STANDARDISATION OF STEM CUTTING TECHNIQUE OF DRAGON FRUIT (*Hylocereus costaricensis* Britton & Rose)

A Thesis
Submitted to the
Assam Agricultural University

In partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE (AGRICULTURE)

In

HORTICULTURE

By

Anurag Borchetia
Registration No. 115 of 2015
[Roll No. 2019-AMJ-78]

DEPARTMENT OF HORTICULTURE
FACULTY OF AGRICULTURE
ASSAM AGRICULTURAL UNIVERSITY
JORHAT- 785013

November, 2021

ASSAM AGRICULTURAL UNIVERSITY

Faculty of Agriculture

CERTIFICATE – I

This is to certify that the thesis entitled **“Standardisation of stem cutting technique of Dragon Fruit (*Hylocereus costaricensis* Britton & Rose)”** submitted to the Faculty of Agriculture, Assam Agricultural University, in partial fulfilment for the degree of **Master of Science (Agriculture) in Horticulture** is a record of research work carried out by **Anurag Borchetia** under my personal supervision and guidance.

All helps received by him have been duly acknowledged.

No part of this thesis has been reproduced elsewhere for any degree.

Place: Jorhat

Dated:

(Manoranjan Neog)
Associate Director of Extension Education (T)
Directorate of Extension Education
Assam Agricultural University
Jorhat- 785013

CERTIFICATE – II

This is to certify that the thesis entitled **"Standardisation of stem cutting technique of Dragon Fruit (*Hylocereus costaricensis* Britton & Rose)"** submitted by **Anurag Borchetia, Roll No. 2019-AMJ-78** to the Assam Agricultural University, in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Horticulture** has been examined and approved by the student's Advisory Committee after viva-voce.

(Manoranjan Neog) Major Advisor	**(Utpal Kotoky)** Chairman Board of Examiners

Members of the Advisory Committee

1. ____________________
   (Utpal Kotoky)

2. ____________________
   (Prakash Kalita)

3. ____________________
   (Raju Pd. Paswan)

Utpal Kotoky Professor and Head Department of Horticulture Assam Agricultural University Jorhat- 785013 (Assam)	**Ajit Baishya** Director Post Graduate Studies Assam Agricultural University Jorhat- 785013 (Assam)

ACKNOWLEDGEMENT

With immense pleasure, the author takes the privilege to express his heartfelt gratitude, endless indebtedness and sincere regards to his Major Advisor and Chairman of the Advisory Committee, Dr. Manoranjan Neog, Associate Director of Extension Education (T), Directorate of Extension Education, Assam Agricultural University, Jorhat for his valuable guidance, keen interest, constant encouragement, constructive views, suggestions and critical interventions in planning and executing the research work and in preparing the manuscript.

The author also extends his sincere gratitude to the members of the Advisory Committee, Dr. Utpal Kotoky, Professor and Head, Department of Horticulture, Dr. Prakash Kalita, Professor, Department of Crop Physiology and Dr. Raju Pd. Paswan, Professor and Head, Department of Agricultural Statistics, AAU, Jorhat for their generous advice and sincere help during the course of the study as well as in the preparation of the manuscript.

The author offers his gratitude to Dr. A. Baishya, Director of Post Graduate Studies, for providing necessary facilities during the course of study.

The author is obliged and indebted to all the staffs of the Directorate of Post Graduate Studies, AAU, Jorhat for their necessary help during the course of his endeavour.

He offers his grateful acknowledgment to all the scientists/ staffs of Krishi Vigyan Kendra, Jorhat specially, Mr. Sanjib Ranjan Borah, I/C Head, Mrs. Sharmistha Borgohain, Subject Matter Specialist (Horticulture) and Mr. Subir Borah, Farm Manager for their help, support and encouragement during the study.

The author acknowledges his indebtedness to Dr. Sailen Gogoi, Professor, Department of Horticulture, AAU, Jorhat for his sincere help and co-operation during the course of study.

The author wishes to put forward heartfelt thanks to the official and field staffs of the Department of Horticulture, AAU, Jorhat for their sincere support and co-operation throughout the study. The field workers, Jintu da and Dipu da enabled the author to carry out his field work smoothly for which he remains thankful to them.

The author offers heartiest thanks to all his fellow classmates, well-wishers, seniors and juniors for their help, encouragement, inspiration and co-operation at different stages of the investigation.

Finally, the author would like to express his utmost thanks to the Almighty who synchronized the things in harmony and blessed him with health, tenacity and courage to complete his tasks successfully.

Lastly, the author vows his heartfelt sense of gratitude to his loving parents and his brother for their blessings, encouragements and inspirations during the course of the study.

Though all could not be mentioned, but none is forgotten.

Dated:

Place: Jorhat — The Author

ABSTRACT

An experiment on "Standardisation of stem cutting technique of Dragon Fruit (*Hylocereus costaricensis* Britton & Rose)" was conducted in the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat during 2020 and 2021 to standardise suitable size and time of cutting with optimum concentration of IBA in Dragon fruit. One year old dragon fruit segments (stem) were collected from the Farm of Krishi Vigyan Kendra, Jorhat. The experiment was laid out in a three factorial Completely Randomised Design with three replications. The treatments were: two time of cuttings – January (M_1) and April(M_2); three sizes of cuttings – 10 cm(L_1), 15 cm(L_2), 20 cm(L_3); four IBA concentrations –100 ppm(I_1), 250 ppm(I_2), 500 pm(I_3) and 0 ppm(I_4). There were twenty-four treatment combinations in the trial. The cuttings were raised in polybags (20 cm x 22 cm). Observations on root and shoot growth, shoot quality parameters were recorded at 40 and 60 days after planting (DAP). Between the January and April month cuttings, the cuttings taken in the month of April gave better performance in terms of root and shoot growth parameters. April cuttings recorded minimum days required for root formation (18.09 days) and shoot initiation (33.44 days) with 98.13% survival. Among the three sizes of cuttings, the 20 cm cuttings exhibited superior root and shoot growth parameters. The 20 cm cuttings recorded early root formation (18.46 days), shoot initiation (29.58 days) and 99.17% survival. Cuttings treated with 250 ppm IBA professed better root and shoot growth parameters among the four IBA concentrations. The 250 ppm IBA treated cuttings recorded maximum root number (13.97 at 40 DAP; 15.97 at 60 DAP), shoot number (3.18 and 5.01 at 40 DAP and 60 DAP respectively), early shoot initiation (29.44 days) and highest survival percentage (99.17 %). The 500 ppm IBA treated cuttings recorded early root formation (15.06 days) and highest length of the longest root (14 cm at 40 DAP; 17 cm at 60 DAP) which was at par with 250 ppm IBA treated cuttings. Among the treatment combinations, T_{22} (April cuttings+ 20 cm size + 250 ppm IBA) took minimum days for root formation (days) and shoot initiation (days) recorded the highest root number (18.84 at 40 DAP ; 20.83 at 60 DAP), root length (18.83 cm at 40 DAP ; 20.83 cm at 60 DAP), root dry weight (0.50 g at 40 DAP ; 0.71 g at 60 DAP) and shoot numbers (4.4 and 5.73 at 40 DAP and 60 DAP respectively), length of primary shoots (21.37 cm at 40 DAP ; 22.7 cm at 60 DAP), shoot dry weight (11.93 and 13.43 g at 40 DAP and 60 DAP respectively), nitrogen percentage (2.71 and 2.75 % at 40 DAP and 60 DAP respectively), protein percentage (16.94 and 17.18 % at 40 DAP and 60 DAP respectively), chlorophyll content (0.45 and 0.51 mg/g at 40 DAP and 60 DAP respectively) and vascular cambium thickness (0.12 and 0.15 mm at 40 DAP and 60 DAP respectively) which was followed by T_{23} (April cuttings+ 20 cm size + 500 ppm IBA).

Thus, it may be inferred that 20 cm cuttings of dragon fruit taken in the month of April treated with 250 ppm IBA appeared to be the best treatment combination which registered minimum days required for root formation and shoot initiation, highest root and shoot growth parameters, shoot nitrogen, protein, chlorophyll content and thickest vascular cambium layer with 100% survival.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

%	:	Per cent
@	:	At the rate
AAU	:	Assam Agricultural University
BSSH	:	Bright Sunshine Hours
CD	:	Critical difference
cm	:	Centimetre
CRD	:	Completely Randomized Design
DAP	:	Days after planting
et al.	:	Et alia (and others)
Fig.	:	Figure
ft.	:	Feet
FYM	:	Farm Yard Manure
g	:	Gram
Ha	:	Hectare
Hr	:	Hour
i.e.	:	That is
IBA	:	Indole-3-Butyric Acid
kg	:	Kilogram
l	:	Litre
m	:	Metre
m^2	:	Square Metre
ml	:	milli litre
mm	:	Millimetre
ºC	:	Degree centigrade
RH	:	Relative humidity
S.Ed.	:	Standard Error Deviation
sp.	:	Species
viz.	:	Videlicet (namely)

CHAPTER I

INTRODUCTION

Dragon fruit (*Hylocereus costaricensis* Britton & Rose) is a perennial epiphytic fast growing vine cacti of the Cactaceae family. It is a non-climacteric fruit with attractive scaly bracts. Though it has its origin in the tropical and sub-tropical forest regions of Central and South America but its cultivation had spread to countries like Vietnam, China, Indonesia, Australia, Taiwan, USA, Israel, India, Sri Lanka etc. with varied agro climatic and agro ecological conditions (Britton and Rose, 1963; Mizrahi *et al*., 1997). Currently, Vietnam, China and Indonesia occupy 93 % share of world dragon fruit production. Vietnam is the leading producer with 51.1 % share of world dragon fruit production. Dragon fruit production in India is very negligible, with a share of only 0.20 % of world dragon fruit production (Karunakaran *et al*., 2019).

Dragon fruit can be commercially cultivated up to an altitude of 1700 m above mean sea level with an annual rainfall requirement of 500 - 2000 mm. The suitable temperature ranges from 20º C to 30º C. It grows well in slightly acidic soils with pH 5.5- 6.5 (Gunasena *et al*., 2007). Due to the presence of xerophytic adaptations of Crassulacean Acid Metabolism (CAM) and presence of a waxy layer over its succulent stems, these plants can even be grown in desert conditions with low rainfall and temperature as high as 38ºC- 40ºC. Dragon fruit plants have shallow roots (less than 40 cm) due to which they are less choosy to specific soil requirements and can be grown in varied soil conditions free from water logging (Cabahug *et al*., 2018).

Dragon fruit is gaining importance due to its health benefits. The fruits are low in calories and rich in vitamin C (4-10 mg/ 100g fresh fruit), calcium (6.3-8.8 mg/ 100 g), phosphorus (30.2- 36.1 mg/ 100 g), iron (0.5- 0.61 mg/100 g), protein (0.16- 0.23 %), fat (0.21- 0.61 %) and fiber (0.7- 0.9 %) (Jalgaonkar *et al.*, 2020). Moreover, its seeds are having polyunsaturated fatty acids predominantly linoleic acid (50.8 %), oleic acid (21.5 %) and palmitic acid (12.6 %) (Jeronimo *et al.*, 2015). The fruits are also rich in neutraceutical elements. The fruits are high in antioxidants (phyto albumins), which help to fight against carcinogenic free radicals forming in the body. Dragon fruit has prebiotic potential along with the antiviral, antimicrobial, wound healing, anti- hyperlipidaemic, anti-obesity, hepatoprotective, anti-inflammatory and anti- anaemia activities. The seeds of the fruit are reported to help in controlling blood glucose levels in people with non-insulin dependent hyperglycaemic conditions (a kind of diabetes). It also treats stomach and endocrine problems. Dragon fruit also improves eyesight and prevents hypertension. Dragon fruit is an emerging fruit crop of the 21st century. The market share of dragon fruit is gradually increasing throughout the world due to its attractive appearance, luscious taste and health benefits. The Mordor Intelligence Report (2020) forecasted that the global dragon fruit market will register a CAGR (Compound Annual Growth Rate) of 3.9 % during the period from 2021 to 2026.

