parameters *viz*., seedling height, girth of plant, number of leaves, leaf area, fresh and dry weight of plant and survival percentage.

Patel *et al*. (2017) investigated the effect of media and GA_3 on seed germination of custard apple (*Annona squamosa* L.) cv. Sindhan. The results indicated that the treatment GA_3 @ 200 mg/L exhibited a significant effect on days taken to seed germination, germination percentage, germination and seed vigour index- I in custard apple.

Chiranjeevi *et al*. (2017) examined the influence of growth regulators, chemicals and biofertilizers on germination, seedling growth and vigour in aonla. Seeds were presoaked with different concentrations of GA_3, NAA (growth regulators), potassium nitrate (chemical) and Azotobactor, Azospirillum, VAM and PSB, (biofertilizers) for 12 hours and noticed the maximum germination percentage, faster rate of germination, seedling growth, highest vigour index of seedlings and earliest germination in treatment GA_3 at 200 ppm with a soaking period of 12 hours.

Bishwas *et al*. (2018) investigated the effect of GA_3 @ 2000, 4000 and 6000 ppm on germination parameters of three varieties of kiwi (Allison, Abbot and Bruno). It was observed that the seeds primed with GA_3 @ 4000 - 6000 ppm increased seed germination percentage, germination rate and lower mean germination time in Abbot and Allison.

Cetinbas and Koyuncu (2018) conducted an experiment on the improvement germination of *Prunus avium* L. seeds by gibberellic acid, potassium nitrate and thiourea. The results showed that the seed treatment with KNO_3 @ 7500 ppm after 120 days of stratification was more effective contributing 64.54 per cent germination of seeds with coat.

In seeds without coat, seed treatment GA_3 @ 500 ppm after 120 days of stratification gave 79.74 per cent germination.

Hota *et al*. (2018) laid an experiment to study the effect of GA_3 on germination, growth and survival of jamun. The treatments comprised of GA_3 @ 150, 300, 450 ppm and control. It was concluded that GA_3 at 450 ppm had maximum shoot height, number of leaves, girth of stem, highest root length, number of roots, fresh weight of shoot and root, dry weight of shoot and root and germination percentage.

Panda *et al*. (2018) invigilated the effect of GA_3 on seed germination and growth of Kagzi lime. Treatment GA_3 at 100 ppm recorded minimum days taken to germination, higher germination percentage, seedling vigour index-I and II. Significantly, highest survival percentage, maximum shoot length, number of leaves, seedling length, root length and fresh weight of seedling were also registered in gibberellic acid (GA_3 100 ppm).

Jadhav and Deshmukh (2019) studied the effect of growth regulators, chemical and organic wastes on the seed germination and seedling diameter of Rangpur lime. The treatments comprised of pre-soaking of seeds with GA_3 at 50 and 100 ppm, NAA at 50 and 100 ppm, KNO_3 at 1 and 2 per cent, cow urine 50 per cent and 100 per cent and cow dung paste and control. It was noticed that GA_3 at 100 ppm was the best treatment for germination under laboratory as well as field conditions.

Sayyad-Amin and Shahsavar (2019) conducted the studies on the effect of stratification duration of 0, 25, 50 and 70 days and GA_3 @ 0, 250, 500 and 750 mg/L on seed germination of *Diospyros lotus* L. The results revealed that the most germination rate was observed in GA_3 at 250 mg/L. Stratification for 70 days had the most germination per cent. The most germination uniformity was observed in GA_3 at 500 mg/L.

2.2 INFLUENCE OF GA_3, THIOUREA AND KNO_3 ON SEEDLING GROWTH

Taylor (1972) studied the influence of GA_3 on the growth of pecan seedlings. It was observed that the average height and diameter of seedlings treated with GA_3-lanolin was higher as compared to lanolin treated and untreated control. The average height and diameter data for the lanolin treated seedlings was remarkably similar to those of control plants. Further, it showed that gibberellins stimulated the growth, not the lanolin.

Pampanna *et al.* (1995) performed an experiment on the effect of growth regulators on seed germination and growth of seedling of sapota following GA_3, ethrel and GA_3 + etherel treatments at different concentration i.e. 200, 300, and 400 ppm. Pre soaking of seeds of sapota with cracked seed coat in GA_3 @ 300 ppm for 24 hours resulted in the highest germination whereas, GA_3 at 400 ppm recorded the highest seedling height and the maximum number of leaves.

Wagh *et al*. (1998) investigated the effect of seed treatment on germination and initial growth of aonla seedling in polybag. Seeds were soaked in GA_3 @ 100-400 ppm,, water and unsoaked (control) for 12 hours. It was noticed that GA_3 @ 400 ppm resulted higher percentage of germination as well as seedling development i.e. plant height, number of leaves/plant and root development.

Gholap *et al*. (2000) emphasised the effect of plant growth regulators on germination and seedling growth of Indian gooseberry (*Phyllanthus emblica* cv. Banarasi). Fresh seeds were pre-treated with 3 different concentrations of GA_3, NAA or thiourea *viz*., 100, 200 and 300 ppm, respectively. The treatment GA_3 @ 200 ppm resulted in the shortest time to initiate germination, highest seed germination percentage, tallest seedling height and greatest seedling stem girth. The highest number of roots per seedling was recorded with the treatment thiourea @ 200 ppm.

Kalalbandi *et al*. (2003) conducted a field experiment to investigate the effect of GA_3 (40, 60 and 80 ppm), NAA (40, 60 and 80 ppm) and KNO_3 (1 %) on the germination and growth of Kagzi lime. It was noticed that seeds soaked in GA_3 and NAA for 12 hours resulted in maximum germination and shoot length. The seed treatment GA_3 @ 80 ppm was the most effective for improving germination, seedling height and number of leaves.

Joolka *et al*. (2004) investigated the influence of bio-fertilizers, GA_3 and their combinations on the growth of pecan seedlings. It was found that maximum linear and radial growth was under VAM + GA_3 (5000 ppm) treatment. Highest internodal length, number of leaves, fresh and dry weight of shoots, root-shoot ratio and 100 per cent graftable plants were obtained with VAM + Azotobacter + GA_3 (5000 ppm) treatment

Mobli and Baninasab (2008) treated six-week old seedlings of *Prunus amygdalus* and *Prunus webbii* with GA_3 (100 mg/L) alone or with GA_3 followed by ethephon (100 and 200

mg/L) or chlormequat chloride (500 and 1000 mg/L) or PBZ (500 and 1000 mg/L). Treatment GA_3 alone was found to be most effective on stem height, leaf area, fresh and dry weight of shoots of both almond species. The thickest stems of *P. amygdalus* and *P. webbii* were obtained from the application of GA_3 (100 mg/L) followed by application of PBZ (1000 and 500 mg/L), respectively.

Deb *et al*. (2010) advocated that proper seed germination and seedling growth is essential for successful seedling production under nursery technique of papaya cultivation. Seeds were soaked with different concentrations of GA_3 i.e. 100, 150 and 200 ppm. The treatment GA_3 @ 150 ppm was found to be superior in respect of seed germination whereas, maximum seedling growth (seedling height and seedling girth) was observed under GA_3 @ 200 ppm.

Kadam *et al*. (2010) conducted an experiment to notice the effect of plant growth regulators and potassium nitrate on seedling growth of Kagzi lime. The results revealed that GA_3 @ 150 ppm produced maximum height, more number of leaves per plant and maximum fresh and dry weight of shoots which remained significantly superior over control.

Munde and Gajbhiye (2010) made investigations on the effect of plant growth regulators on seedling growth of mango stones and observed that GA_3 @ 200 ppm applied to mango stone produced maximum height and more number of leaves. The plant growth regulator IAA at 500 ppm applied to mango stone produced maximum girth and leaf area. It was concluded that GA_3 at 200 ppm and IAA at 500 ppm applied to mango stones induced more growth of mango seedlings.

An experiment was laid out on the effect of pre-sowing seed treatments on seedling growth of jackfruit (*Artocarpus heterophyllus* Lam). Seeds were soaked in distilled water (control), GA_3 @ 100 and 200 ppm, NAA @ 25 and 50 ppm and KNO_3 @ 0.25 and 0.5 per cent for 12 and 24 hours. The observations indicated that soaking seeds in GA_3 @ 200 ppm for 24 hours resulted in maximum seedling height, maximum seedling girth, higher germination percentage, early initiation of germination and less number of days taken for attaining graftable size. Soaking seeds in KNO_3 at 0.5 per cent for 24 hours recorded the maximum leaf area per seedling (Harshavardhan and Rajasekhar, 2012).

Parmar *et al*. (2016) investigated the effect of seed priming treatments on germination and seedling vigour of custard apple. The treatments comprised of different concentrations of

chemicals GA_3 @ 100 and 200 mg/L, KNO_3 @ 1 and 2 %, thiourea @ 500 and 1000 mg/L, fresh cow dung and urine slurry (1:2 ratio) and hot water treatment. Soaking the seed in GA_3 @ 200 mg/L for 12 hours recorded the minimum days taken to germinate the seeds, maximum germination percentage, height of seedling, shoot length, root length, fresh and dry weight of seedling, stem girth, relative growth rate, vigour index-I and II at 120 days of sowing. It was concluded that GA_3 @ 200 mg/L for 12 hours was the best seed priming treatment for maximum germination and seedling growth of custard apple.

Choudhary *et al.* (2018) studied the effect of GA_3 and growing media on seedling growth of papaya (*Carica papaya* L.) cv. Pusa Nanha. It was observed that GA_3 @ 200 ppm found to be the most effective seed treatment for better root growth parameters (number of primary and secondary roots, length of primary and secondary roots, fresh and dry weight of roots), shoot growth parameters (height of the seedling, number of leaves, seedling girth, leaf area, fresh and dry weight of shoot) and survival percentage, whereas root-shoot ratio was found lowest in treatment GA_3 @ 150 ppm.

Mane *et al.* (2018) invigilated the effect of different pre-sowing treatments with 0.1 % potassium nitrate, 1 % thiourea, 0.1 % urea, 10 % cow urine, 10 % cow dung slurry, GA_3 @ 400 ppm, hot water and cold water for 24 hours on shoot growth of custard apple (*Annona squamosa* L.). It was observed that seeds soaked in GA_3 @ 400 ppm solution for 24 hours prior to sowing resulted in maximum stem diameter, maximum height, maximum leaf area, maximum fresh and dry weight of seedling. However, the maximum number of leaves was observed in thiourea (1 %) for 24 hours. The studies concluded that seed treatment of GA_3 @ 400 ppm for 24 hours is desirable for better seed growth of custard apple seedlings,

Rai *et al.* (2018) recorded an improved seed germination and seedling traits by pre-sowing treatments with different concentrations of GA_3 (100 and 200 ppm), thiourea (1 and 2 %) and potassium nitrate (1and 2 %) in khirni (*Manilkara hexandra*). It was observed that the highest germination percentage, shoot length, number of leaves, fresh and dry weight of shoot, seedling vigour index I and II were obtained in the seeds treated with 100 ppm GA_3, while root length, stem diameter, tap root diameter, fresh and dry weight of root and root: shoot ratio were higher in the seeds treated with 200 ppm GA_3. However, treatment of seeds with 200 ppm GA_3 showed overall efficacy in improving seed germination, growth characteristics and vigour of khirni seedlings.

Yadav *et al*. (2018) studied the effect of GA_3@ 200, 300, 400 and 500 ppm and cow urine @ 10, 20, 30 and 40 % on growth and physiology of custard apple seedlings. The results indicated that the seedling growth parameters such as highest fresh and dry weight of shoots and roots, seedling vigour index I and II, Leaf Area Index and Leaf Area Duration and mean survival percentage of seedlings were noticed under the treatment of GA_3 @ 400 ppm.

Barathkumar (2019) conducted an experiment to study the effect of different pre-sowing seed treatments on dormancy breaking in aonla (*Phyllanthus embolic*a L). Seeds were pre-treated with GA_3 (250 and 500 ppm for 24 hours), potassium nitrate (1 and 2 % for 24 hours), sulphuric acid (0.25 and 0.50 % for 3 minutes), hot water (25 and 50°C for 10 seconds), tap water (24 hours) and stratification (5 and 10°C for 10 days). It was observed that the seeds treated with 2 % KNO_3 for 24 hours significantly enhanced the seed germination percentage, highest root length and highest dry matter content followed by GA_3 @ 500 ppm for 24 hours in comparison to other treatments. Shoot length, days taken for 50 per cent germination, days taken for graftable thickness and vigour index was also highest in seeds treated with GA_3 @ 500 ppm for 24 hours.

Sau *et al*. (2019) studied the influence of seed priming on germination and seedling vigour of wood apple (*Feronia limonia* Swingle). It was observed that GA_3 @ 100 ppm increased the germination percentage and vegetative growth (seedling height, shoot and root diameter, leaf number, fresh and dry weight of seedling, leaf chlorophyll content and leaf nitrogen and potassium content).