Dragon fruit was introduced to India in the late 1990s. Initially, its cultivation was undertaken in Gujarat, Tamil Nadu, Maharashtra, Andhra Pradesh, Orissa, West Bengal, Telangana, Kerala and Andaman & Nicobar Islands with a total acreage of 400 hactres. But, according to the recent estimates dragon fruit cultivation has expanded to Rajasthan, Punjab, Haryana, Madhya Pradesh, Uttar Pradesh and North East India leading to an acreage of 3000- 4000 hactres in 2020 (Wakchaure *et al*., 2020). This fruit have also gained popularity in the north-eastern states of India.

Dragon fruit can be propagated through seeds and also vegetatively propagated through stem cuttings, grafting and micropropagation. The seedlings obtained through seed propagation are not true to type and they remain small with thin stems even one year after planting. The seed propagated plants also take 3–4 years to bear fruits. Due to all these reasons seed propagation of dragon fruit is not preferred. Among the vegetative propagation methods grafting is not feasible for mass propagation. Although, micropragation is capable of mass propagation but the requirement of high initial cost, modern infrastructures and technical skills makes it impracticable for supplying bulk quantities of low-cost planting materials. On the other hand, stem cutting technique is comparatively cheap which can be practiced by a layman without any technical skills. Moreover, it is also capable of providing large quantities of true to type planting materials in the shortest time.

In India, farmers are multiplying the dragon fruit with ranges of cutting lengths, there is no standardized length of cuttings in dragon fruit. The acreage of dragon fruit cultivation is rapidly increasing in the North East India. As dragon fruit is a newly introduced crop in this part of the country, there is scarcity of planting materials to cater the needs of the farmers. Hence, stem cutting technique is preferred as a commercial method of dragon fruit propagation. Length of cuttings in dragon fruit plays an important role in rooting which is considered as key factor determining the rooting success. Optimization of cutting length is very essential as longer cuttings could result in wastage of propagation material whereas shorter cuttings might lead to poor rooting and establishment of the plant. Indole butyric acid (IBA) is a widely used rooting hormone and has the ability to stimulate rooting of cuttings in dragon fruit. The success of cuttings also depends on the time of taking the cuttings as the levels of endogenous plant growth regulators and carbohydrates in the mother plant varies in different times of the year (Hartmann *et al.,* 2011). However, reports on propagation of dragon fruit from cuttings and use of growth regulators for better root growth are scanty. Therefore, the current study was undertaken on the propagation of Dragon fruit through stem cuttings with the following objectives:

1) To standardise the size of cuttings of dragon fruit
2) To find out optimum concentration of IBA for rooting and better growth of stem cuttings.
3) To find out the suitable time of cuttings

CHAPTER II

REVIEW OF LITERATURE

Dragon fruit is gaining popularity in the recent years due to its delicious fruits enriched with nutritional and medicinal values and also its adaptability to humid as well as semi-arid tropical and subtropical conditions. Due to its high market demand, it needs rapid and mass multiplication of dragon fruit. But it should be taken care of that the chosen method of propagation should retain the desired quality of the fruits besides perpetuating it in the shortest period of time. Dragon fruit can be propagated by both sexually via seeds as well as asexually via stem cuttings, grafting and also via micropropagation.

In this chapter the propagation techniques of dragon fruit are reviewed with special emphasis to the stem cutting technique of dragon fruit propagation.

2.1 Sexual Propagation

Sexual propagation in dragon fruit is carried out through seeds. The dragon fruit seeds show 83% viability (Ahmed, 2006). But seed propagation is very rare in dragon fruit as seedlings raised from seeds require a long period to yield and also the seedlings are less vigorous and also not true to type when compared to the vegetatively propagated seedlings (Tripathi *et al.*, 2014). But, in genetic studies seed propagation is an indispensable tool as it provides genetic variability, prolonged lifespan and disease and pest resistance to its seedlings up to a certain level.

The literature on the seed propagation in dragon fruit is very limited. The seeds are minute in size and black in colour. A higher germination percentage is obtained when sown soon after extraction. Dragon fruit seed germination is affected by several factors such as sown media, temperature and light intensity received by the seeds. Ahmed (2006) reported highest germination percentage (82%) in peat moss + sand mixture (1:1) and least time required for germination in peat moss (18 days). Ahmed (2006) also reported fastest germination at 16^{o} C and highest germination percentage at 24^{o} C. A drop of 19% rate of germination is reported when the exposure of 2000 lx light intensity is increased from 12 hrs/day to 24 hrs/day. Seeds are sown in polybags or trays and later the two-month-old seedlings are transplanted to pots and kept there until they become ready to be transplanted to the main field. Tripathi *et al.* (2014) stated that the seedlings do not become ready to be transplanted to the main field even one year after germination.

2.2 Asexual Propagation

Hartman *et al*. (2011) stated that every plant cell has the capacity to develop into a new plant. This fact simplifies the use of several plant parts such as the leaves, nodes and internodes, buds, scion, cuttings, bulb, corm etc. in plant propagation (Poethig, 2013). When we say asexual or vegetative propagation in dragon fruit, we commonly refer to the stem cutting technique but a very limited published research articles are found on the grafting technique and in-vitro propagation techniques in dragon fruit.

2.2.1 Propagation through grafting

Grafting is an important asexual propagation technique in dragon fruit. It enables a species of dragon fruit more suitable in a particular climatic and edaphic conditions to be used as rootstock and a species of dragon fruit with desired qualities but less adaptable in the concerned climatic and edaphic conditions to be used as scion. Wang *et al.* (2011) patented a wedge grafting technique in dragon fruit with more than 95 % survival percentage of the grafted plants. Similarly, there are few other grafting techniques in dragon fruit patented by Ziyou (2015), Weixi *et al.* (2015) and Xiankun *et al.* (2013).

2.2.2 Micropropagation or *in-vitro* propagation

Micropropagation refers to the process of vegetative growth and multiplication by providing special growth media to the plant tissues or seeds in aseptic and favourable conditions. The micropropagation technique of dragon fruit is affected by the factors such as the explant used, media used, shoot culturing, sub culturing, *in- vitro* rooting and acclimatization of the *in-vitro* propagated plantlets. In dragon fruit stem segments, areoles with thorns, young *in-vitro* germinated seedlings of about 4 weeks old and 40 days old cotyledonary leaves of the previously germinated seeds are generally used as explants. Vinas and Brenes (2012) reported a greater number of shoots from the areoles taken from the central portion of the stem than the distal and proximal portions. Hua *et al.* (2015), Suman *et al.* (2017), Thiha (2019) and Kasim and Basri (2015) reported maximum number of vigorous shoots in

MS medium supplemented with with 3 µM zeatin + 0.5 µM IBA, 3 mg/L BAP + 1 mg/l KIN, 10 µM BAP and 3 mg/l BAP + 0.5 mg/l NAA, respectively. Kari *et al.* (2010) and Sheng *et al.* (2016) found highest germination percentage of dragon fruit seeds when treated with 0.5 ppm IBA + 1 ppm kinetin and 1 ppm BAP + 0 ppm IBA, respectively. Highest callus induction in dragon fruit was recorded when the medium is supplemented with 3.6 ppm 2, 4-D + 1.8 ppm BAP (Sheng *et al.*, 2016) and 3mg/l BAP + 0.5 mg /l NAA (Kasim and Basri, 2015). Maximum size of the somatic embryos in dragon fruit in MS basal medium supplemented with 2 mg/l of 2, 4-D was reported by Suman *et al.* (2017). Thiha (2019) recommended 0.3µM NAA containing media for root induction and also stated that NAA level higher than 0.3 µM NAA tends to induce abnormal shoots and callus.

2.2.3 Propagation through stem cutting

Stem cutting is the commercial method of dragon fruit propagation as it yields true to type fruits in the shortest period of time. Success of the stem cutting technique depends on various factors such as the size of the cuttings, maturity or age of the cuttings, time of taking cuttings, portion of the stem used for cutting preparation, media used for the rooting of the cuttings, application of plant growth regulators (PGRs), fresh weight of the cuttings and the environmental conditions (Pedda *et al*., 2019).

2.2.3.1 Physiology of rooting in cuttings

Adventitious root formation is the ability of a plant to initiate roots from any part of the plant either as a normal process or as a stress response. Adventitious root formation in the excised stem cuttings mainly occurs due to the following reasons: 1) as a wound response at the cutting portion (2) as a response to the physical separation of the excised portion from the food resource of the mother plant and (3) as a response to the separation of the excised portion from the hormonal signalling pathway of the mother plant (Haissig, 1986). Immediately after the excision of the stem portion, jasmonic acid level increases in the excised stem cutting and jasmonic acid have been reported to enhance the rooting of the stem cuttings. Moreover, cytokinin and strigolactone which are reported to inhibit rooting process are produced in the roots of the mother plants. When the stem cuttings are separated from the mother plants, they also get separated from the roots of the mother plant due to which the levels of cytokinin and strigolactone decreases in the cuttings. Whereas, the auxins are produced in the growing meristematic tissues of the apical portions of the plant and transported towards the base of plant. Due to such basipetal movement of auxins, they get accumulated in the basal portion of the cuttings and support the rooting process of the cuttings. The process of adventitious root formation in the stem cuttings may be divided into three stages: 1) formation of specialised meristematic cells called as root initials (2) differentiation of the root initials into root primordia (3) development of root primordia into a complete root and forming vascular connections with the stem. Depending on the type of plant the root initials that gives rise to adventitious roots may generate from different cells of the plant. In herbaceous plants the root initials are formed in between the vascular bundles whereas in woody plants the root initials are formed from either secondary phloem tissues or cambium cells or pith cells or vascular rays. These root initials develop into complete roots under suitable conditions. However, in some plants a mass of undifferentiated cells called as callus is developed in the wounded portion of the stem cutting and later the callus gives rise to roots. Lazcano *et al.* (1999) reported higher root numbers in the prickly-pear cactus cladodes with the wounding methods having higher cut surface area and treated with auxins. They also reported that suberization of the cut surface prevents rotting of the cladodes.

2.2.3.2 Size of the cuttings

It is one of the most important factors for the rooting or shoot initiation of the dragon fruit cuttings as it is proved that the higher carbohydrate content and higher rate of photosynthesis in the larger cuttings leads to early root and shoot initiation with better quality. The available literatures justify the use of cuttings as small as 5cm to as large as 45 cm for dragon fruit propagation. Ahmed (2006) studied the growth and development of three cutting sizes (5, 15 and 25 cm) and recorded 100, 87 and 65 % rooting of the cuttings of size 25 cm, 15 cm and 5 cm, respectively after one week of planting. Fumuro (2011) evaluated dragon fruit cuttings of 8 cm, 12 cm and 16 cm lengths and recorded highest rooting percentage (83 %) and highest root fresh weight on the cuttings of 16 cm size. Out of the three different sizes of dragon fruit cuttings (5, 10 and 15 cm), the cuttings of 15 cm size showed better shoot and root development even without the application of IBA. (Malswamkimi *et al.*, 2019)

Kakade *et al.* (2019) studied the influence of different cutting sizes (10-15 cm, 15-20 cm, 20-25 cm, 25-30 cm, 30-35 cm, 35-40 cm and 40-45 cm) on shoot and root development in dragon fruit. They recorded maximum length of new shoots, dry weight of shoots and fresh weight of roots in cuttings of 35-40 cm size. Gomez *et al.* (2000) attempted vegetative propagation of three cactus species: Pitaya (*Stenocereus griseus*), Tunillo (*Stenocereus stellatus*) and Jiotilla (*Escontria chiotilla*). Pitaya and tunillo were successfully propagated by stem cuttings of 0.5 m lengths whereas they were unable to propagate Jiotilla. Trivellini *et al.* (2020) compared the rooting percentage of 10 cm and 20 cm sized cuttings of dragon fruit. They reported 100 % rooting of 20 cm sized cuttings after four weeks of planting whereas 10 cm sized led to 100 % rooting only after six weeks of planting.