Chapter-3

MATERIALS AND METHODS

The present investigations titled "**Effect of seed priming on germination and seedling growth in amlook (*Diospyros lotus* L.)**" were carried out at the experimental farm and laboratory of Department of Seed Science and Technology, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan HP during 2019-20. The details of the materials and methods followed during the course of investigations are described below.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The experimental work was carried out at experimental farm of Department of Seed Science and Technology, Nauni, Solan, which is situated at an altitude of 1250 m above mean sea level with 30° 50′ 45″ latitude and 77° 88′ 33″ longitude. It falls in sub-humid, sub temperate and mid-hill zone of Himachal Pradesh.

3.1.2 Climate

The experimental area falls in the mid-hill zone of Himachal Pradesh agro-climatically and is characterized by moderate rainfall ranging from 1000-1300 mm. The hottest months are May and June, while December and January are the coldest. The meteorological data pertaining to cropping period of amlook i.e. from January to December, 2019 have been recorded (Appendix-I). Mean temperature during the growth period varied from 8.85 to 25.75°C, whereas the relative humidity varied from 44 to 79 per cent. The average rainfall during the cropping period varied from 5.60 to 225.80 mm, most of which was received in the month of August. Graphical representation of monthly data pertaining to the rainfall, maximum and minimum temperature, relative humidity during the growing season are given in Fig 1 and 2.

3.1.3 Soil

The soil structure of the experimental site was loam to gravelly clay loam with pH ranging from 6.85 - 7.04.

Fig 1: Graphical representation of monthly data pertaining to the temperature and relative humidity during the cropping period (January-December, 2019)

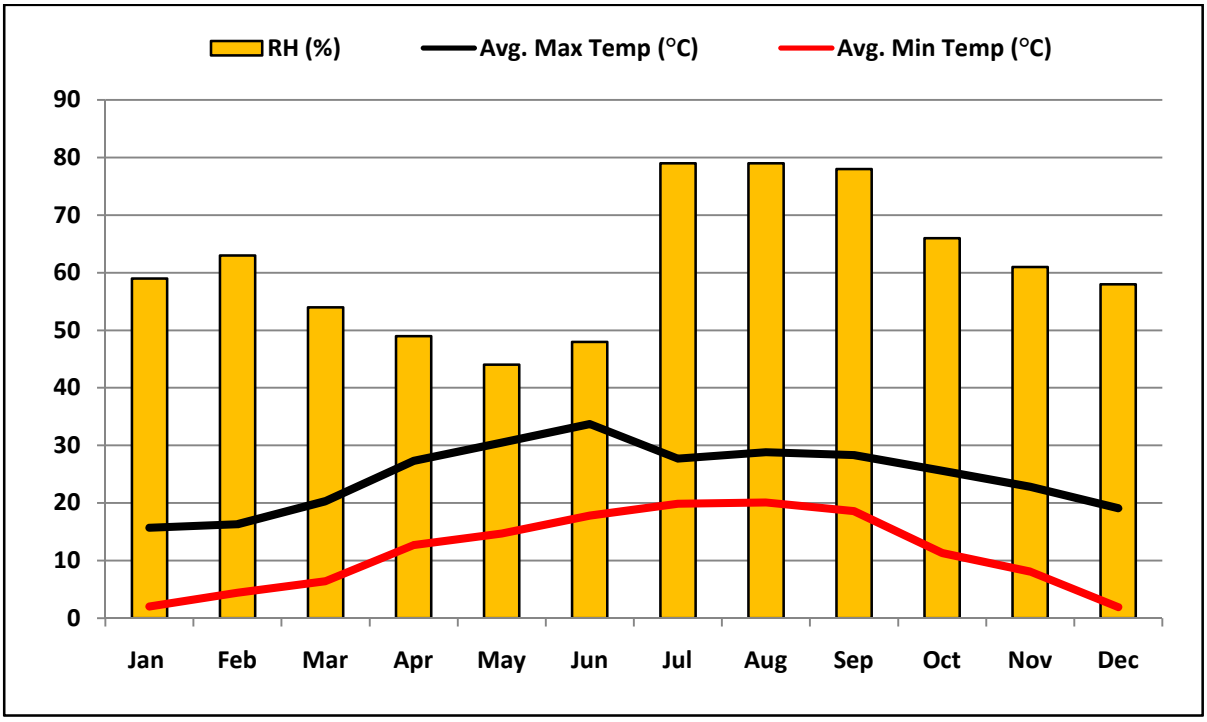
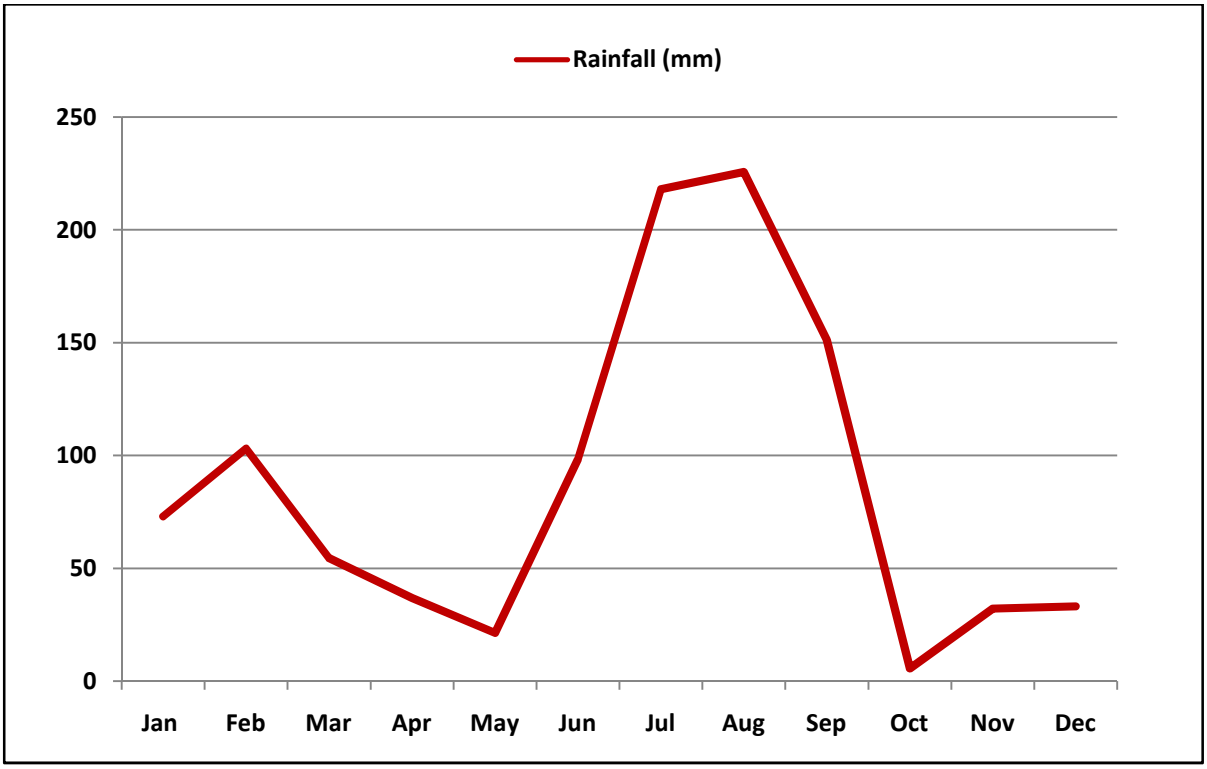


Fig 2: Graphical representation of monthly data pertaining to the rainfall during the cropping period (January-December, 2019)



Source: Meteorological Observatory, Department of Environmental Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) 173 230.

3.2 EXPERIMENT DETAILS

The detailed technical programme of present investigations is as under:

3.2.1 TECHNICAL PROGRAMME

3.2.1.1 EXPERIMENT-1

Effect of seed priming on germination and seedling growth in amlook (*Diospyros lotus* L.).

3.2.1.2 Details of the experiment

Treatment Code		Treatments
T_1	:	Priming with GA_3 @ 250 ppm
T_2	:	Priming with GA_3 @ 500 ppm
T_3	:	Priming with GA_3 @ 750 ppm
T_4	:	Priming with Thiourea @ 2500 ppm
T_5	:	Priming with Thiourea @ 5000 ppm
T_6	:	Priming with Thiourea @ 7500 ppm
T_7	:	Priming with KNO_3 @ 2500 ppm
T_8	:	Priming with KNO_3 @ 5000 ppm
T_9	:	Priming with KNO_3 @ 7500 ppm
T_{10}	:	Hydro-priming
T_{11}	:	No priming (control)

Number of replications	:	3
Number of seeds per replication	:	50
Plot size	:	1 × 1.5 m
Design	:	Randomized Block Design

3.3 PREPARATION OF SOLUTION OF GA_3 AND DIFFERENT CHEMICALS

3.3.1 Preparation of GA_3 solution

A stock solution of gibberellic acid (GA_3) of 6000 ppm concentration was prepared by dissolving 6 grams of GA_3 in small quantity 50 per cent ethanol and making the final volume to 1000 ml with distilled water. From the stock solution, GA_3 solution of 250 ppm, 500 ppm and 750 ppm concentration were prepared.

3.3.2 Preparation of Thiourea and KNO_3 solution

2.5g, 5g, 7.5g of Thiourea and KNO_3 separately were weighed on electrical weighing balance and dissolved in water to make the final volume of 1000 ml. Thus 2500 ppm, 5000 ppm and 7500 ppm solution of Thiourea and KNO_3 were prepared.

3.3.3 Seed treatments: Amlook seeds were stratified for 45 days in the alternate layers of sand in a wooden box and kept at the lower chamber of refrigerator during January. The seeds were soaked in given concentrations of GA_3, Thiourea and KNO_3 solutions for 24 hours. The seeds, then shade dried for two hours before sowing in nursery beds.

3.4 PREPARATIONS OF NURSERY BEDS AND SOWING OF SEEDS

The experimental field was prepared by repeated ploughing with the help of power tiller. At the time of preparation of field, well rotten FYM @ 20-25 kg/m^2 area was mixed in the soil. The nursery beds were prepared and seeds were sown in these beds in the first week of March, 2019. After sowing, the nursery beds were covered with dry grass mulch and irrigated lightly. Nursery operations like weeding and irrigation were done at a regular interval.

3.5 OBSERVATIONS RECORDED

3.5.1 Days taken to germination

The days taken for germination were recorded from the date of sowing to the initiation of first germination appeared in nursery beds under each treatment.

3.5.2 Seed germination percentage

The germination in each treatment was recorded from the emergence of seedlings after sowing till the emergence has stopped. Number of seedlings were counted and expressed as germination percentage.

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

3.5.3 Seedling height

The height of seedling was measured with the help of measuring tape at the end of growing season in December. The height was measured from the base of shoot to the growing tip and expressed in centimetres (cm).

Plate 1: Seed priming with different chemicals

Plate 2: Sowing of seeds

Plate 3: FYM was mixed in the soil

Plate 4: An overview of field after mulching

3.5.4 Seedling diameter

The diameter of shoot above the root collar region was recorded with the help of Vernier Callipers at the end of growing season in December and expressed in millimetres (mm).

3.5.5 Number of leaves per plant

The data on number of leaves per plant were recorded during the month of October before the onset of leaf fall. All the leaves, irrespective of their size were counted and average number of leaves per plant was calculated.

3.5.6 Leaf Area

Five fully expanded leaves were collected at random from each replication in the first week of October and the area of leaves was measured with the help of Leaf Area Meter (LI-COR Model-3100) and expressed in square centimetres (cm^2).

3.5.7 Leaf chlorophyll content

Five fully expanded and mature leaves from each replicated bed were collected in the month of October during morning hours (Halfacre *et al*., 1968), immediately placed in ice box and brought to the laboratory. The samples were then kept in the refrigerator to avoid degradation of chlorophyll pigments.

Extraction

Leaves from each sample were washed and chopped into fine pieces under subdued light and 100 mg of chopped material was placed in vial containing 7 ml of dimethyl sulphoxide (DMSO). The contents of the vials were incubated at 65°C temperature for 30 minutes and then extract was transferred to graduated test tube and the final volume was made to 10 ml with dimethyl sulphoxide (Hiscox and Israelstam, 1979).

Estimation

Optical density (OD) of the above extract was recorded on Spectronic 20 D at 645 and 663 nm wavelength against a DMSO blank and total chlorophyll content was calculated by using the following formula:

$$\text{Total chlorophyll} = \frac{20.2\ A_{645} + 8.02\ A_{663}}{A \times 1000 \times W} \times V$$

Where,

V = Volume of extract used

A = Length of the light path in cell (1 cm)

W = Weight of the sample (g)

A_{645} = Absorbance at 645 nm wavelength

A_{663} = Absorbance at 663 nm wavelength

The results were expressed chlorophyll content in mg/g of fresh weight.

3.5.8 Fresh weight of shoots

At the end of season during December five seedlings per replication were uprooted. The leafless shoot portion was cut into small pieces and the fresh weight was weighed on top pan electronic balance and expressed in grams (g).

3.5.9 Dry weight of shoots

The shoots cut for recording the fresh weight were chopped into pieces and dried in an oven at a temperature of 65°C for about 72 hours. The dry weight of shoots was weighed on top pan electronic balance and expressed in grams (g).

3.5.10 Total root length

The entire root system of each seedling was washed with tap water under pressure and then cut into small pieces. The total length of roots was measured with the help of root length scanner (Comair Root Length Scanner) and was expressed in metres (m).

3.5.11 Fresh weight of roots

The root portion of five seedlings per replication was cut into small pieces and the fresh weight was weighed on top pan electronic balance and expressed in grams (g).

3.5.12 Dry weight of roots

The roots cut for recording the fresh weight were chopped and dried in an oven at a temperature of 65°C for about 72 hours. The dry weight of roots was weighed on top pan electronic balance and expressed in grams (g).

3.5.13 Root shoot ratio

The root to shoot ratio was calculated for each plant on the fresh weight basis by dividing the fresh weight of root by fresh weight of shoot using the given formula:

Plate 5: Amlook seedlings

Plate 6: An overview of experimental field

$$\text{Root: shoot ratio} = \frac{\text{Fresh weight of root (g)}}{\text{Fresh weight of shoot (g)}}$$

3.5.14 Biomass of seedlings (Dry weight basis)

The biomass of seedlings was calculated on dry weight basis by adding the dry weight of entire shoots and root system of each seedling. The results were expressed in grams (g).

3.5.15 Seedling vigour index-I

Seedling vigour index-I was calculated from the formula given by Abdul-Baki and Anderson (1973).

Vigour index-I = Seedling length (cm) × germination percentage (%)

3.5.16 Seedling vigour index-II

Seedling vigour index-II was worked out using formula given by Abdul-Baki and Anderson (1973).

Vigour index-II = Seedling dry weight (g) × germination percentage (%)

3.5.17 Survival percentage

The survival percentage of each treatment was recorded at the end of growing season. It was calculated by using formula as given below:

$$\text{Survival percentage} = \frac{\text{Total number of survived seedlings}}{\text{Total number of germinated seedlings}} \times 100$$

3.5.18 Number of graftable seedlings

The diameter of seedlings at 5 cm above from the ground level recorded during December. The seedlings having the diameter of 5 mm or above were considered as graftable seedlings. The proportion of such seedlings was calculated on percentage basis.

3.6 STATISTICAL ANALYSIS

The data recorded on various parameters were appropriately computed, tabulated and analyzed by applying Randomized Block Design (Panse and Sukhatme, 2000) using MS-

Excel and OPSTAT. The results were interpreted on the basis of 'F' test value and critical difference (CD) was calculated at 5 % level of significance.

The analysis of variance was calculated as follows:

Source of variation (SV)	Degrees of freedom (df)	Sum of squares (SS)	Mean sum of squares (MSS)	F cal
Replications	(r-1)	S_r	$\frac{Sr}{(r-1)} = M_r$	$\frac{M_r}{M_e}$
Treatments	(t-1)	S_t	$\frac{St}{(t-1)} = M_t$	$\frac{M_t}{M_e}$
Error	(r-1) (t-1)	S_e	$\frac{Se}{(r-1)(t-1)} = M_e$	
Total	(rt-1)	ST		

Where,

R	=	Number of replications
T	=	Number of treatments
S_r	=	Sum of squares due to replications
S_t	=	Sum of squares due to treatments
S_e	=	Sum of squares due to error
ST	=	Total sum of squares
M_r	=	Mean sum of squares due to replications
M_t	=	Mean sum of squares due to treatments
M_e	=	Mean sum of squares due to error

The replication and treatment mean sum of square was tested against error mean squares by 'F' test for (r-1), (r-1) (t-1) and (t-1), (r-1) (t-1) degree of freedom for RBD at 5% level of significance.

The calculated F-value was compared with tabulated F-value. When F-test was found significant, critical difference was calculated to find out the superiority of one treatment over the others.

The critical differences and standard error were calculated as follows:

$CD_{0.05}$ = S.E. (d) x $t_{(0.05)}$ (r-1) (t-1) df

SE (d) ± = $\frac{\sqrt{2Me}}{r}$

SE (m) ± = $\sqrt{\frac{Me}{r}}$

Where,

SE (m) ±	=	Standard error of mean
SE (d) ±	=	Standard error of difference of mean
$CD_{0.05}$	=	Critical difference at 5 per cent level of significance

Chapter-4

RESULTS AND DISCUSSION

The present investigations entitled **"Effect of seed priming on germination and seedling growth in amlook (*Diospyros lotus* L.)"** were carried out at the experimental farm and laboratory of Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP during 2019-20. The results obtained during the course of investigations have been presented and discussed as under:

A. GERMINATION PARAMETERS

4.1 Days taken to germination

4.2 Seed germination (%)

B. GROWTH PARAMETERS

4.3 Seedling height (cm)

4.4 Seedling diameter (mm)

4.5 Number of leaves per seedling

4.6 Leaf area (cm^2)

4.7 Leaf chlorophyll content (mg/g)

4.8 Fresh weight of shoots (g)

4.9 Dry weight of shoots (g)

4.10 Total root length (m)

4.11 Fresh weight of roots (g)

4.12 Dry weight of roots (g)

4.13 Root: shoot ratio

4.14 Biomass of seedlings (g) (on dry weight basis)

4.15 Seedling vigour index- I

4.16 Seedling vigour index- II

4.17 Survival percentage

4.18 Number of graftable seedlings (%)

A. GERMINATION PARAMETERS

4.1 DAYS TAKEN TO GERMINATION

The data related to the effect of seed priming on days taken to germination were recorded, statistically analyzed and presented in Table 4.1.

Table 4.1: Effect of seed priming treatments on days taken to germination in amlook

Treatment code	Treatments	Days taken to germination
T_1	Priming with GA_3 @ 250 ppm	40.03
T_2	Priming with GA_3 @ 500 ppm	38.40
T_3	Priming with GA_3 @ 750 ppm	39.30
T_4	Priming with Thiourea @ 2500 ppm	42.17
T_5	Priming with Thiourea @ 5000 ppm	43.57
T_6	Priming with Thiourea @ 7500 ppm	45.05
T_7	Priming with KNO_3 @ 2500 ppm	44.37
T_8	Priming with KNO_3 @ 5000 ppm	43.87
T_9	Priming with KNO_3 @ 7500 ppm	39.77
T_{10}	Hydro-priming	52.25
T_{11}	No priming (control)	55.17
$CD_{(0.05)}$		7.13

A perusal of data (Table 4.1) clearly indicates that different priming treatments possessed significant effect on days taken to germination. Significantly less days taken to seed germination (38.40 days) were recorded with treatment T_2 (GA_3 @ 500 ppm) as compared to T_{10} (Hydro-priming) and T_{11} (Control-no priming) taking 52.25 days and 55.17 days, respectively. However, priming with different chemicals remained statistically at par with each other.

The early germination in our studies with chemical priming may be attributed to their effect on enzymatic activities and various physiological processes inside the seeds. Lesser days taken to seed germination by GA_3 treatments might be due to the fact that gibberellins have antagonistic effect on germination inhibitors (Brian and Hemming, 1958; Wareing and Foda, 2006) and endogenous gibberellins were reported to increase due to soaking (Mathur *et al*. 1971). Gibberellins help in the synthesis and activation of α -amylase enzymes in the aleurone layer which converts the starch into simple sugars. These simple sugars are the source of energy that is required for various metabolic and physiological activities inside the seed. GA_3 acts directly on embryo relieving them from dormancy through promoting protein synthesis and also helps the production of ethylene. This ethylene increases the activities of

hydrolyzing enzyme and α-amylase at initial stage of germination and facilitated the germination process (Stewart and Freebairn, 1969). The remarkable effect of GA_3 on seed germination especially in breaking seed dormancy has been well established by Singh *et al*. (1989) in sweet orange, Pampanna *et al*. (1995) in sapota and Hore and Sen (1994) in ber.

Our findings are in consonance with the studies of Ratan and Reddy (2004) who have also reported the earliest germination of custard apple seeds treated with 400 ppm of GA_3.

4.2 SEED GERMINATION (%)

The observations regarding the effect of seed priming on seed germination (%) are presented in Table 4.2.

Table 4.2: Effect of seed priming treatments on seed germination (%) in amlook

Treatment code	Treatments	Seed germination (%)
T_1	Priming with GA_3 @ 250 ppm	59.70
T_2	Priming with GA_3 @ 500 ppm	64.26
T_3	Priming with GA_3 @ 750 ppm	63.57
T_4	Priming with Thiourea @ 2500 ppm	57.13
T_5	Priming with Thiourea @ 5000 ppm	56.50
T_6	Priming with Thiourea @ 7500 ppm	52.13
T_7	Priming with KNO_3 @ 2500 ppm	53.70
T_8	Priming with KNO_3 @ 5000 ppm	55.63
T_9	Priming with KNO_3 @ 7500 ppm	61.20
T_{10}	Hydro-priming	40.03
T_{11}	No priming (control)	38.62
$CD_{(0.05)}$		9.59

The data (Table 4.2) revealed that different priming treatments have significantly affected the seed germination. The maximum seed germination (64.26 %) was recorded under treatment T_2 (GA_3 @ 500 ppm), which was found statistically at par with T_3 (GA_3 @ 750 ppm), T_9 (KNO_3 @ 7500 ppm), T_1 (GA_3 @ 250 ppm), T_4 (Thiourea @ 2500 ppm), T_5 (Thiourea @ 5000 ppm) and T_8 (KNO_3 @ 5000 ppm). The minimum seed germination (38.62 %) was noticed under treatment T_{11} (Control-no priming).

The higher germination in amlook seed by different chemical priming treatments might be due to their effect to bring about a favourable internal condition (breaking of seed dormancy) for maximum germination. The breakdown of starch into simple sugars by enzymatic (amylase) action precedes seed germination. GA_3 also induce the production of more hydrolytic enzymes. Thus, the acceleration of germination process can be attributed to

the increased activity of enzymatic mechanism of germinating seed. It also enhances the activity of RNA and protein synthesis (Bradbeer and Pinfield, 1967) which stimulates germination. According to Wagh *et al*. (1998), the application of GA_3, might have triggered the activity of specific enzymes that promoted early germination, such as α-amylase, which have brought an increase in availability of starch assimilation.

Our results are in accordance with the findings of Choudhari and Chakrawar (1981) in Kagzi lime, Ferreira *et al*. (1998) in custard apple and Bertocci *et al.* (1997) in papaya for initiation of germination.

B. GROWTH PARAMETERS

4.3 SEEDLING HEIGHT (cm)

The data related to the effect of seed priming treatments on seedling height in amlook are presented in Table 4.3.

Table 4.3: Effect of seed priming treatments on seedling height (cm) in amlook

Treatment code	Treatments	Seedling height (cm)
T_1	Priming with GA_3 @ 250 ppm	28.25
T_2	Priming with GA_3 @ 500 ppm	29.10
T_3	Priming with GA_3 @ 750 ppm	28.83
T_4	Priming with Thiourea @ 2500 ppm	27.47
T_5	Priming with Thiourea @ 5000 ppm	26.38
T_6	Priming with Thiourea @ 7500 ppm	25.82
T_7	Priming with KNO_3 @ 2500 ppm	26.17
T_8	Priming with KNO_3 @ 5000 ppm	27.70
T_9	Priming with KNO_3 @ 7500 ppm	28.00
T_{10}	Hydro-priming	24.75
T_{11}	No priming (control)	23.50
$CD_{(0.05)}$		0.51

It is evident from the data (Table 4.3) that seedling height was significantly affected by the different seed priming treatments. The maximum seedling height (29.10 cm) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) bearing seedling height (28.83 cm) and was significantly higher over all the other treatments including control. Minimum height of seedlings (23.50 cm) was recorded under T_{11} (Control-no priming).

The increase in height of seedling with application of GA_3 treatment might be due to early germination, cell division and quick cell elongation (Shanmugavalli *et al.* 2007). Our findings are in consonance with the investigations of Kumar and Shahnaz (2013), who also recorded the maximum seedling length with seed treatment of 500 ppm GA_3, in an experiment on the effect of growth regulators in wild apricot. Various workers have reported that gibberellins increased cell elongation (Haber *et al*., 1969), quicker cell multiplication (Mobli and Baninasab, 2008) and internodal length (Anjanawe *et al*., 2013).

4.4 SEEDLING DIAMETER (mm)

The data pertaining to the effect of seed priming treatments on seedling diameter in amlook are presented in Table 4.4.

Table 4.4: Effect of seed priming treatments on seedling diameter (mm) in amlook

Treatment code	Treatments	Seedling diameter (mm)
T_1	Priming with GA_3 @ 250 ppm	5.60
T_2	Priming with GA_3 @ 500 ppm	6.27
T_3	Priming with GA_3 @ 750 ppm	6.00
T_4	Priming with Thiourea @ 2500 ppm	5.53
T_5	Priming with Thiourea @ 5000 ppm	5.43
T_6	Priming with Thiourea @ 7500 ppm	5.30
T_7	Priming with KNO_3 @ 2500 ppm	5.37
T_8	Priming with KNO_3 @ 5000 ppm	5.73
T_9	Priming with KNO_3 @ 7500 ppm	5.87
T_{10}	Hydro-priming	4.97
T_{11}	No priming (control)	4.70
$CD_{(0.05)}$		0.31

A perusal of data (Table 4.4) clearly indicates that seedling diameter was significantly affected by the different seed priming treatments. The maximum seedling diameter (6.27 mm) was recorded with the treatment T_2 (GA_3 @ 500ppm) closely followed by T_3 (GA_3 @ 750 ppm) bearing seedling diameter (6.00 mm) and was significantly higher over all the other treatments including control. Minimum seedling diameter (4.70 mm) was recorded under treatment T_{11} (Control-no priming).