2.2.3.3 Age of the cuttings

While selecting the stem of the mother plant to be used for the preparation of the cuttings, the age or maturity of the selected stem is an important factor which must be taken into consideration. The ability to form adventitious roots is more in juvenile cuttings than the mature cuttings (Cavalcante and Martins, 2008). The reason for this is due to the presence of some rooting promoters such as auxin, ethylene and carbohydrate in juvenile cuttings and rooting inhibitors such as cytokinin, abscisic acid and gibberellin in mature cuttings. Fumuro (2011) studied the effects of age of dragon fruit cuttings on rooting by considering immature cuttings, one year old cuttings and two-year-old cuttings. The cuttings of one year old, two-year-old and immature cuttings led to 95%, 95 % and 25 % rooting after two months. However, the root fresh weight and dry matter percentage was highest in cuttings of one year old and two-year-old cuttings, respectively.

2.2.3.4 Effect of portion of the stem used for cutting

Various experiments were carried out to determine whether the proximal, central or distal portions of the stem gives better quality root and shoot characteristics. Fumuro (2011) studied the effect of part of the stem used for propagation on rooting ability of dragon fruit cuttings. It was concluded that basal or proximal portions of the stem led to 100 % rooting, highest root fresh weight (2.25 g) and dry matter percentage (13.10 %). Nandi *et al.* (2019) evaluated the part of the stem used for dragon fruit propagation on rooting ability. They concluded that the middle part of the stem leads to maximum alive cuttings (100 %).

2.2.3.5 Effect of fresh weight of the cuttings

As the stored food materials in the cuttings helps in the rooting of dragon fruit cuttings therefore, the fresh weight of the cuttings is an important factor for the success of the cuttings. Fumuro (2011) evaluated dragon fruit stem cuttings of three fresh weight groups (30 – 50 g, 51 – 70 g and 71 – 90 g) each of 12 cm lengths for their rooting performance. The group containing cuttings of 71 – 90 g fresh weight gave highest rooting percentage (100 %) and root fresh weight (2.89 g).

2.2.3.6 Time of taking cuttings

Cuttings should be taken at a particular time of the year due to the fact that the levels of endogenous plant growth regulators, rooting cofactors and carbohydrates in the mother plant varies in different parts of the year (Hartmann *et al.,* 2011). The seasonal variation for the success of the cuttings may be attributed to the changes in the levels of phenolic compounds in the mother plant (Curir *et al*., 1992). The seasonal variation in the success of cuttings also depends on the levels of shoot RNA, whose levels are high during the season having highest number of successful cuttings (Davies, 1984). It was reported that for the initiation of the cell division of the root initials, a certain level of protein and DNA synthesis is required and the gene regulation for protein and DNA synthesis is regulated by increased shoot RNA activity (Molnar and Croix, 1972; Davies, 1984). It was also found that there is higher cambial activity in the season showing highest rooting percentage which is attributed to the fact that there are higher levels of endogenous auxins during the season which enhances the cambial activity (Davies, 1984; Wodzicki, 1978). Nandi *et al.* (2019) conducted an experiment on red dragon fruit at Onda block of Bankura district in West Bengal to find out the best month in a year for its propagation. They reported 100 % of alive cuttings during the months of November, December, January, February and March. They also reported lowest survival percentage during September and October (20 % and 10 % respectively).

2.2.3.7 Effect of Plant Growth Regulators (PGRs)

Plant growth regulators, especially auxins and cytokinins are responsible for the rooting of cuttings. The auxins promote rooting whereas the cytokinins inhibit rooting. Although, there is higher levels of endogenous auxins in the peak period for cutting but the importance of its exogenous application arises in order to carry out year-round production of the cuttings and also to enhance rooting of smaller size cuttings. Indole-3-Butyric Acid (IBA), 1-Napthalene Acetic Acid and Indole-3-Acetic Acid (IAA) are widely used auxins for rooting of dragon fruit stem cuttings. Ahmad *et al.* (2016) conducted an experiment to find out the best IBA concentration among 0 ppm, 50 ppm, 75 ppm and 100 ppm for the rooting of dragon fruit cuttings. They reported highest root number (13.2), root fresh and dry weight (2.7 g and 0.8 g respectively), root length (12.7 cm) and root diameter (1.5 mm) at 100 ppm IBA concentration. Malswamkimi *et al.* (2019) reported that stem cuttings treated with 1000 ppm IBA concentration recorded better shoot growth and establishment of the stem cuttings in the field whereas total nitrogen and protein percentage was reported to be higher at 250 ppm IBA concentration.

Ahmed (2006) tested 5, 10 and 15 mM IBA solutions for the rooting of dragon fruit cuttings and concluded that 10 mM solution provides better rooting percentage, root number and root length in smaller size cuttings of 5 cm. Siddiqua and Thippesha (2018) tested IBA, NAA and there combinations and found that cuttings treated with IBA 7000 ppm recorded maximum shoot length (17.45 cm), shoot diameter (3.53 mm), shoot fresh and dry weight (56.66 g and 11.12 g respectively), sprouting percentage (58.67 %), number of sprouts (2.43) and root to shoot ratio (0.67). Dhruve (2017) found that the cuttings treated with 6000 ppm solution of IBA required less days for sprouting with maximum rooting percentage, root number, root fresh and dry weight, maximum length of roots and shoots, and maximum number of shoots. Minz (2020) reported early sprouting (35 days) and highest root to shoot ratio (0.93) and survival percentage (98.34 %) in dragon fruit stem cuttings treated with IBA 7000 ppm. Root growth was found best in the cuttings treated with IBA 8000 ppm (Seran and Thiresh, 2015). In a study on dragon fruit conducted by Fumuro (2011), it was found that cuttings treated with NAA of 2000 ppm solution recorded the highest rooting percentage (98.3 %) and root fresh weight (5.43 g).

2.2.3.8 Rooting media

The rooting media plays a crucial role in the rooting of the cuttings. The media should have proper water holding capacity combined with a proper drainage capacity in order to provide sufficient water to the cuttings by avoiding stagnation of water in the medium. Normally soil, farmyard manure and sand mixture in the ratio of 1:1:2 is used as rooting media for the stem cuttings of dragon fruit (Tripathi *et al.*, 2014). Ahmed (2006) evaluated peat moss, peat moss + sand (1:1) and sand for the rooting of dragon fruit cuttings. Highest root number (43) was reported in peat moss whereas highest root length (8.2 cm) was reported in sand at 21th day after planting. Vermicompost was better than compost for the rooting of dragon fruit cuttings (Sudarjat *et al.*, 2018). It took least time for root initiation when grown in IAA 300 ppm + 100 % soil and maximum root numbers was recorded in cuttings grown in IAA 200 ppm + 100 % soil at 100th day after planting (Rahad *et al.*, 2016). Soil + sand + cocopeat + vermicompost (2:1:1:1) gave superior results in both root and shoot parameters.

2.3 Effect of environmental factors

Generally, the environmental conditions considered during raising of cuttings comprises of the sunlight percentage received, temperature of the media or the atmosphere and the relative humidity of the atmosphere. The cuttings should receive an optimum level of sunlight so that the cuttings can carry on the photosynthesis process and also have minimum degradation of endogenous auxins stored in the cuttings, as it was found that light cause degradation of the pre - existing auxins (Hartmann *et al.*, 2011). Therefore, an optimum shade should be provided to the cuttings. Lone *et al.* (2018) studied the effects of different sunlight percentages on the growth of dragon fruit cuttings and recommended partial shading of 23% - 42% for the better growth of roots and shoots. Sousa *et al.* (2021) reported that the cuttings grown under 50 % shading showed better growth with higher plant height, root dry mass, length of root and secondary cladodes. Fumuro (2015) observed that increased light penetration enhanced root dry weight percentage in both old cladode and new cladode. Raveh *et al.* (1998) reported that 30 % shade in *Hylocereus polyrhizus* and 60 % shade in Seleniferous *megalanthus* gave better growth and development. However, no literatures are available on temperature of the media or the atmosphere and the relative humidity of the atmosphere in which dragon fruit cuttings are to be raised is found up to date.

2.4 Biochemical factors associated with rooting process

The success of the rooting of cuttings is largely depended on some of the biochemical changes in the cuttings.

2.4.1 Carbohydrate and nitrogen content

A certain amount of carbohydrate and nitrogen is required in the cuttings for cell-division, cell differentiation and root primordia formation. It was found that a comparatively higher amount of carbohydrate and a lower amount of nitrogen is required in the cuttings for optimum shoot and root regeneration (Hartmann *et al*., 2002). Weismann and Lavee (2011) studied the effect of carbohydrate on rooting of cuttings. They concluded that a higher carbohydrate content in the cuttings led to better rooting of the cuttings. Das *et al.* (1997) studied the effect of auxins on rooting of cuttings. They reported rapid starch hydrolysis in the cuttings treated with IBA and NAA and subsequently reduction of C: N ratio of the cuttings. Rana (1996) studied the relation of carbohydrate, nitrogen and phenol content of the cuttings with the rooting of the cuttings when treated with IBA 3000 ppm + NAA 3000 ppm. They reported a positive correlation with the carbohydrate and phenol content and a negative correlation with the nitrogen content to the rooting of cuttings.

Ghosh and Basu (1973) measured the carbohydrate content of IBA and NAA treated cuttings from pre root emergence upto post root emergence. They reported slight decrease in carbohydrate content upto root emergence whereas they reported rapid decrease in carbohydrate content when the root initiation took place.

2.4.2 Chlorophyll content

A higher chlorophyll content in the cuttings enhances the rooting and shooting process. It was found that auxins like IBA and NAA increases the chlorophyll content in the cuttings. Deb *et al.* (2009) studied the effect of IBA on leaf chlorophyll content of semi hardwood cuttings of lemon (*Citrus limon*). They reported maximum chlorophyll content (45.41 mg / g) when treated with IBA 2500 ppm. Kaur *et al.* (2002) studied the effect of IBA on leaf chlorophyll content on the stem cuttings of grapes. They reported increase in the leaf chlorophyll content when treated with IBA.

2.5 Survival of Cuttings

The propagated cuttings must show a high survival percentage in the field. The survivality of the cuttings is reported to be enhanced by the IBA treatment. Minz *et al*. (2021) and Dhruve (2017) reported 7000 ppm and 6000 ppm IBA solution respectively to provide maximum survival percentage. Rahad *et al*. (2016) reported highest survival percentage in cuttings with IBA 500 ppm + 100 % soil as rooting media. Sugunakrishnan (2015), Shivaji *et al*. (2014), Abbas *et al*. (2013), Upadhyay and Badyal (2007) and Abdullah and Al-Khateeb (2004) recorded highest survival in cuttings when treated with IBA. Sugunakrishnan (2015) also reported the effects of time of cutting on survival of cuttings.

CHAPTER III

MATERIALS AND METHODS

A field experiment on "Standardisation of stem cutting technique of Dragon Fruit (*Hylocereus costaricensis* Britton & Rose)" was conducted during 2020 and 2021 at the Experimental farm of Department of Horticulture, Assam Agricultural University, Jorhat. The details of the methodologies followed, materials used and analysis of various observations adopted in the investigation are described below.

3.1 Geographical location of the experimental site

The experimental site is located in the experimental farm of Department of Horticulture, A.A.U., Jorhat which falls in the Upper Brahmaputra Valley Agro Climatic Zone of Assam. The geographical coordinates of the location is Latitude- 26º44/ N and Longitude- 94º12/ E with an altitude of 87 m above mean sea level.