The increase in the seedling diameter by the treatment of gibberellins may be due to the fact that it caused the stimulation of cambium cells and immediate cell progeny by cell multiplication process (Dhankhar and Singh, 1996). Our results are in agreement with Kumar and Shahnaz (2013), who visualized an increased seedling girth in the wild apricot seeds

soaked in different concentrations of gibberellic acid. Similarly, Qureshi *et al*. (2016) also recorded the highest stem diameter with pre-soaking treatment of walnut seeds in GA_3 solution. Rao and Reddy (2005) recorded the increased seedling diameter in mango with GA_3 treatments.

4.5 NUMBER OF LEAVES PER SEEDLING

The observations regarding the effect of seed priming on number of leaves per seedling are presented in Table 4.5.

Table 4.5: Effect of seed priming treatments on number of leaves per seedling in amlook

Treatment code	Treatments	Number of leaves per seedlings
T_1	Priming with GA_3 @ 250 ppm	14.97
T_2	Priming with GA_3 @ 500 ppm	17.07
T_3	Priming with GA_3 @ 750 ppm	16.43
T_4	Priming with Thiourea @ 2500 ppm	14.80
T_5	Priming with Thiourea @ 5000 ppm	14.47
T_6	Priming with Thiourea @ 7500 ppm	13.90
T_7	Priming with KNO_3 @ 2500 ppm	13.27
T_8	Priming with KNO_3 @ 5000 ppm	13.77
T_9	Priming with KNO_3 @ 7500 ppm	14.60
T_{10}	Hydro-priming	12.53
T_{11}	No priming (control)	12.00
$CD_{(0.05)}$		1.24

The data (Table 4.5) reveals that seed priming treatments significantly increased the number of leaves per seedling. The maximum number of leaves per seedling (17.07) were observed under treatment T_2 (GA_3 @ 500 ppm) and was found statistically at par with treatment T_3 (GA_3 @ 750 ppm). The number of leaves per seedling (12.00) was found to be minimum under treatment T_{11} (Control-no priming).

Plant height is directly correlated to the number of leaves, which means more the height, greater will be the number of leaves and hence more photosynthetic area which ultimately leads to more yield and productivity (Kaushal, 2016). Gibberellins help in invigoration of physiological process of plants and its stimulatory effect to form new leaves at faster rate (Sharma *et al*., 1999). More number of leaves may also be due to more height of seedling and faster rate of cell multiplication and cell elongation as suggested by Agha *et al.* (1990) in sour orange and citrange.

The production of highest number of leaves by the pre-sowing treatment with GA_3 in our studies may be due to the reason that gibberellins helped in vigorous plant growth and increased number of branches, which resulted into better harvest of sunshine to yield a greater number of leaves per plant. Gibberellins were found to move to shoot tip, increased cell division and cell growth ultimately lead to the production and development of new leaves (Chawla and Mehta, 2015).

Our findings are in consonance with the studies of Al-Hawezy (2013), who also found that the seed treatment of GA_3 resulted into increased number of leaves, while studying the effect of different concentrations of gibberellins on germination and seedling growth in loquat. Similarly, Rawat (2016) and Chiranjeevi *et al*. (2017) also observed the maximum number of leaves per seedling with seed treatment of GA_3 in custard apple and aonla fruit crops, respectively.

4.6 LEAF AREA (cm^2)

The data related to the effect of seed priming treatments on leaf area in amlook are presented in Table 4.6.

Table 4.6: Effect of seed priming treatments on leaf area (cm^2) in amlook

Treatment code	Treatments	Leaf area (cm^2)
T_1	Priming with GA_3 @ 250 ppm	73.02
T_2	Priming with GA_3 @ 500 ppm	86.04
T_3	Priming with GA_3 @ 750 ppm	85.34
T_4	Priming with Thiourea @ 2500 ppm	72.04
T_5	Priming with Thiourea @ 5000 ppm	70.19
T_6	Priming with Thiourea @ 7500 ppm	70.40
T_7	Priming with KNO_3 @ 2500 ppm	66.71
T_8	Priming with KNO_3 @ 5000 ppm	78.21
T_9	Priming with KNO_3 @ 7500 ppm	79.15
T_{10}	Hydro-priming	63.88
T_{11}	No priming (control)	60.61
$CD_{(0.05)}$		5.29

It is pertinent from the data (Table 4.6) that leaf area was significantly affected by the different priming treatments. The maximum leaf area (86.04 cm^2) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) bearing leaf area (85.34 cm^2) and was significantly higher over all the other treatments including control. Minimum leaf area (60.61 cm^2) was recorded under treatment T_{11} (Control-no priming).

The higher leaf area with the GA_3 treatments may be due to its contribution in cell division, elongation and multiplication (Mane *et al*., 2018). Our findings are in consonance with the studies of Anjanawe *et al*. (2013), who observed the maximum leaf area with the GA_3 application in papaya seedlings. Similarly, Kumar and Shahnaz (2013) also recorded the maximum leaf area by the seed priming treatment of 500 ppm gibberellic acid.

4.7 LEAF CHLOROPHYLL CONTENT (mg/g)

The data pertaining to the effect of seed priming on chlorophyll content were recorded, statistically analyzed and are presented in Table 4.7.

Table 4.7: Effect of seed priming treatments on leaf chlorophyll content (mg/g) in amlook

Treatment code	Treatments	Chlorophyll content (mg/g)
T_1	Priming with GA_3 @ 250 ppm	1.87
T_2	Priming with GA_3 @ 500 ppm	2.05
T_3	Priming with GA_3 @ 750 ppm	1.99
T_4	Priming with Thiourea @ 2500 ppm	1.77
T_5	Priming with Thiourea @ 5000 ppm	1.70
T_6	Priming with Thiourea @ 7500 ppm	1.63
T_7	Priming with KNO_3 @ 2500 ppm	1.68
T_8	Priming with KNO_3 @ 5000 ppm	1.75
T_9	Priming with KNO_3 @ 7500 ppm	1.85
T_{10}	Hydro-priming	1.25
T_{11}	No priming (control)	1.20
$CD_{(0.05)}$		0.07

It is evident from the data that leaf chlorophyll content was significantly affected by the different priming treatments. The maximum leaf chlorophyll content (2.05) was recorded under T_2 (GA_3 @ 500 ppm) which was found statistically at par with T_3 (GA_3 @ 750 ppm). The minimum chlorophyll content (1.20) was recorded under T_{11} (Control-no priming).

The more leaf chlorophyll content with the treatment of GA_3 may be attributed to the fact that gibberellins are helpful in the improvement of ultra-structural morphogenesis of plastids along with chlorophyll retention and delaying of senescence (Arteca, 1997). Our findings are also in concomitant with the studies of Barman *et al*. (2016), while studying the effect of gibberellic acid and benzyl adenine on seed germination and morpho-physiological features in jamun and observed that seed treatment with various concentrations of GA_3 and BA significantly improved leaf chlorophyll content.

Increased leaf chlorophyll content with the seed treatment of GA_3 might be due to the faster synthesis of protein in plants and is indirectly exhibited by increase in leaf chlorophyll content. These results are in accordance with Yadav *et al.* (2012) in acid lime and Ramteke *et al.* (2016) in papaya.

4.8 FRESH WEIGHT OF SHOOTS (g)

The data related to the effect of seed priming treatments on fresh weight of shoots in amlook are presented in Table 4.8.

Table 4.8: Effect of seed priming treatments on fresh weight of shoots (g) in amlook

Treatment code	Treatments	Fresh weight of shoots (g)
T_1	Priming with GA_3 @ 250 ppm	15.66
T_2	Priming with GA_3 @ 500 ppm	16.32
T_3	Priming with GA_3 @ 750 ppm	16.00
T_4	Priming with Thiourea @ 2500 ppm	14.73
T_5	Priming with Thiourea @ 5000 ppm	14.39
T_6	Priming with Thiourea @ 7500 ppm	13.87
T_7	Priming with KNO_3 @ 2500 ppm	13.53
T_8	Priming with KNO_3 @ 5000 ppm	13.67
T_9	Priming with KNO_3 @ 7500 ppm	14.64
T_{10}	Hydro-priming	13.25
T_{11}	No priming (control)	12.64
$CD_{(0.05)}$		0.58

A perusal of data (Table 4.8) clearly indicates that fresh weight of shoots was significantly affected by the different seed priming treatments. The maximum fresh weight of shoots (16.32 g) was recorded with the treatment T_2 (GA_3 @ 500ppm) closely followed by the treatment T_3 (GA_3 @ 750 ppm) bearing fresh weight of roots (16.00 g) and was significantly higher over all the other treatments including control. Minimum fresh weight of roots (12.64 g) was recorded under treatment T_{11} (Control-no priming).

The increased fresh weight of shoots with GA_3 application may be due to the early and increased vegetative growth. Gibberellins are helpful in transportation of minerals and water at higher rate leading to more production of photosynthates and translocated them to vegetative plant parts resulting into better seedling growth and increased fresh weight (Choudhary *et al*., 2018). Our findings are also in line with the observations depicted by Parvin *et al*. (2015), who observed maximum fresh weight of shoots with the treatment of GA_3 @ 400 ppm with two months cold stratification in Eastern black walnut seedlings.

Similarly, Mane *et al.* (2018) also recorded an increased fresh weight of shoots with the seed treatment of GA_3 @ 400 ppm for 24 hours in custard apple.

Our findings are in agreement with the studies of Hull and Lewis (1959), who reported that the fresh weight of cherry and peach seedlings increased with the application of gibberellins. Similarly, Dilip *et al*. (2017) found that application of GA_3 @ 80 ppm resulted in maximum fresh weight of shoots in Rangpur lime.

4.9 DRY WEIGHT OF SHOOTS (g)

The data pertaining to the effect of seed priming treatments on dry weight of shoots in amlook are presented in Table 4.9

Table 4.9: Effect of seed priming treatments on dry weight of shoots (g) in amlook

Treatment code	Treatments	Dry weight of shoots (g)
T_1	Priming with GA_3 @ 250 ppm	7.80
T_2	Priming with GA_3 @ 500 ppm	8.57
T_3	Priming with GA_3 @ 750 ppm	8.30
T_4	Priming with Thiourea @ 2500 ppm	7.73
T_5	Priming with Thiourea @ 5000 ppm	7.23
T_6	Priming with Thiourea @ 7500 ppm	6.90
T_7	Priming with KNO_3 @ 2500 ppm	6.81
T_8	Priming with KNO_3 @ 5000 ppm	6.85
T_9	Priming with KNO_3 @ 7500 ppm	7.41
T_{10}	Hydro-priming	6.63
T_{11}	No priming (control)	6.31
$CD_{(0.05)}$		0.33

It is evident from the data (Table 4.9) that dry weight of shoots was significantly affected by the different treatments. The maximum dry weight of shoots (8.57 g) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) recording dry weight of shoots (8.30 g) and was significantly higher over all the other treatments including control. Minimum dry weight of shoots (6.31 g) was recorded under treatment T_{11} (Control-no priming).

The higher shoot dry weight with GA_3 priming treatment may be attributed to the overall seedling growth and an increased photosynthetic rate, ultimately lead to the overall assimilation and distribution of photosynthates in the seedlings. These findings are in agreement with the studies of Kumar and Shahnaz (2013), who observed the maximum dry

weight of shoots with the seed treatment of GA_3 (500 ppm) in wild apricot. Similarly, Anjanawe *et al*. (2013) also recorded the maximum dry weight of shoots with GA_3 seed treatment in papaya in their experiment on the influence of growth regulators and media on seed germination and seedling growth.

Hull and Lewis (1959) recorded the increased dry weight of cherry and peach seedlings with the application of gibberellins. Similarly, Hota *et al.* (2018) reported that the dry weight of shoots was maximum in jamun with the seed treatment of GA_3. However, Dilip *et al*. (2017) also found maximum dry weight of shoots in Rangpur lime with the application of GA_3 @ 80 ppm.

4.10 TOTAL ROOT LENGTH (m)

The output for the effect of priming treatments on total root length in amlook is depicted in Table 4.10.

Table 4.10: Effect of seed priming treatments on total root length (m) in amlook

Treatment code	Treatments	Total root length (m)
T_1	Priming with GA_3 @ 250 ppm	1.33
T_2	Priming with GA_3 @ 500 ppm	1.45
T_3	Priming with GA_3 @ 750 ppm	1.40
T_4	Priming with Thiourea @ 2500 ppm	1.32
T_5	Priming with Thiourea @ 5000 ppm	1.27
T_6	Priming with Thiourea @ 7500 ppm	1.23
T_7	Priming with KNO_3 @ 2500 ppm	1.17
T_8	Priming with KNO_3 @ 5000 ppm	1.24
T_9	Priming with KNO_3 @ 7500 ppm	1.34
T_{10}	Hydro-priming	0.84
T_{11}	No priming (control)	0.76
$CD_{(0.05)}$		0.08

The perusal of data (Table 4.10) reveals that total root length (1.45 m) was maximum in seeds treated with T_2 (GA_3 @ 500 ppm) closely followed by seeds treated with T_3 (GA_3 @ 750 ppm) having a total root length of (1.40 m) and was significantly higher than all the other treatments. The minimum total root length (0.76 m) was observed in treatment T_{11} (Control).

The increase in total root length by gibberellins might be attributed to the fact that the increased vegetative growth synthesized higher photoassimilates and transported them to the roots of the seedlings thus enhancing the root growth. These findings are in consonance with

Kumar *et al*. (2013), who studied the effect of growth regulators on apple nursery plants and reported that GA_3 @ 12.5 ppm increased the root length of plants. Similarly Hota *et al*. (2018) investigated the effect of GA_3 on germination, growth and survival of jamun and found the highest root length of seedlings with gibberellin treated seeds.

The higher total root length in our findings through seed priming with GA_3 may be due to the fact that gibberellins increased the physiological processes in the plants, which is essential for cell division and cell enlargement (Vishwakarma, 2013). Our results are in agreement with the findings of Bandana (2014), who also recorded the higher total root length with the seed treatment of gibberellic acid in apple. Similarly, Pratibha *et al*. (2015), observed maximum root length by the seed treatment with gibberellic acid in papaya.

4.11 FRESH WEIGHT OF ROOTS (g)

The data related to the effect of seed priming treatments on fresh weight of roots in amlook are presented in Table 4.11.

Table 4.11: Effect of seed priming treatments on fresh weight of roots (g) in amlook

Treatment code	Treatments	Fresh weight of roots (g)
T_1	Priming with GA_3 @ 250 ppm	10.71
T_2	Priming with GA_3 @ 500 ppm	11.97
T_3	Priming with GA_3 @ 750 ppm	11.41
T_4	Priming with Thiourea @ 2500 ppm	10.64
T_5	Priming with Thiourea @ 5000 ppm	10.04
T_6	Priming with Thiourea @ 7500 ppm	9.94
T_7	Priming with KNO_3 @ 2500 ppm	9.69
T_8	Priming with KNO_3 @ 5000 ppm	9.93
T_9	Priming with KNO_3 @ 7500 ppm	10.52
T_{10}	Hydro-priming	9.37
T_{11}	No priming (control)	8.94
$CD_{(0.05)}$		0.58

The data (Table 4.11) reveals that various seed priming treatments have significant influence on fresh weight of roots over T_{11} (Control-no priming). Fresh weight of roots (11.97 g) was maximum in treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) bearing fresh weight of roots (11.41 g). The minimum fresh weight of roots (8.94 g) was observed under T_{11} (Control-no priming).

The more fresh weight of roots by GA_3 treatment in our investigations may be attributed to the fact that gibberellins plays an important role in cell division, cell elongation, auxin metabolism, cell wall plasticity and cell membrane permeability ultimately leading to increased vegetative growth (Rai *et al.,* 2018). The activity of gluconeogenic enzymes during early stages of germination and seedling vigour reflected in terms of increased primary and secondary root length, which ultimately increased the fresh weight of roots. The present results are in agreement with the findings of Verma *et al*. (2019), who also noticed the maximum fresh weight of roots in Indian gooseberry seedlings under poly house + GA_3 @ 600 ppm in their studies on the influence of seed treatment with gibberellic acid and thiourea on seedling growth performance under different growing conditions. Similarly, Sheoran *et al.* (2018) also observed the highest fresh weight of roots by the soaking treatments of ber seeds with gibberellins.

Our findings are in consonance with the studies of Hota *et al*. (2018), who revealed that the fresh weight of roots was maximum in jamun plants treated with GA_3. Similarly, Dilip *et al*. (2017) also reported that the application of GA_3 @ 80 ppm on Rangpur lime significantly increased the fresh weight of roots.

4.12 DRY WEIGHT OF ROOTS (g)

The observations for the effect of seed priming treatments on dry weight of roots in amlook are presented in Table 4.12.

Table 4.12: Effect of seed priming treatments on dry weight of roots (g) in amlook

Treatment code	Treatments	Dry weight of roots (g)
T_1	Priming with GA_3 @ 250 ppm	6.02
T_2	Priming with GA_3 @ 500 ppm	6.24
T_3	Priming with GA_3 @ 750 ppm	6.10
T_4	Priming with Thiourea @ 2500 ppm	5.86
T_5	Priming with Thiourea @ 5000 ppm	5.64
T_6	Priming with Thiourea @ 7500 ppm	5.57
T_7	Priming with KNO_3 @ 2500 ppm	5.30
T_8	Priming with KNO_3 @ 5000 ppm	5.40
T_9	Priming with KNO_3 @ 7500 ppm	5.74
T_{10}	Hydro-priming	5.18
T_{11}	No priming (control)	5.10
$CD_{(0.05)}$		0.20

It is clear from the data (Table 4.12) that dry weight of roots was significantly affected by the different priming treatments. The maximum dry weight of roots (6.24 g) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) bearing dry weight of roots (6.10 g) and was significantly higher over all the other treatments including control. Minimum dry weight of roots (5.10 g) was recorded under T_{11} (Control-no priming).

The increase dry weight of roots with GA_3 treatment in our studies may be due to the fact that higher seedling growth synthesized more photosynthetic assimilates and translocated them to the roots. Our observations are confirmed by the results of Al-Hawezy (2013), who also found the highest dry weight of roots by GA_3 treatment in loquat. Similarly, Kumar and Shahnaz (2013) recorded the maximum dry weight of roots with the seed treatment of GA_3 @ 500 ppm. Pratibha *et al*. (2015) investigated the effect of chemical treatments on papaya seed germination and recorded the maximum dry weight of roots under GA_3 treatment.

Gibberellins increased length and number of roots thereby, increased the fresh and dry weight of roots. Our findings are in accordance with Hota *et al*. (2018), who reported that the appliction of GA_3 on jamun resulted in maximum dry weight of roots. Similarly, Dilip *et al*. (2017) also reported that the application of GA_3 on Rangpur lime significantly increased the dry weight of roots.

4.13 Root: shoot ratio

The outcomes for the effect of seed priming treatments on root: shoot ratio on fresh weight basis in amlook is shown in Table 4.13.

Table 4.13: Effect of seed priming treatments on root: shoot in amlook

Treatment code	Treatments	Root: shoot ratio
T_1	Priming with GA_3 @ 250 ppm	0.68
T_2	Priming with GA_3 @ 500 ppm	0.74
T_3	Priming with GA_3 @ 750 ppm	0.71
T_4	Priming with Thiourea @ 2500 ppm	0.72
T_5	Priming with Thiourea @ 5000 ppm	0.70
T_6	Priming with Thiourea @ 7500 ppm	0.71
T_7	Priming with KNO_3 @ 2500 ppm	0.72
T_8	Priming with KNO_3 @ 5000 ppm	0.73
T_9	Priming with KNO_3 @ 7500 ppm	0.72
T_{10}	Hydro-priming	0.71
T_{11}	No priming (control)	0.71
$CD_{(0.05)}$		NS

The data pertaining to this observation were found to be non-significant. However, the maximum root: shoot ratio (0.74) was recorded in T_2 (GA_3 @ 500 ppm). The minimum root: shoot ratio was recorded in T_5 (Thiourea @ 5000 ppm) bearing 0.70 root: shoot ratio.

4.14 BIOMASS OF SEEDLINGS (g) ON DRY WEIGHT BASIS

The influence of seed priming treatments on biomass of seedlings (g) on dry weight basis in amlook is depicted in Table 4.14.

Table 4.14: Effect of seed priming on biomass of seedlings on dry weight basis (g)

Treatment code	Treatments	Biomass of seedlings (g)
T_1	Priming with GA_3 @ 250 ppm	13.82
T_2	Priming with GA_3 @ 500 ppm	14.81
T_3	Priming with GA_3 @ 750 ppm	14.40
T_4	Priming with Thiourea @ 2500 ppm	13.60
T_5	Priming with Thiourea @ 5000 ppm	12.87
T_6	Priming with Thiourea @ 7500 ppm	12.47
T_7	Priming with KNO_3 @ 2500 ppm	12.11
T_8	Priming with KNO_3 @ 5000 ppm	12.25
T_9	Priming with KNO_3 @ 7500 ppm	13.16
T_{10}	Hydro-priming	11.81
T_{11}	No priming (control)	11.41
$CD_{(0.05)}$		0.38

The perusal data (Table 4.14) reveals that biomass of seedlings was significantly improved by different seed priming treatments. The biomass of seedlings (14.81 g) was maximum in treatment T_2 (GA_3 @ 500 ppm), which was significantly higher than all the other treatments. However, the minimum biomass of seedlings (11.41 g) was observed with the treatment T_{11} (Control-no priming).

The increased vegetative growth due to the faster rate of cell division, cell elongation and more synthesis and accumulation of photosynthates could be the possible reason for the improved seedling biomass with the seed priming treatment of GA_3. These findings are in agreement with the observations of Sau *et al*. (2019) who also reported the increased seedling dry weight in wood apple by seed priming with GA_3

Our results are also in line with the findings of Joolka *et al*. (2004) who studied the influence of bio-fertilizers, GA_3 and their combinations on the growth of pecan seedlings and

found that application of bio-fertilizers and GA_3 alone and in combinations exerted significant influence of biomass seedlings.

4.15 SEEDLING VIGOUR INDEX- I

The effect of seed priming treatments on seedling vigour index- I in amlook is visualized in Table 4.15.

Table 4.15: Effect of seed priming treatments on seedling vigour index- I in amlook

Treatment code	Treatments	Seedling vigour index-I
T_1	Priming with GA_3 @ 250 ppm	2,295.15
T_2	Priming with GA_3 @ 500 ppm	2,547.88
T_3	Priming with GA_3 @ 750 ppm	2,494.14
T_4	Priming with Thiourea @ 2500 ppm	2,123.85
T_5	Priming with Thiourea @ 5000 ppm	2,028.46
T_6	Priming with Thiourea @ 7500 ppm	1,826.19
T_7	Priming with KNO_3 @ 2500 ppm	1,910.05
T_8	Priming with KNO_3 @ 5000 ppm	2,089.00
T_9	Priming with KNO_3 @ 7500 ppm	2,314.13
T_{10}	Hydro-priming	1,343.08
T_{11}	No priming (control)	1,243.43
$CD_{(0.05)}$		215.34

The data (Table 4.15) emphasises that the highest seedling vigour index- I (2547.88) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by the treatments T_3 (GA_3 @ 750 ppm) which was significantly superior over the remaining treatments. While the least seedling vigour index- I (1243.43) was observed with the treatment T_{11} (Control-no priming).

The more vigorous seedlings with GA_3 treatment in our studies may be due to the earlier seed germination, more number of leaves, higher shoot and root length, which lead to more assimilation and distribution of food material to the whole plant (Brian and Hemming, 1958). Our results are in conformity with Palepad *et al*. (2017), who conducted an experiment on the effect of different seed treatments on germination and growth rate of custard apple and recorded the maximum seed vigour index- I, when seeds were treated with gibberellic acid. Similarly, Al-Hawezy (2013) in loquat, also found that seeds soaked in GA_3 solution resulted in the maximum vigour index

4.16 SEEDLING VIGOUR INDEX- II

The results regarding the influence of seed priming treatments on seedling vigour index- II of amlook are given in Table 4.16.

Table 4.16: Effect of seed priming treatments on seedling vigour index-II in amlook

Treatment code	Treatments	Seedling vigour index-II
T_1	Priming with GA_3 @ 250 ppm	825.07
T_2	Priming with GA_3 @ 500 ppm	951.91
T_3	Priming with GA_3 @ 750 ppm	915.11
T_4	Priming with Thiourea @ 2500 ppm	776.86
T_5	Priming with Thiourea @ 5000 ppm	726.52
T_6	Priming with Thiourea @ 7500 ppm	650.44
T_7	Priming with KNO_3 @ 2500 ppm	650.94
T_8	Priming with KNO_3 @ 5000 ppm	681.56
T_9	Priming with KNO_3 @ 7500 ppm	801.52
T_{10}	Hydro-priming	472.87
T_{11}	No priming (control)	440.48
$CD_{(0.05)}$		77.71

The data (Table 4.16) reveals that the different seed priming treatments exerted the significant effect on the seedling vigour index-II. The treatment T_2 (GA_3 @ 500 ppm) showed the significantly higher vigour index-II (951.91) over all the other treatments. The least seedling vigour index- II (440.48) was observed in the treatment T_{11} (Control-no priming).

The possible reason for the enhanced vigour index- II with GA_3 treatment may be attributed to higher germination percentage and vigorous seedling growth that lead to the production of more dry matter content of seedlings. The above findings are in agreement with Palepad *et al*. (2017), who conducted an experiment on the effect of seed treatment on germination and growth rate of custard apple and recorded the maximum seedling vigour index- II with GA_3 seed treatment. Yadav (2018) also found the highest seedling vigour index- II in the seed treatment of GA_3 @ 400 ppm in custard apple.

4.17 SURVIVAL PERCENTAGE

The observations on the effect of seed priming treatments on survival (%) in amlook are presented in Table 4.17.