3.2 Meteorological conditions

The climate of the experimental site is subtropical hot humid summer followed by relatively dry and cold winter. Summer is experienced during May to August and winter from December to January. Mild cold temperature is experienced during September to November and February to April. The rainfall intensity reaches its peak during monsoon which normally begins from the first week of June. However, pre monsoon showers are received in the month of April and the rainy season extends from April - October. The period between January to March experiences scanty rain. The annual maximum temperature lies between 32º C – 34º C in July- August and the minimum temperature ranges from 9.9º C- 10.9º C in December- January.

The meteorological parameters recorded at the meteorological observatory of Assam Agricultural University during the entire period of the investigation are furnished in Table 3.1 and Table 3,2 and graphically represented in Fig.3.1 and Fig 3.2.

Table 3.1 Meteorological observations during the period of the experiment in 2020

Month	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Relative Humidity (%) at 6:13 a.m.	Relative Humidity (%) at 1:13 p.m.	Rainfall (mm)	Bright Sunshine Hours per day
January	22.6	9.8	99.4	63.5	1.0	4.41
February	24.9	12.0	97.1	59.3	0.4	4.54
March	28.8	15.9	93.1	61.0	0.2	5.8
April	29.1	17.6	93.1	66.0	3.6	4.79
May	29.8	21.0	92.0	72.1	7.6	4.15
June	31.5	24.3	95.1	78.1	13.7	3.8
July	31.5	25.0	96.5	80.9	11.9	1.86

Table 3.2 Meteorological observations during the period of the experiment in 2021

Month	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Relative Humidity (%) at 6:13 a.m.	Relative Humidity (%) at 1:13 p.m.	Rainfall (mm)	Bright Sunshine Hours per day
January	23.5	10.4	99.7	62.9	0.5	4.3
February	27.3	11.5	97.1	47.4	0.1	6.3
March	29.3	16.2	94.6	54.8	1.7	4.6
April	31.7	18.6	86.9	50.7	1.4	6.3
May	31.0	21.9	92.8	73.2	5.5	3.1
June	32.0	24.3	93.6	75.0	9.0	3.7
July	33.1	25.2	93.6	73.9	5.5	4.4

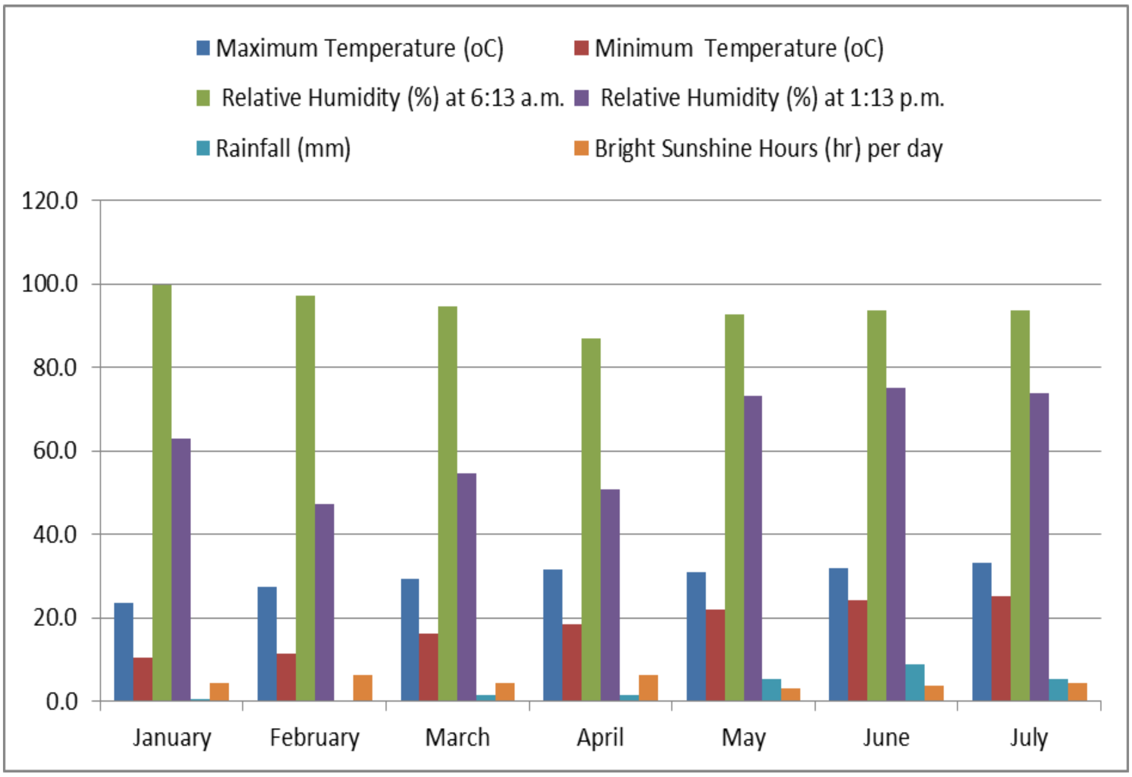


Fig. 3.1 Graphical representation of meteorological observations during the period of the experiment in 2020

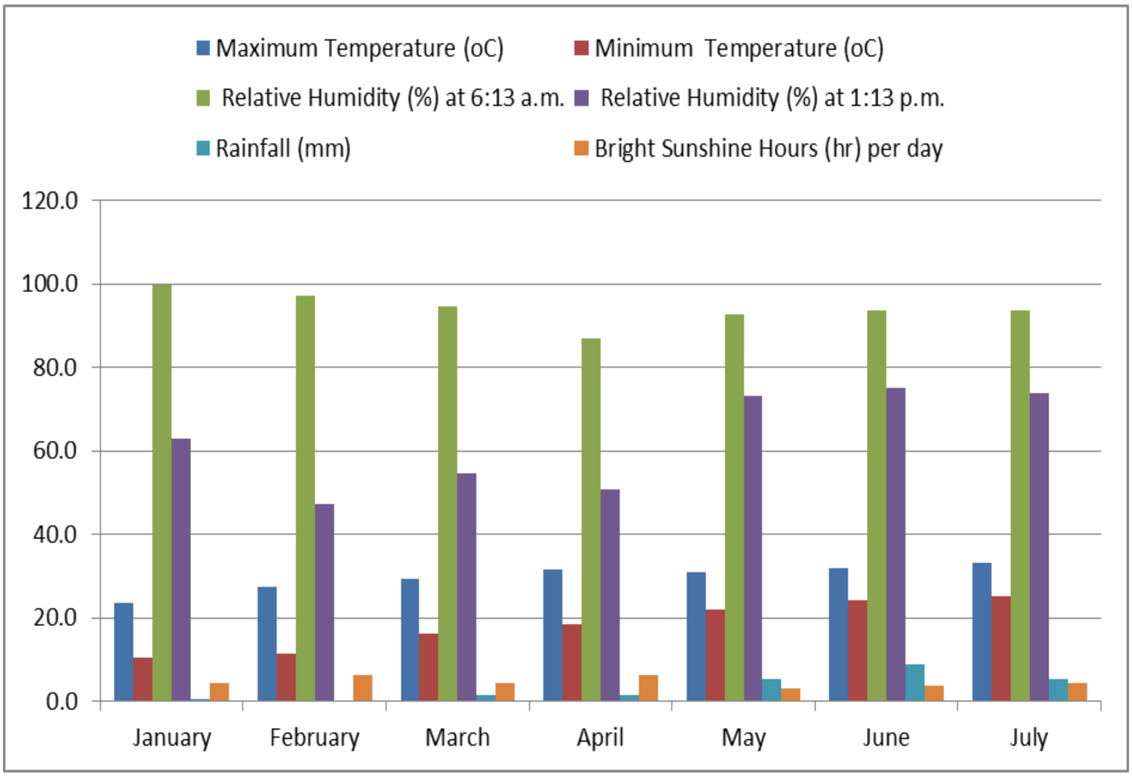


Fig. 3.2 Graphical representation of meteorological observations during the period of the experiment in 2021

The data pertaining to the temperature, relative humidity and sun light intensity inside the shade net house during the entire period of the investigation are furnished in Table 3.3 and Table 3.4 and graphically represented in Fig3.3 and Fig.3.4

Table 3.3 Meteorological data inside the shade net house during the period of the experimentation in 2020

Month	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Relative Humidity (%) at 6:13 a.m.	Relative Humidity (%) at 1:13 p.m.	Sunlight intensity inside shadenet house (lux)	Sunlight intensity outside shadenet house (lux)
January	21.7	8.5	99.6	66.7	753.9	1617.2
February	24.0	10.7	97.3	62.5	762.79	1627.41
March	27.9	14.6	93.3	64.2	792.8	1641.82
April	28.2	16.3	93.3	69.2	836.31	1728.9
May	28.9	19.7	92.2	75.3	809.1	1743.17
June	30.6	23.0	95.3	81.3	914.71	1812.83
July	30.6	23.7	96.7	84.1	954.62	1827.4

Table 3.4 Meteorological data inside the shade net house during the period of the experimentation in 2021

Month	Maximum Temperature (ºC)	Minimum Temperature (ºC)	Relative Humidity (%) at 6:13 a.m.	Relative Humidity (%) at 1:13 p.m.	Sunlight intensity inside shadenet house (lux)	Sunlight intensity outside shadenet house (lux)
January	22.8	9.3	99.8	66.2	741.62	1652.9
February	26.6	10.4	97.2	50.7	817.31	1641.74
March	28.6	15.1	94.7	58.1	836.18	1639.52
April	31.0	17.5	87.0	54.0	862.3	1728.7
May	30.3	20.8	92.9	76.5	879.8	1764.72
June	31.3	23.2	93.7	78.3	918.32	1832.38
July	32.4	24.1	93.7	77.2	927.1	1873.91

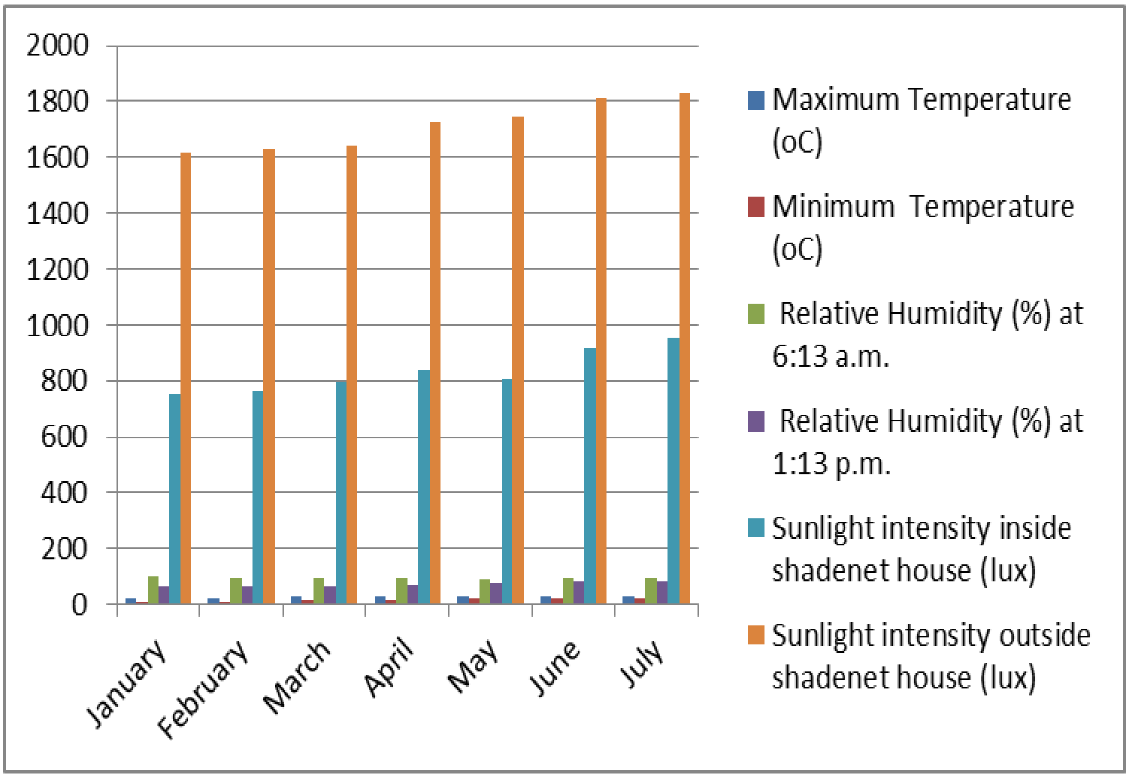


Fig.3.3 Graphical representation of meteorological observations inside the shade net house during the period of the experiment in 2020