Table 4.17: Effect of seed priming treatments on survival (%) in amlook

Treatment code	Treatments	Survival (%)
T_1	Priming with GA_3 @ 250 ppm	80.71 (63.92)
T_2	Priming with GA_3 @ 500 ppm	93.84 (75.64)
T_3	Priming with GA_3 @ 750 ppm	90.68 (72.20)
T_4	Priming with Thiourea @ 2500 ppm	78.00 (62.01)
T_5	Priming with Thiourea @ 5000 ppm	75.65 (60.41)
T_6	Priming with Thiourea @ 7500 ppm	72.86 (58.59)
T_7	Priming with KNO_3 @ 2500 ppm	74.76 (59.82)
T_8	Priming with KNO_3 @ 5000 ppm	83.06 (65.68)
T_9	Priming with KNO_3 @ 7500 ppm	86.06 (68.07)
T_{10}	Hydro-priming	69.32 (56.35
T_{11}	No priming (control)	68.18 (55.65)
$CD_{(0.05)}$		1.61

* Figures in parentheses are angular transformed values

The data (Table 4.17) reveals that various seed priming treatments had significant influence on survival percentage of seedling. Significantly higher survival (93.84 %) was recorded under the treatment T_2 (GA_3 @ 500 ppm) as compared to all other treatments including control. Minimum survival (68.18 %) was recorded under treatment T_{11} (Control-no priming).

The highest survival rate of seedlings resulted from GA_3 treated seeds may be due to the earlier and faster root initiation, which resulted into vigorous and sturdy seedlings (Palepad *et al*., 2017). Our findings are supported by Meena *et al*. (2003), who observed that GA_3 significantly affected the germination percentage and survival percentage in all the cultivars of papaya.

Our results are also in concomitant with the findings of Vishwakarma (2013), who investigated the effect of growing media and gibberellic acid on germination and survival rate of seedlings in acid lime and recorded the maximum survival rate of seedling with the treatment of GA_3 @ 150 ppm in combination with soil + slurry + Azatobacter (1: 1: 5g/kg) media. Similarly, Rawat (2016) also found that the seed treatment with GA_3 significantly increased the survival rate of custard apple seedlings.

4.18 NUMBER OF GRAFTABLE SEEDLINGS (%)

The outcomes of the impact of seed priming treatments on number of graftable seedlings in amlook is depicted in Table 4.18.

Table 4.18: Effect of seed priming treatments on number of graftable seedlings (%) in amlook

Treatment code	Treatments	Number of graftable seedlings (%)
T_1	Priming with GA_3 @ 250 ppm	87.38 (69.17)
T_2	Priming with GA_3 @ 500 ppm	96.99 (80.17)
T_3	Priming with GA_3 @ 750 ppm	93.23 (74.91)
T_4	Priming with Thiourea @ 2500 ppm	82.11 (64.95)
T_5	Priming with Thiourea @ 5000 ppm	79.51 (63.07)
T_6	Priming with Thiourea @ 7500 ppm	77.04 (61.35)
T_7	Priming with KNO_3 @ 2500 ppm	78.26 (62.19)
T_8	Priming with KNO_3 @ 5000 ppm	88.33 (70.04)
T_9	Priming with KNO_3 @ 7500 ppm	91.02 (72.56)
T_{10}	Hydro-priming	71.79 (57.89)
T_{11}	No priming (control)	69.73 (56.60)
$CD_{(0.05)}$		1.91

* Figures in parentheses are angular transformed values

It is evident from the data (Table 4.18) that seed priming treatments significantly influenced the number of graftable seedlings. The seed treatment T_2 (GA3 @ 500 ppm) resulted in production of highest number of graftable seedlings (96.99 %), which was significantly greater than any other treatments applied. The least number of graftable seedings (69.73 %) were obtained in the treatment T_{11} (Control-no priming).

The significant increase in seedling height and diameter along with well developed root system in the seed treatment of GA_3 may be the possible reason for higher number of graftable seedlings. Our results are in line with the findings of Dilip *et al*. (2017), who found that the seed treatment with gibberellic acid resulted into increased seedling height and diameter of Rangpur lime and also increased the buddable seedlings. Similarly, Al-Hawezy (2013) also recorded an increased height and diameter of loquat seedlings with seed soaking in various concentrations of GA_3, which ultimately increased the number of graftable seedlings.

Chapter-5

SUMMARY AND CONCLUSION

The present investigations entitled "**Effect of seed priming on germination and seedling growth in amlook (*Diospyros lotus* L.)**" were conducted at the experimental farm and laboratory of Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during 2019-20. The experiment was conducted in Randomised Block Design with eleven treatments and three replications. The results thus obtained under present investigations are summarized below:

5.1 EFFECT OF SEED PRIMING WITH GA_3, THIOUREA AND KNO_3 ON SEED GERMINATION, SEEDLING GROWTH AND QUALITY PARAMETERS IN AMLOOK

5.1.1 Significantly less days taken to seed germination (38.40 days) were recorded with treatment T_2 (GA_3 @ 500 ppm) as compared to T_{10} (Hydro-priming) and T_{11} (Control-no priming) taking 52.25 days and 55.17 days, respectively.

5.1.2 The maximum seed germination (64.26 %) was recorded under treatment T_2 (GA_3 @ 500 ppm) which was found statistically at par with T_3 (GA_3 @ 750 ppm), T_9 (KNO_3 @ 7500 ppm), T_1 (GA_3 @ 250 ppm), T_4 (Thiourea @ 2500 ppm), T_5 (Thiourea @ 5000 ppm) and T_8 (KNO_3 @ 5000 ppm). The minimum seed germination (38.62 %) was recorded under treatment T_{11} (control).

5.1.3 The maximum seedling height (29.10 cm) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) bearing seedling height (28.83 cm) and was significantly higher over all the other treatments including control. Minimum height of seedlings (23.50 cm) was recorded under T_{11} (Control-no priming).

5.1.4 The maximum seedling diameter (6.27 mm) was recorded with the treatment T_2 (GA_3 @ 500ppm) closely followed by T_3 (GA_3 @ 750 ppm) recording seedling diameter (6.00 mm) and was significantly higher over all the other treatments including control. Minimum seedling diameter (4.70 mm) was recorded under treatment T_{11} (Control-no priming).

5.1.5 The maximum number of leaves per seedling (17.07) were observed under treatment T_2 (GA_3 @ 500 ppm) and was found statistically at par with treatment T_3 (GA_3 @ 750

ppm). The number of leaves per seedling (12.00) was found to be minimum under treatment T_{11} (Control-no priming).

5.1.6 The maximum leaf area (86.04 cm^2) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) bearing leaf area (85.34 cm^2) and was significantly higher over all the other treatments including control. Minimum leaf area (60.61 cm^2) was recorded under treatment T_{11} (Control-no priming).

5.1.7 The maximum leaf chlorophyll content (2.05 mg/g) was recorded under T_2 (GA_3 @ 500 ppm) which was found statistically at par with T_3 (GA_3 @ 750 ppm). The minimum chlorophyll content (1.20 mg/g) was recorded under T_{11} (Control-no priming).

5.1.8 The maximum fresh weight of shoots (16.32 g) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by the treatment T_3 (GA_3 @ 750 ppm) bearing fresh weight of roots (16.00 g) and was significantly higher over all the other treatments including control. Minimum fresh weight of roots (12.64 g) was recorded under treatment T_{11} (Control-no priming).

5.1.9 The maximum dry weight of shoots (8.57 g) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) recording dry weight of shoots (8.30 g) and was significantly higher over all the other treatments including control. Minimum dry weight of shoots (6.31 g) was recorded under treatment T_{11} (Control-no priming).

5.1.10. Total root length (1.45 m) was maximum in seeds treated with T_2 (GA_3 @ 500 ppm) closely followed by seeds treated with T_3 (GA_3 @ 750 ppm) having a total root length of (1.40 m) and was significantly higher than all the other treatments. Minimum total root length (0.76 m) was observed in treatment T_{11} (Control).

5.1.11 Fresh weight of roots (11.97 g) was maximum in treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) bearing fresh weight of roots (11.41 g). The minimum fresh weight of roots (8.94 g) was observed under T_{11} (Control-no priming).

5.1.12 The maximum dry weight of roots (6.24 g) was recorded with the treatment T_2 (GA_3 @ 500 ppm) closely followed by T_3 (GA_3 @ 750 ppm) bearing dry weight of roots (6.10 g) and was significantly higher over all the other treatments including control. Minimum dry weight of roots (5.10 g) was recorded under T_{11} (Control-no priming).

5.1.13 Different treatments could not affect the root: shoot ratio significantly. However, maximum root: shoot ratio (0.74) was recorded in treatment T_2 (GA_3 @ 500 ppm).

Minimum root: shoot ratio was recorded in T_5 (Thiourea @ 5000 ppm) bearing 0.70 root: shoot ratio.

5.1.14 The biomass of seedlings (14.81 g) was maximum in treatment T_2 (GA_3 @ 500 ppm), which was significantly higher than all the other treatments. However, the minimum biomass of seedlings (11.41 g) was observed with the treatment T_{11} (Control-no priming).

5.1.15 The highest seedling vigour index- I (2547.88) was recorded in treatment T_2 (GA_3 @ 500 ppm) closely followed by the treatment T_3 (GA_3 @ 750 ppm) and was significantly superior over the remaining treatments. While the least seedling vigour index- I (1243.43) was observed with the treatment T_{11} (Control-no priming).

5.1.16 The treatment T_2 (GA_3 @ 500 ppm) exhibited the significantly higher vigour index- II (951.91) over all the other treatments. The least seedling vigour index- II (440.48) was observed in the treatment T_{11} (Control-no priming).

5.1.17 Significantly higher survival (93.84 %) was recorded under the treatment T_2 (GA_3 @ 500 ppm) as compared to all other treatments including control. Minimum survival (68.18 %) was recorded under treatment T_{11} (Control-no priming).

5.1.18 The seed treatment T_2 (GA_3 @ 500 ppm) resulted in production of highest number of graftable seedlings (96.99 %), which was significantly greater than any other treatments applied. The least number of graftable seedings (69.73 %) were obtained in the treatment T_{11} (Control-no priming).

5.2 CONCLUSION

Based on the results obtained from the current investigations, it may be concluded that the seed priming treatment of amlook with GA_3 (500 ppm) for 24 hours was significantly superior in terms of days taken to seed germination (38.40), seed germination (64.26 %) and seedling growth *viz*., seedling height (29.10 cm), seedling diameter (6.27 mm), number of leaves per seedling (17.07), leaf area (86.04 cm^2), leaf chlorophyll content (2.05 mg/g), fresh weight of shoots (16.32 g), dry weight of shoots (8.57 g), total root length (1.45 m), fresh weight of roots (11.97 g), dry weight of roots (6.24 g), biomass of seedlings (14.81 g), seedling vigour index-I (2547.88), seedling vigour index-II (951.91), survival rate (93.84 %) and number of graftable seedlings (96.99 %) over Control-no priming.

LITERATURE CITED

Abdul-Baki A A and Anderson J E. 1973. Vigour determination in soybean seed by multiple criteria. *Crop Science* **13**:630-35.

Agha J T, Nasir R F and Mohmad A R S. 1990. Effect of stratification and GA_3 on seed germination of sour orange and citrange rootstock. *Mesopotamia Journal Agriculture* **22**:35-43.

Agrawal P K and Dadlani M. 1995. *Techniques in Seed Science and Technology.* Second edition. South Asian Publishers New Delhi International Book Company Absecon Highlands. pp. 109-13.

Ahmad M F. 2010. Enhancement of seed germination in kiwifruit by stratification and gibberellic acid application. *Indian Journal of Horticulture* **67**:34-36.

AI-Hawezy S M N. 2013. The role of the different concentrations of GA_3 on seed germination and seedling growth of loquat (*Eriobotrya japonica* L.). *Journal of Agriculture and Veterinary Science* **4**:03-06.

Ak B E, Ozguven A I and Nikpeyma Y. 1995. The effect of GA_3 application on pistachionut seed germination and seedling growth. *Acta Horticulturae* **419**:115-20.

Anjanawe S R, Kanpure R N, Kachouli B K and Mandloi D S. 2013. Effect of plant growth regulators and growth media on seed germination and growth vigour of papaya (*Carica papaya* L.) seedling cv. Barwani Red. *Annals of Plant and Soil Research* **15**:31-34.

Annonymous. 2019. Horticulture development in Himachal Pradesh at a glance (hpagrisnet.gov.in).

Arteca R N. 1997. *Plant Growth Substances: Principles and Applications.* CBS Publishers, New Delhi. 332p.

Bandana. 2014. Studies on the nursery production of apple (*Malus* × *domestica* Borkh.) under protected conditions. M. Sc. Thesis. Department of Fruit Science, College of Horticulture, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P).

Barathkumar T R. 2019. Studies on effect of different seed treatments on dormancy breaking in aonla (*Phyllanthus emblic*a L). *Journal of Pharmacognosy and Phytochemistry* **2**:131-33.

Barman P, Rekha A and Paneerselvan P. 2016. Effect of different dose of gibberellic acid and benzyl adenine on germination and morpho-physiological characters in jamun (*Syzygium cumini* L. Skeels) under different propagation substrates. *Journal of Farm Science* **29**: 140-42.