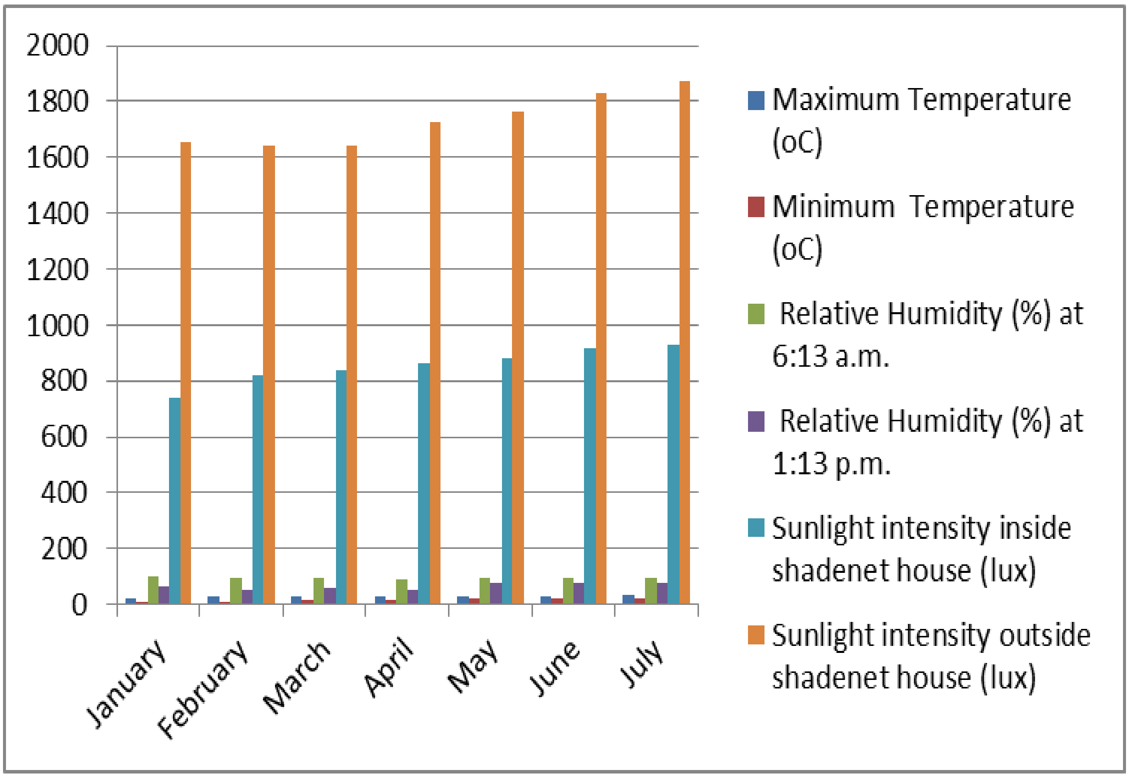


Fig.3.4 Graphical representation of meteorological observations inside the shade net house during the period of the experiment in 2021

3.3 Design and layout of the experiment

The experiment was laid out in a three factorial Completely Randomised Design. There was total twenty-four treatment combinations with three replications. A total of twenty stem cuttings were taken in each treatment combinations. The total experimental area was 100 m^2.

3.4 Treatment details

First factor: Time of cutting

Month	**Notation**
January	M_1
April	M_2

Second factor: Size of cuttings

Length of cuttings	**Notation**
10 cm	L_1
15 cm	L_2
20 cm	L_3

Third factor: Concentration of IBA

IBA concentration	**Notation**
100 ppm	I_1
250 ppm	I_2
500 ppm	I_3
0 ppm	I_4

Table 3.5 Treatment combinations

Combinations	Notations
$M_1L_1I_1$	T_1
$M_1L_1I_2$	T_2
$M_1L_1I_3$	T_3
$M_1L_1I_4$	T_4
$M_1L_2I_1$	T_5
$M_1L_2I_2$	T_6
$M_1L_2I_3$	T_7
$M_1L_2I_4$	T_8
$M_1L_3I_1$	T_9
$M_1L_3I_2$	T_{10}
$M_1L_3I_3$	T_{11}
$M_1L_3I_4$	T_{12}
$M_1L_1I_1$	T_{13}
$M_2L_1I_2$	T_{14}
$M_2L_1I_3$	T_{15}
$M_2L_1I_4$	T_{16}
$M_2L_2I_1$	T_{17}
$M_2L_2I_2$	T_{18}
$M_2L_2I_3$	T_{19}
$M_2L_2I_4$	T_{20}
$M_2L_3I_1$	T_{21}
$M_2L_3I_2$	T_{22}
$M_2L_3I_3$	T_{23}
$M_2L_3I_4$	T_{24}

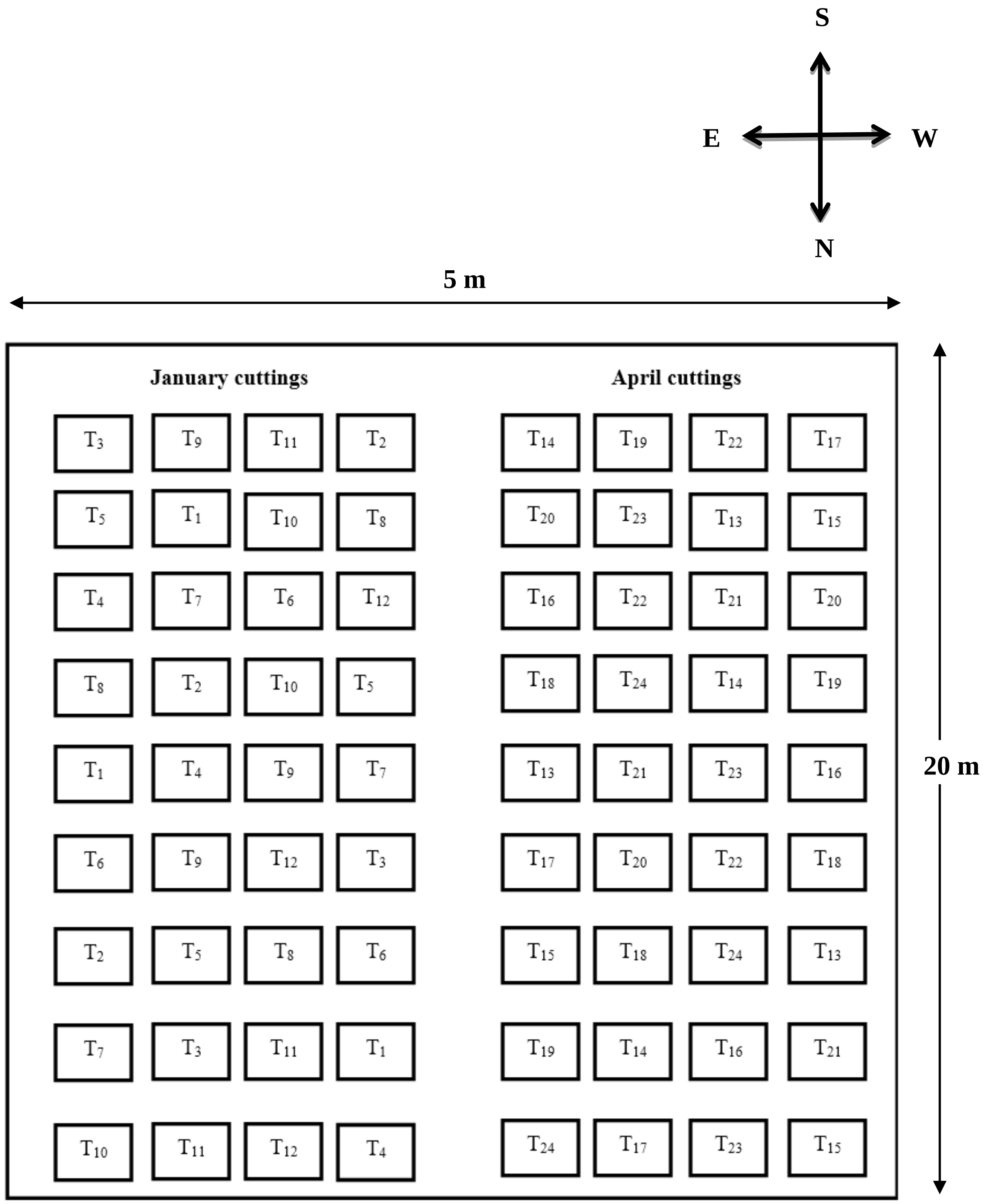


Fig. 3.5 Layout of the experimental plot

3.5 Planting materials

One year old stems having 4-5 nodes each were collected from the healthy mother plants of the five-year-old dragon fruit plantation of Krishi Vigyan Kendra (KVK), Jorhat during the months of January and April. The species selected for the study was *Hylocereus costaricensis* Britton & Rose. It bears red coloured fruits with ovoid shape and reddish flesh. The stems were then sized to the desired lengths of 10 cm, 15 cm and 20 cm respectively. A slant cut was given at the basal portion of each of the cuttings to increase the maximum absorbing surface for effective rooting. The cuttings were then dipped in 0.1 % Carbendazim WP solution for half hour. After that the cuttings were shade dried for one day prior to planting to dry the ooze coming out of the fresh cuttings. The basal portion of the cuttings were treated with Indole-3-Butyric Acid of specific concentrations (100 ppm, 250 ppm, 500 ppm and 0 ppm) as per the treatments prior to planting.

3.6 Preparation of Indole-3-Butyric Acid solution

The plant growth regulator used during the study was Indole-3-Butyric acid ($C_{12}H_{13}NO_2$) with four different concentrations of 100 ppm, 250 ppm, 500 ppm and 0 ppm. To prepare 100 ppm, 250 ppm and 500 ppm IBA solution, 0.1 g, 0.25 g and 0.5 g of IBA were weighed, respectively and then the chemicals were dissolved separately in small quantity of ethanol (95% concentration) and volume was made up to 1 litre by adding distilled water.

3.7 Rooting Media

Farm Yard Manure (FYM), sand and soil were mixed in 1: 2: 1 ratio and filled in black polybags of 20 cm x 22 cm size. After that the mixture was drenched with 0.3 % Captan WP solution as a prophylactic measure to kill the fungal spores present in the mixture. The pH of the rooting mixture was 6.2 and contained 0.86 % organic carbon and 287 kg/ha nitrogen.

Organic carbon was analysed by Wet digestion method (Piper, 1966), available Nitrogen by Kjeldahl’s method (Jackson, 1973) and pH by Control Dynamic pH meter.

3.8 Planting of cuttings

The basal portion of the cuttings were dipped in IBA solutions of specific concentrations for 10 minutes each and allowed to dry under shade for 15 minutes. After that the cuttings were planted in the polybags containing the rooting media. The treated cuttings were inserted into the soil to about 5 cm depth. Holes were made before to prevent damage to the basal end of the cuttings during planting of the cuttings. The base of the cuttings were pressed firmly to avoid air pockets. The cuttings were planted in a slightly slanting position. After planting the polybags were watered with a rose can. The planted cuttings in polybags were kept in shade net house providing 50 % shading.

3.9 After care

Watering was done on alternate days, so as to maintain sufficient moisture in the rooting media. Weeds were pulled out carefully without disturbing the cuttings whenever necessary. The planted cuttings were treated with 0.1 % carbendazim WP solution at fortnightly intervals to check the disease incidence. The cuttings were also treated with chlorpyriphos 20 % EC at the rate of 3 ml / litre water to control the hairy caterpillar, ants and other insect pest as and when required.

3.10 Observations recorded

3.10. 1 Root parameters

Five cuttings were selected randomly along with the polybags. The cuttings were uprooted and the soil adhered to the roots were removed gently by dipping it in a tub of water. After that the roots were collected in a clean container and the following parameters were observed:

3.10.1.1 Days required for root formation

The planted cuttings under each treatment were observed at five days intervals and the number of days required for root formation was recorded. After that the mean days required for root formation was calculated and expressed in numbers.

3.10.1.2 Number of roots

The number of adventitious roots per cutting were counted at 40 and 60 days after planting under each treatment and their mean were calculated and expressed in numbers. However, this excludes the lateral roots present on the adventitious roots.

3.10.1.3 Length of the longest root (cm)

The length of the longest root per cutting under each treatment were measured from the point of initiation to the growing tip using a graduated scale at 40 and 60 days after planting. After that the mean length was calculated and expressed in centimetres (cm).

3.10.1.4 Root length (cm)

The length of the adventitious roots per cutting under each treatment were measured at 40 and 60 days after planting from the point of initiation to the growing tip using a graduated scale. After that the mean length was calculated and expressed in centimetres (cm).

3.10.1.5 Diameter of the longest root (mm)

The diameter of the longest root per cutting under each treatment was measured at 40 and 60 days after planting using a micrometer at three positions of the root (near the base, at the centre and near the tip) and their mean was calculated and expressed in millimetres (mm).

3.10.1.6 Fresh weight of the roots (g)

The roots were separated from the sampled cuttings and the fresh weight was measured at 40 and 60 days after planting using an electric balance and the mean weight was calculated and expressed in grams (g).

3.10.1.7 Dry weight of the roots (g)

After measuring the fresh weight, the same root samples were dried at 85ºC in the oven until constant weight was obtained. After that the weight was measured using an electric balance and the mean weight was calculated and expressed in grams (g).

3.10.1.8 Percentage of rooted cuttings

The percentage of rooted cuttings were calculated at 40 and 60 days after planting of the cuttings. It was calculated by taking the ratio of number of cuttings rooted to the number of cuttings planted and multiplied the ratio with 100 and expressed in percentage (%). This parameter was calculated using the following formula:

Percentage of rooted cuttings= (Number of cuttings rooted/Number of cuttings planted) x 100

3.10.2 Shoot parameters

3.10.2.1 Days required for shoot initiation

The planted cuttings under each treatment were observed daily and the number of days required for the shoot initiation was recorded and their mean was calculated and expressed in numbers.

3.10.2.2 Number of shoots per cutting

Five cuttings were randomly selected at 40 and 60 days after planting for each treatment. The number of shoots per cutting were recorded. There mean was calculated and expressed in numbers.

3.10.2.3 Length of primary shoots (cm)

Five cuttings were randomly selected at 40 and 60 days after planting for each treatment. The length of the primary shoots was measured using a graduated scale. Their mean was calculated and expressed in centimetres (cm).

3.10.2.4 Length of secondary shoots (cm)

Five cuttings were randomly selected at 40 and 60 days after planting for each treatment. The length of the secondary shoots was measured using a graduated scale. Their mean was calculated and expressed in centimetres (cm).

3.10.2.5 Fresh weight of shoot (g)

Five cuttings were randomly selected at 40 and 60 days after planting for each treatment. The shoots were separated from the sampled cuttings and the fresh weight was recorded using an electric balance. After that their mean was calculated and expressed in grams (g).

3.10.2.6 Dry weight of shoot (g)

After recording the fresh weight of the shoots, the same samples were dried in oven at 85 ^{o} C until constant weight was obtained. After that the weight was measured using an electric balance and the mean weight was calculated and expressed in grams (g).

3.10.2.7 Root to shoot ratio

The root to shoot ratio was calculated at 40 and 60 days after planting by dividing the root dry weight by shoot dry weight. The mean of their results was calculated and expressed in numbers. The parameter was calculated using the following formula:

Root to shoot ratio = Root dry weight/ Shoot dry weight

3.10.2.8 Nitrogen content in shoot (%)

The nitrogen content was estimated at 40 and 60 days after planting for each treatment. It was estimated by Kjeldahl method (Thimmaiah, 1999) using the following formula:

$$\text{Nitrogen \%} = \frac{\text{(ml HCL in sample) - (ml HCL in blank) x normality of acid x 14.01 x 100}}{\text{Weight of sample (mg)}}$$

3.10.2.9 Protein content in shoot (%)

The protein content in shoot was estimated at 40 and 60 days after planting for each treatment. Protein content was estimated using the following formula (Thimmaiah, 1999):

Protein % = Nitrogen % x 6.25

3.10.2.10 Total chlorophyll content in the shoot (mg/ g)

The total chlorophyll content was estimated at 40 and 60 days after planting for each treatment. It was determined using acetone method as suggested by Thimmaiah, 1999. Fresh and fully matured stems of each treatment were collected in a polythene bag at 40 and 60 days after planting and cut into small pieces. After that 0.2 g of the sample were taken and crushed with mortar pestle along with few sand particles. Then few millilitres of 80 % acetone was mixed with the crushed sample and filtered with filter paper. This process was repeated until the colour of the crushed sample becomes colourless. After that the volume was made up to 25 ml in volumetric flask. At last the absorbance was recorded in spectrophotometer at 645 nm and 663 nm wavelengths by taking 80 % acetone solution as blank.

The total chlorophyll content was calculated using the following formula:

Total chlorophyll content (mg/ g) = 20.2 (A_{645}) + 8.02 (A_{663}) x V/ (1000 x W)

Where, A = Absorbance at specific wavelengths

V = Final volume of chlorophyll extract in 80 % acetone

W = Fresh weight of the tissue extracted

3.10.2.11 Vascular cambium thickness (mm)

The vascular cambium thickness was measured at 40 and 60 days after planting for each treatment. Fresh shoots of each treatment were collected and slides were prepared by taking fine cross sections of the shoots. Vascular cambium thickness was measured using ocular and stage micrometers. At first the ocular micrometer was calibrated with the stage micrometer. After that the slides were observed under microscope using ocular micrometer in the eye piece and the thickness was expressed in millimetres (mm) (Johanson, 1940).

3.10.3 Survival of the saplings (%)

The survival of the saplings was calculated at 60 days after planting using the formula:

Survival (%) = Number of cuttings survived/Number of cuttings planted x 100

3.10.4 Individual treatment combination cost

The total cost of production per sapling was calculated by adding the costs of the requisite components.

3.11 Statistical Analysis of the Data

All the experimental data were analysed statistically. Observations made from the field experimentation were subjected to analysis of variance. The data generated during the experiment were statistically analysed using Factorial Completely Randomised Design (CRD). Significance and non-significance of variance were determined by calculating the respective 'F' values (Panse and Sukhatme, 1985). Critical differences (CD) at 5% probability level were calculated only when 'F' value was significant.

$$\text{Standard Error of difference (S.Ed.)} = \sqrt{2 \times \frac{\text{EMS}}{\text{r}}}$$

Where,

Ems is the error mean square and 'r' is the number of replications

$$\text{Critical difference (CD)} = \text{SEd} \times' \text{t}' 5\% \text{ value for error d.f.}$$

CHAPTER IV

EXPERIMENTAL FINDINGS

The study on some of the physico-chemical characters of the roots and the shoots of dragon fruit saplings were carried out to obtain a better understanding of the factors affecting the growth and quality of dragon fruit saplings raised from cuttings. The experimental findings were recorded, statistically analyzed and presented under different headings in this chapter.

4.1 Root parameters

4.1.1 Days required for root formation

Perusal of pooled data presented in Table 4.1 and Fig.4.1 revealed that there was significant effect of time and size of cutting and IBA concentration on days required for root formation. Early root formation was recorded in the cuttings taken in April (18.09 days). The cuttings of 20 cm size recorded early root formation (18.46 days) whereas late root formation was found in cuttings of 10 cm size (22 days). The IBA concentration of 500 ppm led to early root formation (15.06 days) whereas the non-treated cuttings recorded late root formation (25.89 days).

There was significant interaction effect among different treatment combinations on days required for root formation (Table 4.2, Fig 4.2). Earliest root formation was obtained in T_{23} (14 days) whereas root formation was delayed in T_4 (28 days). However, the effects of treatment combinations *viz*., T_{22}, T_{19}, T_{18}, T_{15}, T_{11}, T_{10} and T_7 were statistically at par with the T_{23} treatment combination.

Table 4.1 Effect of time and size of cutting and IBA concentration on days required for root formation

Treatment	Days required for root formation		
	2020	**2021**	**Pooled**
Time of cutting			
M_1 - January	20.69	20.77	20.73
M_2 - April	18.1	18.08	18.09
SEd (±)	1.11	1.1	1.11
CD (5%)	2.22	2.2	2.21
Size of cutting			
L_1 - 10 cm	22.33	21.67	22
L_2 - 15 cm	21.32	21.34	21.33
L_3 - 20 cm	18.79	18.13	18.46
SEd (±)	1.36	1.35	1.36
CD (5%)	2.74	2.72	2.73
IBA concentration			
I_1 - 100 ppm	22.06	21.39	21.72
I_2 - 250 ppm	18.25	18.27	18.26
I_3 - 500 ppm	15.39	14.72	15.06
I_4 - 0 ppm	26.22	25.56	25.89
SEd (±)	1.57	1.56	1.57
CD (5%)	3.16	3.14	3.15

Table 4.2 Interaction effect of time and size of cutting and IBA concentration on days required for root formation

Treatment Combination	Days required for root formation		
	2020	**2021**	**Pooled**
T_1 ($M_1L_1I_1$)	23.33	22.67	23
T_2 ($M_1L_1I_2$)	21.67	21	21.33
T_3 ($M_1L_1I_3$)	18.33	17.67	18
T_4 ($M_1L_1I_4$)	28.33	27.67	28
T_5 ($M_1L_2I_1$)	20	19.33	19.67
T_6 ($M_1L_2I_2$)	18.33	17.67	18
T_7 ($M_1L_2I_3$)	16.67	16	16.33
T_8 ($M_1L_2I_4$)	26.67	26	26.33
T_9 ($M_1L_3I_1$)	21.67	21	21.33
T_{10} ($M_1L_3I_2$)	16.67	16	16.33
T_{11} ($M_1L_3I_3$)	15	14.33	14.67
T_{12} ($M_1L_3I_4$)	21.67	21	21.33
T_{13} ($M_2L_1I_1$)	23	22.33	22.67
T_{14} ($M_2L_1I_2$)	19.67	19	19.33
T_{15} ($M_2L_1I_3$)	18	17.33	17.67
T_{16} ($M_2L_1I_4$)	26.33	25.67	26
T_{17} ($M_2L_2I_1$)	23	22.33	22.67
T_{18} ($M_2L_2I_2$)	18	17.33	17.67
T_{19} ($M_2L_2I_3$)	16.67	15.99	16.33
T_{20} ($M_2L_2I_4$)	28	27.33	27.67
T_{21} ($M_2L_3I_1$)	21.33	20.67	21
T_{22} ($M_2L_3I_2$)	16.33	15.67	16
T_{23} ($M_2L_3I_3$)	14.33	13.67	14
T_{24} ($M_2L_3I_4$)	26.33	25.67	26
SEd (±)	3.84	3.82	3.83
CD (5%)	7.74	7.68	7.71