Bertocii F, Vecchio V and Casini P. 1997. Effect of seed treatment on germination response of papaya (*Carica papaya* L.). *Advances in Horticultural Science* **11**:99-102.

Bishwas K C, Khanal A, Subedi S, Raj Kumar K C and Regmi D. 2018. Effect of GA_3 on germination parameters of different varieties of kiwi. *Current Investigations in Agriculture and Current Research* **4**:516-22.

Bradbeer J W and Pinfield N J. 1967. The effect of gibberellins on dormant seeds of *Corylus avellana* L. *New Phytologist* **66**:515-23.

Brian P W and Hemming H G. 1958. Complementary action of gibberellic acid and auxin in pea internode extension. *Annals of Botany* **22**:1-17.

Brijwal M and Kumar R. 2013. Studies on the seed germination and subsequent seedling growth of guava (*Psidium guajava* L.). *Indian Journal of Agricultural Research* **47**:347-52.

Caliskan O, Mavi K and Polat A. 2012. Influence of pre-sowing treatments on the germination and emergence of fig seeds (*Ficus carica* L.). *Acta Scientiarum* **34**:119-23.

Cetinbas M and Koyuncu F. 2018. Improving germination of *Prunus avium* L. seeds by gibberellic acid, potassium nitrate and thiourea. *Horticultural Science* **33**:119-23.

Chawla W and Mehta K. 2015. Effect of different growing media on survival and growth of transplanted litchi layers. *The Asian Journal of Horticulture* **10**:257-61.

Chiranjeevi M R, Muralidhara B M, Sneha M K, Shivan and Hongal. 2017. Effect of growth regulators and biofertilizers on germination and seedling growth of aonla (*Emblica officinalis* Gaertn.). *International Journal of Current Microbiology and Applied Sciences* **6**:1320-26.

Choudhari B K and Chakrawar V R. 1981. Effect of some chemicals on the germination of Kagzi lime (*Citrus aurantifolia* Swingle). *Journal of Maharastra Agricultural University* **5**:173-74.

Choudhary R C, Kanwar J, Chouhan G S, Singh P and Tanwar D R. 2018. Effect of GA_3 and growing media on seedling growth of papaya (*Carica papaya* L.) cv. Pusa Nanha. *International Journal of Chemical Studies* **6**:1008-12.

Deb P, Das A, Ghosh S K and Suresh C P. 2010. Improvement of seed germination and seedling growth of papaya (*Carica papaya* L) through different pre-sowing seed treatments. *Acta Horticulturae* **851**:313-16.

Debeaujon I and Koornneef M. 2000. Gibberellin requirement for arabidopsis seed germination is determined both by testa characteristics and embryonic abscisic acid. *Plant Physiology* **122**:415-24.

Dhaka S S and Pal S L. 2009. A study on lime (*Citrus aurantifolia*) seed germination as affected by gibberellic acid. *Annals of Horticulture* **2**:228-29.

Dhankhar G S and Singh M. 1996. Seed germination and seedling growth in aonla (*Phyllanthus emblica* L.) as influenced by gibberellic acid and thiourea. *Crop Research* **12**:363-66.

Dilip W S, Singh D, Moharana D, Rout S and Patra S. 2017. Effect of gibberellic acid (GA) different concentrations at different time intervals on seed germination and seedling growth of Kagzi lime. *Journal of Scientific Agriculture* **1**:62-69.

EL-Dengawy E F A and Hussein A A. 2014. The effects of treating persimmon (*Diospyros lotus)* seeds with moist-chilling and growth regulators on seeds germination, the subsequent seedling characters and their induced drought tolerance. *Journal of Agriculture and Veterinary Science* **7**:45-53.

Ferreira G, Cereda E, Silva C P and Patel J F. 1998. Effect of GA_3 on the germination of seeds of custard apple (*Annona squamosa* L.). *Congress of Botany* **49**:186-87.

Finkelstein R, Reeves W, Ariizumi T, Steber C. 2008. Molecular aspects of seed dormancy. *Annual Review of Plant Biology* **59**:387-415.

Gharge V R, Kadam A S, Patil V K, Lakade S K and Dhomane P A. 2011. Effect of various concentrations of GA_3 and soaking periods on seed germination of custard apple (*Annona squamosa* L.). *Green Farming* **2**:550-51.

Gholap S V, Dod V N, Huyar S A and Bharad S G. 2000. Effect of plant growth regulators on seed germination and seedling growth in aonla (*Phyllanthus emblica* L.) under climatic condition of Akola. *Crop Research* (Hisar) **20**:546-48.

Griffith E, Griffith M E and Mc Daniel J C. 1982. *Persimmons for everyone*. North American Fruit Exporters. 145p.

Gurung N, Swamy G S K, Sarkar S K and Ubale N B. 2014. Effect of chemicals and growth regulators on germination, vigour and growth of passionfruit (*Passiflora edulis* Sims.). *The Bioscan* **9**:155-57.

Haber A H and Leopold H J. 1960. Effect of gibberellins on gamma irradiated wheat. *American Journal of Botany* **47**:140-44.

Haber A H, Ford D E and Perdue U. 1969. Action of GA and abscisic acid on lettuce seed germination without acting as nucleus DNA synthesis. *Plant Physiology* **44**:463-67.

Halfacre R G, Baradent J A and Pollens J H A. 1968. Effect of alar on morphology, chlorophyll contents and net CO_2 assimilation rate of young apple trees. *Proceedings of the American Society for Horticultural Science* **193**:40-52.

Harshavardan A and Rajasekhar M. 2012 Effect of pre-sowing seed treatments on seedling growth of jackfruit (*Artocarpus heterophyllus* Lam.). *Journal Research ANGRAU* **40**:87-89.

Hartmann H T, Kester D E, Davies F Jr and Geneve R L. 1997. *Plant Propagation*: *Principles and Practices.* Sixth edition. New Jersey, Prentice Hall. 770p.

Hiscox J D and Israelstam G F. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany* **57**:1332-34.

Hore J K and Sen S K. 1994. Role of pre sowing seed treatment on germination, seedling growth and longevity of ber (*Zizyphus mauritiana*) seeds. *Indian Journal of Agricultural Research.* **28**:285-89.

Hota S N, Karna A K, Jain P K and Dakhad B. 2018. Effect of gibberellic acid on germination, growth and survival of jamun (*Syzygium cumini* L. Skeels). *The Pharma Innovation Journal* **7**:323-26.

Hull J and Lewis L N. 1959. Response of one-year-old cherry and mature bearing cherry, peach and apple trees to gibberellins. *Journal of American Society of Horticultural Sciences* **74**:93-100.

Jadhav A C, Bhagure Y L and Raundal R M. 2015. Effect of PGR, chemicals and plant extract on seed germination and seedling growth of custard apple (*Annona squamosa*). *The Asian Journal of Horticulture* **10**:184-86.

Jadhav N G and Deshmukh H S. 2019. Effect of growth regulators, chemical and organic wastes on the seed germination and seedling diameter of Rangpur lime. *Journal of Pharmacognosy and Phytochemistry* **8**:448-51.

Jones R L and Kaufman P B. 1983. Role of gibberellins in plant cell elongation. *Critical Reviews in Plant Sciences* **1**:23-47.

Joolka N K, Singh R R and Sharma M K. 2004. Influence of biofertilizers, GA_3 and their combinations on the growth of pecan seedlings. *Indian Journal of Horticultural Sciences* **61**:226-28.

Kadam A B, Singh D B and Kade R A. 2010. Effect of plant growth regulators and potassium nitrate on growth of seedling of Kagzi lime. *The Asian Journal of Horticulture* **5**:431-34.

Kalalbandi B M, Dabhade R S, Ghadge P M and Bhagat V. 2003. Effect of gibberelic acid, napthalene acetic acid and potassium nitrate on germination and growth of Kagzi lime. *Annals of Plant Physiology* **17**:84-87.

Kalyani M, Bharad S G and Parameshwar P. 2014. Effect of growth regulators on seed germination in guava. *International Journal on Biological Sciences* **5**:81-99.

Kaushal M. 2016. Studies on macro and micro nutrients on yield and quality of garlic. M. Sc. Thesis. Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan.

Koyunchu F. 2005. Breaking seed dormancy in black mulberry (*Morus nigra* L.) by cold stratification and exogenous application of gibberellic acid. *Acta Biological Cracoviensia Series Botanica* **47:**23-26.

Kumar A and Shahnaz E. 2013. Effect of growth regulating substances on stratification of wild apricot (*Prunus armeniaca* L.) kernels under Kashmir conditions. *Indian Journal of Agricultural Sciences* **83**:1253-56.

Kumar H S Y, Swamy G S K, Kanmadi V C, Kumar P and Sowmaya B N. 2008. Effect of organics and chemicals on germination, growth and graft take in mango. *The Asian Journal of Horticulture* **3**:336-39.

Kumar J, Sharma V P and Thakur D. 2013. Studies on the effect of growth regulators on production of apple nursery plants. *Asian Journal of Horticulture* **8**:93-96.

Mane S B, Naglot U M and Parse R N. 2018. Effect of different pre-sowing treatments on shoot growth of custard apple (*Annona squamosa* L.). *Journal of Pharmacognosy and Phytochemistry* **7**:1945-47.

Mathur D D, Couvillon G A, Vines H M and Hendershott C H. 1971. Stratification effects on endogenous gibberellic acid (GA) in peach seeds. *HortScience* **6**:538-39.

Meena R R, Jain M C and Mukherjee S. 2003. Effect of pre-sowing dip seed treatment with gibberellic acid on germination and survivability of papaya. *Annals of Plant and Soil Research* **5**:120-21.

Mehanna T H, George C M and Nishijima C. 1985. Effects of temperature, chemical treatments and endogenous hormone content on peach seed germination and subsequent seedling growth. *Scientia Horticulturae* **27**:63-73.

Mobli M and Baninasab B. 2008. Effects of plant growth regulators on growth and carbohydrate accumulation in shoots and roots of two almond rootstock seedlings. *Fruits* **63**:363-70.

Munde G R and Gajbhiye R P. 2010. Effect of plant growth regulators on seedling growth of mango stones. *Green Farming* **1**:288-89.

Ono E O, Leonel S, Filho J D and Rodrigues J D. 2000. Effects of storage and exogenous GA_3 on lychee seed germination. *Brazilian Archives of Biology and Technology* **43**:441-45.

Palepad K B, Bharad S G and Bansode G S. 2017. Effect of seed treatments on germination, seedling vigour and growth rate of custard apple (*Annona squamosa*). *Journal of Pharmacognosy and Phytochemistry* **6**:20-23.

Pampanna Y, Sulikeri G S and Hulmani N C. 1995. Effect of growth regulators on seed germination and growth of seedling of sapota. *Journal of Farm Sciences* **8**:60-64.

Panda P A, Karna A K and Sinha K. 2018. Effect of gibberellic (GA_3) acid on seed germination and growth of Kagzi lime (*Citrus aurantifolia* Swingle). *International Journal of Chemical Studies* **6**:2803-05.

Panse V G and Sukhatme P V. 2000. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research. New Delhi. India. pp. 157-65.

Parmar R K, Patel M J, Thakkar R M and Tsomu T. 2016. Influence of seed priming treatments on germination and seedling vigour of custard apple (*Annona squamosa* L.) cv. Local. *International Journal of Life Sciences* **11**:389-93.

Parvin P, Khezri M, Tavasolian I and Hosseini H. 2015. The effect of gibberellic acid and chilling stratification on seed germination of Eastern black walnut. *Journal of Nuts* **6**:67-76.

Patel M S, Nurbhanej K H, Rathod M J, Vyas S V and Bhutiya N H. 2017. Effect of media and GA_3 on seed germination of custard apple (*Annona squamosa* L.) cv. Sindhan. *International Journal of Pure and Applied Bioscience* **9**:582-86.

Pawar V B, Gore R V, Patil V K and Narsude P B. 2010. Effect of gibberellic acid on seed germination and growth of *Jatropha curcas* L. *The Asian Journal of Horticulture* **5**:311-13.

Pawshe Y H, Patti B N and Patil L P. 1997. Effect of pre-germination seed treatment on germination and vigour of seedlings in aonla (*Emblica officianlis* Garten.). *PKV Research Journal* **21**:152-53.

Peche P M, Barbosa C M A, Pio R, Sousa P H A and Valle M H. 2016. Seed stratification, gibberellic acid and temperature in obtaining rootstock in the persimmon. *Revista Ciencia Agronomica* **47**:387-92.

Pratibha C, Teja T and Krishna P M. 2015. Effect of chemical treatments on the germination and subsequent seedling growth of papaya (*Carica papaya* L.) seeds cv. Pusa Nanha. *Journal of Agricultural Engineering and Food Technology* **2**:189-91.

Purbey S K, Meghwal P R. 2005. Effect of pre-sowing seed treatment on seed germination and vigour of aonla seedlings. *Research on Crops* **6**:560-61.

Qureshi S N, Wani M S and Javaid K. 2016. Effect of stratification and gibberellic acid on seed germination and seedling growth of walnut under Kashmir valley conditions. *Indian Journal of Horticulture* **73**:171-76.

Rahemi M and Baninasab B. 2000. Effect of gibberellic acid on seedling growth in two wild species of pistachionut. *Journal of Horticultural Science and Biotechnology* **75**:336-39.