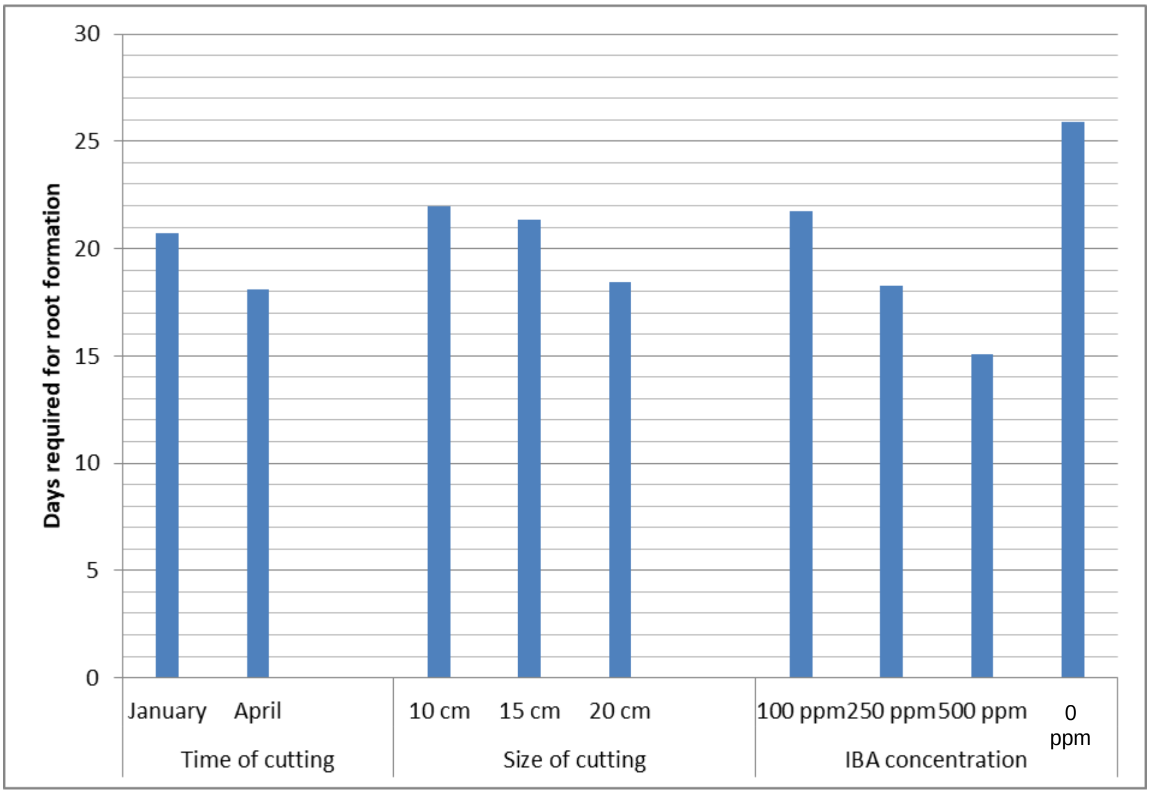


Fig 4.1 Effect of time and size of cutting and IBA concentration on days required for root formation

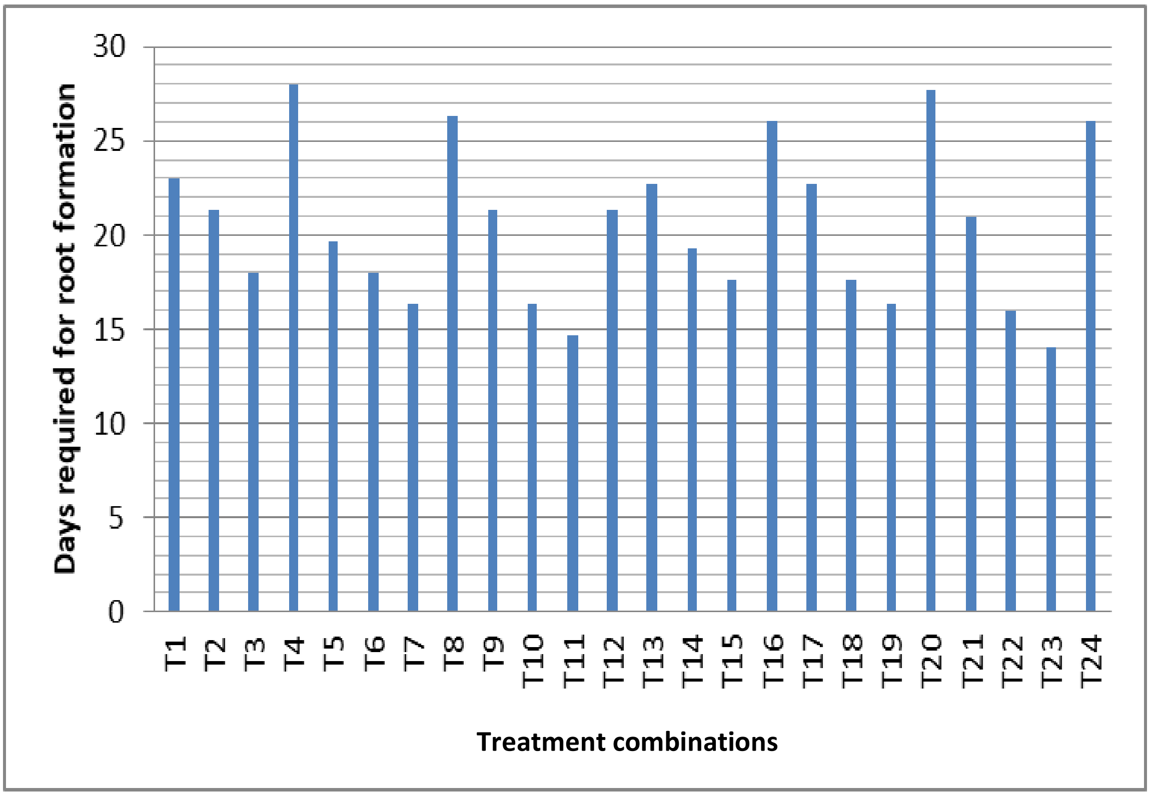


Fig 4.2 Interaction effect of time and size of cutting and IBA concentration on days required for root formation

4.1.2 Number of roots

The data presented in Table 4.3 and Fig. 4.3 revealed that there was significant effect of time and size of cutting and IBA concentration on number of roots at both 40 DAP and 60 DAP. Pooled data indicated that highest root number was recorded in the cuttings of April (10.79 at 40 DAPS; 12.79 at 60 DAP). Highest root number (12.81 at 40 DAPS; 14.81 at 60 DAP) was recorded in cuttings of 20 cm size whereas lowest root number (7.25 at 40 DAPS; 9.25 at 60 DAP) was recorded in cuttings of 10 cm size. The effect of 15 cm size of cutting was statistically at par with the 20 cm size of cuttings at both 40 DAP and 60 DAP. IBA concentration of 250 ppm recorded highest root numbers (13.97 at 40 DAPS; 15.97 at 60 DAP) whereas the control treatment recorded lowest root numbers (5.82 at 40 DAP; 7.82 at 60 DAP). There were no significant differences between 500 ppm and 250 ppm IBA concentration on number of roots at both 40 DAP and 60 DAP.

The interaction effect of time and size of cutting and IBA concentration on number of roots were found significant during both the years (Table 4.4 and Fig. 4.4). Pooled analysis data exhibited that highest root number (18.84 at 40 DAP ; 20.83 at 60 DAP) was recorded in T_{22} whereas lowest number of roots (3.63 at 40 DAP ; 5.63 at 60 DAP) were recorded in T_4. The effects of treatment combinations *viz*., T_{21}, T_{23}, T_{18}, T_{17} , T_{10} and T_6 were found statistically at par with T_{22}.

Table 4.3 Effect of time and size of cutting and IBA concentration on root number

Treatment	Root number					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	7.51	9.19	8.35	10.07	10.78	10.43
M_2 - April	10.21	11.37	10.79	12.54	13.03	12.79
SEd (±)	1.28	1.05	1.17	1.19	1.06	1.13
CD (5%)	2.57	2.11	2.34	2.39	2.14	2.27
Size of cutting						
L_1 - 10 cm	6.62	7.88	7.25	8.95	9.54	9.25
L_2 - 15 cm	10.13	10.84	10.49	12.46	12.51	12.48
L_3 - 20 cm	12.15	13.47	12.81	14.48	15.13	14.81
SEd (±)	1.57	1.28	1.43	1.46	1.3	1.38
CD (5%)	3.16	2.58	2.87	2.94	2.63	2.79
IBA concentration						
I_1 - 100 ppm	9.36	10.29	9.82	11.69	11.96	11.82
I_2 - 250 ppm	13.58	14.37	13.97	15.91	16.03	15.97
I_3 - 500 ppm	10.21	12	11.11	12.54	13.67	13.11
I_4 - 0 ppm	5.38	6.26	5.82	7.71	7.92	7.82
SEd (±)	1.81	1.48	1.65	1.68	1.51	1.6
CD (5%)	3.65	2.98	3.32	3.39	3.03	3.21

***DAP – Days after planting**

Table 4.4 Interaction effect of time and size of cutting and IBA concentration on root number

Treatment Combination	Root number					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	4.2	5.27	4.73	6.53	6.93	6.73
T_2 ($M_1L_1I_2$)	8.33	8.87	8.6	10.67	10.53	10.6
T_3 ($M_1L_1I_3$)	9	10.8	9.9	11.33	12.47	11.9
T_4 ($M_1L_1I_4$)	2.93	4.33	3.63	5.27	6	5.63
T_5 ($M_1L_2I_1$)	11.2	11.6	11.4	13.53	13.27	13.4
T_6 ($M_1L_2I_2$)	14.2	14.27	14.23	16.53	15.93	16.23
T_7 ($M_1L_2I_3$)	9.47	10.33	9.9	11.8	12	11.9
T_8 ($M_1L_2I_4$)	3.53	4.6	4.07	5.87	6.27	6.07
T_9 ($M_1L_3I_1$)	10.87	12.2	11.53	13.2	13.87	13.53
T_{10} ($M_1L_3I_2$)	16.8	18	17.4	19.13	19.67	19.4
T_{11} ($M_1L_3I_3$)	10.33	12.73	11.53	12.67	14.4	13.53
T_{12} ($M_1L_3I_4$)	7.8	8.07	7.93	10.13	9.73	9.93
T_{13} ($M_2L_1I_1$)	5.2	5.87	5.54	7.53	7.53	7.53
T_{14} ($M_2L_1I_2$)	9.33	9.93	9.63	11.67	11.6	11.63
T_{15} ($M_2L_1I_3$)	10	12.27	11.13	12.33	13.93	13.13
T_{16} ($M_2L_1I_4$)	3.93	5.67	4.8	6.27	7.33	6.8
T_{17} ($M_2L_2I_1$)	12.2	13.2	12.7	14.53	14.87	14.7
T_{18} ($M_2L_2I_2$)	14.53	15.73	15.13	16.87	17.4	17.13
T_{19} ($M_2L_2I_3$)	10.87	11.47	11.17	13.2	13.13	13.17
T_{20} ($M_2L_2I_4$)	5	5.53	5.27	7.33	7.2	7.27
T_{21} ($M_2L_3I_1$)	12.47	13.6	13.03	14.8	15.27	15.03
T_{22} ($M_2L_3I_2$)	18.27	19.4	18.84	20.6	21.07	20.83
T_{23} ($M_2L_3I_3$)	11.6	14.4	13	13.93	16.07	15
T_{24} ($M_2L_3I_4$)	9.07	9.33	9.2	11.4	11	11.2
SEd (±)	4.44	3.63	4.04	4.13	3.69	3.91
CD (5%)	8.88	7.31	8.1	8.3	7.43	7.87