Rai R, Samir M, Srivastava R and Uniyal S. 2018. Improving seed germination and seedling traits by pre-sowing treatments in khirni (*Manilkara hexandra*). *Bulletin of Environment, Pharmacology and Life Sciences* **7**:77-81.

Ramteke V, Paithankar D H, Baghel M M and Kurrey V K. 2016. Effect of GA_3 and propagation media on growth rate and leaf chlorophyll content of papaya seedlings. *Research Journal of Agricultural Sciences* **7**:169-71.

Ramteke V, Paithankar D H, Ningot E P and Kurrey V K. 2015. Effect of GA_3 and propagation media on germination, growth and vigour of papaya cv. Coorg Honey Dew. *The Bioscan* **10**:1011-16.

Rao V and Reddy Y T N. 2005. Effect of osmopriming on germination, seedling growth and vigour of mango (*Mangifera indica* L.) stones. *The Karnataka Journal of Horticulture* **1**:29-35.

Ratan P B and Reddy Y N. 2003. Influence of potassium nitrate on germination and subsequent seedling growth of custard apple (*Annona squamosa* L.). *Journal Research ANGRAU* **31**:70-73.

Ratan P B and Reddy Y N. 2004. Influence of gibberellic acid on custard apple (*Annona squamosa* L.) seed germination and subsequent seedling growth. *Journal Research ANGRAU* **32**:93-95.

Rawat U S. 2016. Studies on effect of seed treatment on germination, seedling vigour and survivability of custard apple. M. Sc. Thesis. Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India.

Sachs K M, Bretz C and Lang A. 1959. Cell division and gibberellic acid. *Experimental Cell Review*. pp. 230-44.

Samir M, Rai R and Prasad B. 2015. Seed germination behaviour as influenced by pre-sowing treatments in khirni. *Journal of Hill Agriculture* **6**:132-35.

Sau S, Pal B, Sarkar S and Sarkar T. 2019. Influence of seed priming on germination and seedling vigour of wood apple (*Feronia limonia* Swingle). *International Journal of Bio-resource and Stress Management* **10**:128-36.

Sayyad-Amin P and Shahsavar A R. 2019. Improvement of seed germination of date-plum (*Diospyros lotus* L.) by physical and chemical treatments. *Journal of Chemical Health Risks* **9**:51-56.

Shanmugavalli M, Ranganayaki P R and Menaka C. 2007. Seed dormancy and germination improvement treatments in mandarian. *SAT e-journal.icrisat.org*. pp. 13-22.

Sharma M C, Ughreja P P and Jambukia T K. 1999. Effect of some plant growth regulators, chemicals and organic waste on germination and subsequent seedling growth on Kagzi lime. International Symposium on Citriculture, Nagpur. 51p.

Sheoran V, Kumar M, Vijay, Sharma S and Pathak D V. 2018. Effect of seed scarification treatments on ber (*Ziziphus rotundifolia* Lamk.) seedling biomass. *International Journal of Current Microbiology and Applied Sciences* **7**:2591-96.

Shim S I, Moon J C, Jang C S, Raymer P and Kim W. 2008. Effect of potassium nitrate priming on seed germination of seashore paspalum. *HortScience* **43**:2259-62.

Shinde B N, Kalalbandi B M and Gaikwad A R. 2008. Effect of pre-sowing seed treatment on seed germination, rate and percentage of Rangpur lime. *International Journal of Plant Sciences* **3**:321-22.

Singh M, Singh G N, Singh L N and Singh B N. 1989. Effect of gibberellic acid on seed germination in sweet orange (*Citrus sinensis* Osbeck). *Haryana Journal Horticultural Sciences* **18**:29-33.

Srivastava R P and Singh L. 1967. The influence of presowing treatment with gibberellic acid on the germination and growth of fruit plants in Hill Lemon and Malta. *The Punjab Horticultural Journal* **42**:12-16.

Stewart E R and Freebairn H T. 1969. Ethylene, seed germination and epinasty. *Plant Physiology* **44**:955-58.

Taha F A. 1987. Effect of plant growth regulators on seed germination and seedling characters of persimmon root-stock (*Diospyros kaki). Egyptian Journal Horticulture* **14**:15-20.

Taylor R M. 1972. Influence of gibberellic acid on early patch budding of pecan seedlings. *Journal of American Society of Horticultural Sciences* **97**:677-79.

Thakur B. 2015. Effect of growth regulator, scarification and thiourea on seed germination in peach (*Prunus persica* L.Batsch) rootstock Flordaguard. *International Journal of Current Research and Academic Review* **3**:252-61.

Verma R, Pandey C S, Pandey S K and Sahu K. 2019. Influence of pre-sowing seed treatment and growing conditions on growth performance of Indian gooseberry seedlings (*Emblica officinalis* Gaertn.). *International Journal of Current Microbiology and Applied Sciences* **8**:1936-48.

Verma S K, Pant K C, Muneem K C and Arya R R. 1998. Seed germination studies in kiwi fruit (*Actinidia chinensis*). *South Indian Horticulture* **46**:279-81.

Vishwakarma D. 2013. Effect of growing media and GA_3 on seed germination, growth and survival of acid lime (*Citrus aurantifolia* Swingle.) var. Kagzi. M. Sc. Thesis. Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P.

Wagh A P, Choudhary M H, Kulwal L V, Jadhav B J and Joshi P S. 1998. Effect of seed treatment on germination of seed and initial growth of aonla seedling in polybag. *PKV Research Journal* **22**:176-77.

Wareing P F and Foda H A. 2006. Growth inhibitors and dormancy in Xanthium seed. *Physiologia Plantarum* **10**:266-80.

Yadav R K, Jain M C and Jhakar R P. 2012. Effect of media on growth and development of acid lime (*Citrus aurantifolia* Swingle) seedling with or without Azotobacter. *African Journal of Agricultural Research* **7**:6421-26.

Yadav R S, Sharma T R, Pandey S K and Maske G. 2018. Effect of GA_3 and cow urine on growth and physiology of custard apple at seedling stage. *The Pharma Innovation Journal* **7**:395-97.

APPENDIX-I

Monthly meteorological data during crop growth period from January 2019 to December 2019

Month and Year	Temperature (°C)			Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum	Mean		
January, 2019	15.70	2.00	8.85	59.00	73.00
February, 2019	16.30	4.40	10.35	63.00	103.10
March, 2019	20.30	6.40	13.35	54.00	54.60
April, 2019	27.30	12.70	20.00	49.00	36.80
May, 2019	30.50	14.70	22.60	44.00	21.30
June, 2019	33.70	17.80	25.75	48.00	98.50
July, 2019	27.70	19.90	23.80	79.00	218.10
August, 2019	28.80	20.10	24.45	79.00	225.80
September, 2019	28.30	18.60	23.45	78.00	151.40
October, 2019	25.60	11.30	18.45	66.00	5.60
November, 2019	22.80	8.10	15.45	61.00	32.20
December, 2019	19.10	1.90	10.50	58.00	33.20

Source: Meteorological Observatory, Department of Environmental Science, College of Forestry, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, India - 173230

APPENDIX-II

Effect of seed priming on germination and seedling growth in amlook (*Diospyros lotus* L.)

ANOVA for days taken to germination

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	65.822		
Treatment	10	853.982	85.398	4.942
Error	20	345.615	17.281	
Total	32	1,265.419		

ANOVA for seed germination (%)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	232.263		
Treatment	10	2,185.84	218.584	6.991
Error	20	625.326	31.266	
Total	32	3,043.43		

ANOVA for seedling height (cm)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.402		
Treatment	10	92.197	9.220	105.263
Error	20	1.752	0.088	
Total	32	94.351		

ANOVA for seedling diameter (mm)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.177		
Treatment	10	6.054	0.605	18.633
Error	20	0.650	0.032	
Total	32	6.881		

ANOVA for number of leaves per seedling

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.243		
Treatment	10	68.756	6.876	13.142
Error	20	10.464	0.523	
Total	32	79.463		

ANOVA for leaf area (cm^2)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	5.442		
Treatment	10	2,035.279	203.528	21.425
Error	20	189.994	9.500	
Total	32	2,230.714		

ANOVA for leaf chlorophyll content (mg/g)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.008		
Treatment	10	2.169	0.217	125.131
Error	20	0.035	0.002	
Total	32	2.212		

ANOVA for fresh weight of shoots (g)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.260		
Treatment	10	41.893	4.189	37.231
Error	20	2.250	0.113	
Total	32	44.404		

ANOVA for dry weight of shoots (g)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.057		
Treatment	10	15.294	1.529	40.798
Error	20	0.750	0.037	
Total	32	16.101		

ANOVA for total root length (m)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0		
Treatment	10	1.426	0.143	67.682
Error	20	0.042	0.002	
Total	32	1.469		

ANOVA for fresh weight of roots (g)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.130		
Treatment	10	23.317	2.332	20.502
Error	20	2.275	0.114	
Total	32	25.721		

ANOVA for dry weight of roots (g)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.051		
Treatment	10	4.372	0.437	30.982
Error	20	0.282	0.014	
Total	32	4.706		

ANOVA for root: shoot ratio

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.001		
Treatment	10	0.006	0.001	0.458
Error	20	0.025	0.001	
Total	32	0.032		

ANOVA for biomass of seedlings (g) (on dry weight basis)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	0.013		
Treatment	10	35.667	3.567	72.969
Error	20	0.978	0.049	
Total	32	36.658		

ANOVA for seedling vigour index-I

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	90,540.313		
Treatment	10	5,376,735.381	537,673.538	34.109
Error	20	315,265.044	15,763.252	
Total	32	5,782,540.739		

ANOVA for seedling vigour index-II

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	14,486.643		
Treatment	10	789,100.217	78,910.022	38.445
Error	20	41,051.200	2,052.560	
Total	32	844,638.060		

ANOVA for survival percentage

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	4.649		
Treatment	10	1,232.985	123.298	140.320
Error	20	17.574	0.879	
Total	32	1,255.208		

ANOVA for number of graftable seedlings (%)

Source of Variation	df	SS	MSS	F-Calculated
Replication	2	2.909		
Treatment	10	1,635.553	163.555	132.265
Error	20	24.732	1.237	
Total	32	1,663.193		

Dr YS Parmar University of Horticulture and Forestry
Nauni, Solan (HP) 173 230
SEED SCIENCE AND TECHNOLOGY

Title of Thesis	:	**"Effect of seed priming on germination and seedling growth in amlook (*Diospyros lotus* L.)"**
Name of the Student	:	Reva Jaryal
Admission Number	:	H-2018-31-M
Major Advisor	:	Dr C L Sharma
Major Field	:	Seed Science and Technology
Minor Field(s)	:	Fruit Science
Date of Thesis Submission	:	
No. of pages in Thesis	:	56+vi
No. of words in Abstract	:	194

ABSTRACT

The present investigations entitled **"Effect of seed priming on germination and seedling growth in amlook (*Diospyros lotus* L.)"** were conducted at the experimental farm and laboratory of Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, (HP) during 2019-20. The experiment was laid out in Randomized Block Design with eleven seed priming treatments *viz*., GA_3 (250, 500, 750 ppm), Thiourea (2500, 5000, 7500 ppm), KNO_3 (2500, 5000, 7500 ppm), hydro-priming and control (no priming) replicated thrice. Among all the treatments GA_3 @ 500 ppm performed significantly better than all other treatments over control in terms of germination i.e. seed germination (64.26 %), days taken to germination (38.40) and growth parameters i.e. seedling height (29.10 cm), seedling diameter (6.27 mm), number of leaves per seedling (17.07), leaf area (86.04 cm^2), leaf chlorophyll content (2.05 mg/g), fresh weight of shoots (16.32 g), dry weight of shoots (8.57 g), total root length (1.45 m), fresh weight of roots (11.97 g), dry weight of roots (6.24 g), biomass of seedlings (14.81 g), seedling vigour index-I (2547.88), seedling vigour index-II (951.91), survival rate (93.84 %) and number of graftable seedlings (96.99 %).

Signature of Major Advisor **Signature of the Student**

Countersigned

Professor and Head
Department of Seed Science and Technology
Dr YS Parmar University of Horticulture and Forestry
Nauni, Solan (HP)-173 230

BRIEF BIO-DATA

Name : Reva Jaryal

Father's name : Sh. Santosh Kumar Jaryal

Mother's name : Smt. Savita Devi

Date of birth : 1 June, 1997

Sex : Female

Marital status : Unmarried

Nationality : Indian

Permanent Address : Vill. Danoon PO Sundla Teh. Salooni, Distt Chamba (H.P.) 176312

Academic Qualifications:

Certificate/Degree	Year	Name of School/College	Board/ University	Marks (%)	Division
Matric	2012	B.S.P Central School Surangani Distt. Chamba	CBSE	79.80	First
12^{th}	2014	B.S.P Central School Surangani Distt. Chamba	CBSE	79.80	First
B. Sc. (Hons.) Horticulture	2018	College of Horticulture and Forestry, Neri-Hamirpur	Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP)	76.70	First

Whether sponsored by some state/ Central Govt./Univ./SAARC : NA

Scholarship/Stipend/Fellowship, any other financial assistance received during study period : Stipend

(Reva Jaryal)