***DAP – Days after planting**

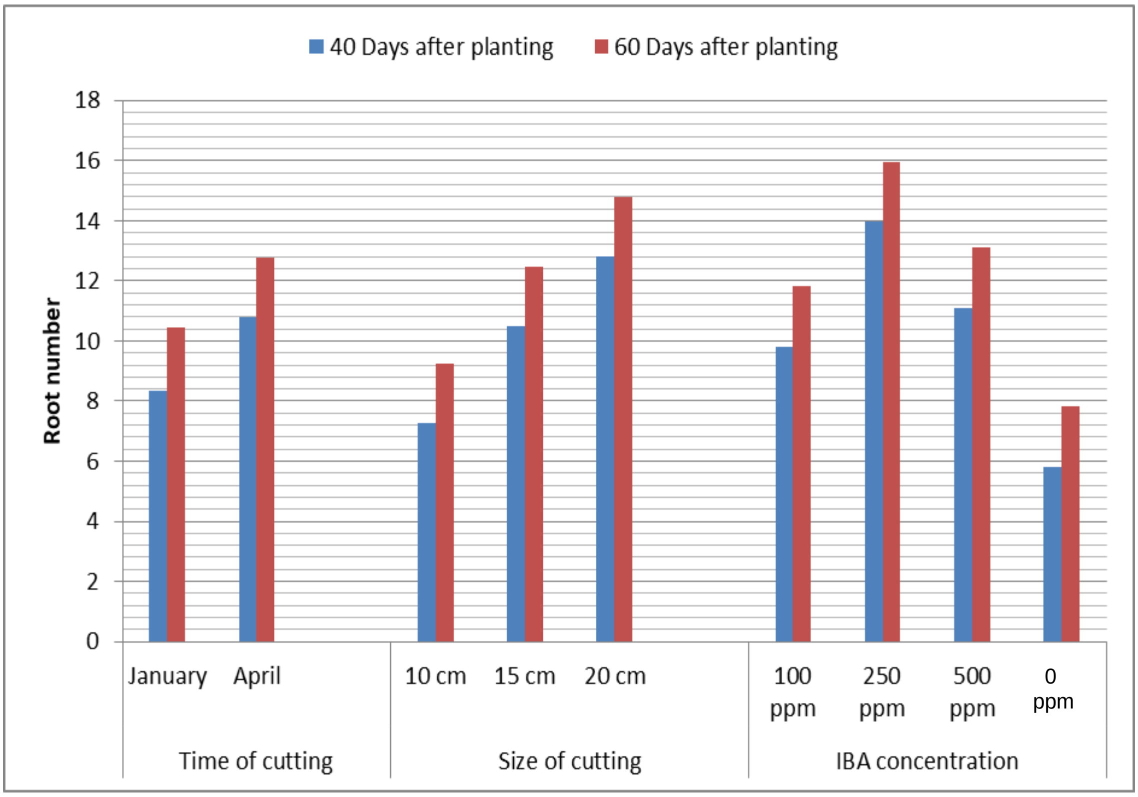


Fig. 4.3 Effect of time and size of cutting and IBA concentration on root number

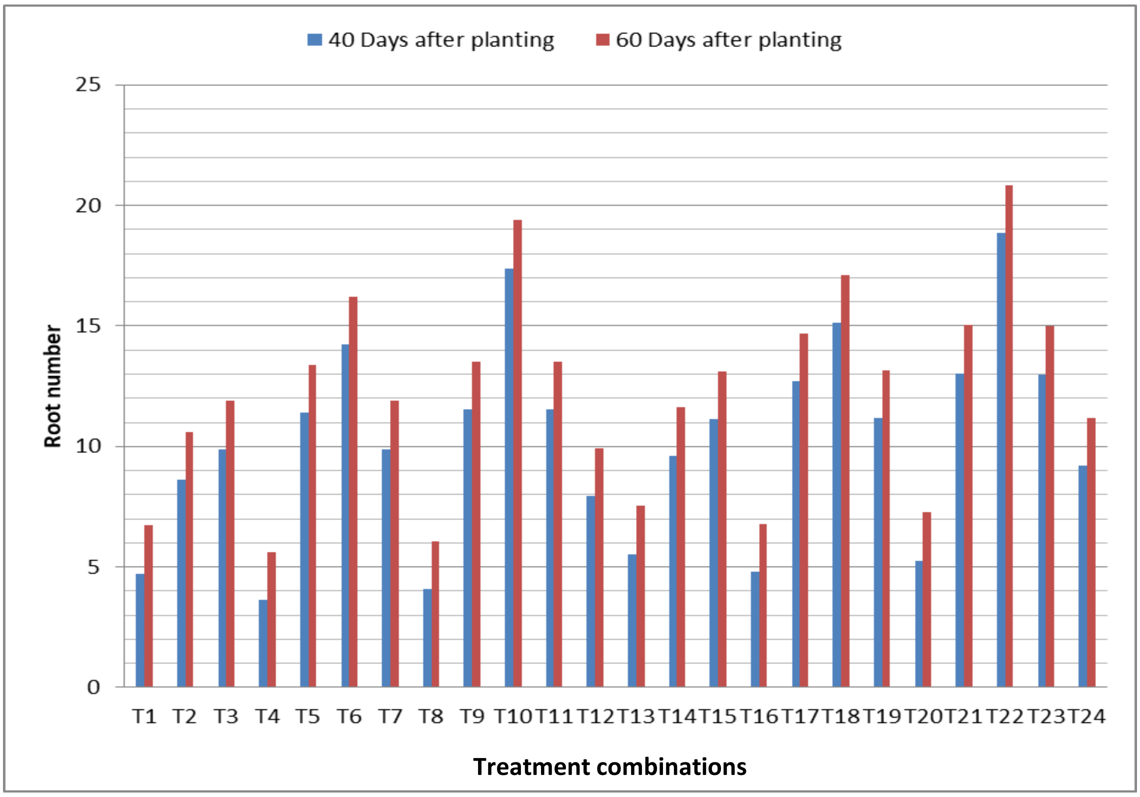


Fig. 4.4 Interaction effect of time and size of cutting and IBA concentration on root number

4.1.3 Length of longest root (cm)

The time and size of cutting and IBA concentration had significant effect on the length of the longest root at both 40 DAP and 60 DAP (Table 4.5 and Fig. 4.5). The pooled data revealed that the cuttings taken in April recorded the longest root (11.94 cm at 40 DAP; 14.94 cm at 60 DAP. Longest root (14.37 cm at 40 DAP; 17.37 cm at 60 DAP) was achieved in cuttings of 20 cm size whereas the lowest length of the longest root (8.15 cm at 40 DAP; 11.15 cm at 60 DAP) was recorded in cuttings of 10 cm size. However, there was no remarkable variation among the 20 cm and 15 cm size of cutting with respect to the length of the longest root. The IBA concentration of 500 ppm recorded the longest root (14 cm at 40 DAP; 17 cm at 60 DAP) whereas the control treatment recorded the shortest length (7.82 cm at 40 DAP; 10.82 cm at 60 DAP) of the longest root. The pooled analysis data revealed that there was no significant difference in length of the longest root between the 250 ppm and 500 ppm IBA concentration at both 40 DAP and 60 DAP.

The data pertaining to the interaction effect of time and size of cutting and IBA concentration on the length of the longest root as depicted in Table 4.6 and Fig. 4.6 showed that there was significant interaction effect of the different treatment combinations. Longest root (16.28 cm at 40 DAP ; 19.28 cm at 60 DAP) was recorded in T_{22} whereas shortest length (4.92 cm at 40 DAP ; 7.92 cm at 60 DAP***)*** of the longest root was recorded in T_4. The pooled analysis data revealed that the effects of the treatment combinations *viz.*, T_{23}, T_{21}, T_{10}, T_{11}, T_{10}, T_9 and T_6 were statistically at par with T_{22} .

Table 4.5 Effect of time and size of cutting and IBA concentration on length of the longest root (cm)

Treatment	Length of the longest root (cm)					
	40 DAP			60 DAP		
	2020	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
Time of cutting						
M_1 - January	9.23	10.29	9.76	12.76	13.1	12.93
M_2 - April	11.43	12.46	11.94	14.76	15.13	14.94
SEd (±)	0.99	0.92	0.96	0.91	0.9	0.91
CD (5%)	1.98	1.84	1.92	1.82	1.8	1.82
Size of cutting						
L_1 - 10 cm	7.63	8.67	8.15	10.97	11.33	11.15
L_2 - 15 cm	12.15	13.18	12.67	15.48	15.85	15.67
L_3 - 20 cm	13.85	14.88	14.37	17.18	17.55	17.37
SEd (±)	1.21	1.12	1.17	1.12	1.1	1.12
CD (5%)	2.43	2.26	2.35	2.26	2.22	2.24
IBA concentration						
I_1 - 100 ppm	10.13	11.15	10.64	14.01	14.03	14.02
I_2 - 250 ppm	13.13	14.16	13.64	16.46	16.83	16.65
I_3 - 500 ppm	13.48	14.52	14	16.82	17.18	17
I_4 - 0 ppm	7.31	8.34	7.82	10.64	11.01	10.82
SEd (±)	1.4	1.3	1.35	1.29	1.27	1.28
CD (5%)	2.81	2.61	2.71	2.6	2.56	2.58

***DAP – Days after planting**

Table 4.6 Interaction effect of time and size of cutting and IBA concentration on length of the longest root (cm)

Treatment Combination	Length of the longest root (cm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	5.6	6.63	6.12	8.93	9.3	9.12
T_2 ($M_1L_1I_2$)	8.2	9.23	8.72	11.53	11.9	11.72
T_3 ($M_1L_1I_3$)	11.47	12.5	11.98	14.8	15.17	14.98
T_4 ($M_1L_1I_4$)	4.4	5.43	4.92	7.73	8.1	7.92
T_5 ($M_1L_2I_1$)	12.2	13.23	12.72	15.53	15.9	15.72
T_6 ($M_1L_2I_2$)	15.2	16.23	15.72	18.53	18.9	18.72
T_7 ($M_1L_2I_3$)	14	15.03	14.52	17.33	17.7	17.52
T_8 ($M_1L_2I_4$)	6.33	7.37	6.85	9.67	10.03	9.85
T_9 ($M_1L_3I_1$)	14.33	15.37	14.85	17.67	18.03	17.85
T_{10} ($M_1L_3I_2$)	15.33	16.37	15.85	18.67	19.03	18.85
T_{11} ($M_1L_3I_3$)	14.33	15.37	14.85	17.67	18.03	17.85
T_{12} ($M_1L_3I_4$)	10.53	11.57	11.05	13.87	14.23	14.05
T_{13} ($M_2L_1I_1$)	6.03	7.07	6.55	9.37	9.73	9.55
T_{14} ($M_2L_1I_2$)	8.63	9.67	9.15	11.97	12.33	12.15
T_{15} ($M_2L_1I_3$)	11.9	12.93	12.42	15.23	15.6	15.42
T_{16} ($M_2L_1I_4$)	4.83	5.87	5.35	8.17	8.53	8.35
T_{17} ($M_2L_2I_1$)	12.63	13.67	13.15	15.97	16.33	16.15
T_{18} ($M_2L_2I_2$)	15.63	16.67	16.15	18.97	19.33	19.15
T_{19} ($M_2L_2I_3$)	14.43	15.47	14.95	17.77	18.13	17.95
T_{20} ($M_2L_2I_4$)	6.77	7.8	7.28	10.1	10.47	10.28
T_{21} ($M_2L_3I_1$)	14.77	15.8	15.28	18.1	18.47	18.28
T_{22} ($M_2L_3I_2$)	15.77	16.8	16.28	19.1	19.47	19.28
T_{23} ($M_2L_3I_3$)	14.77	15.8	15.28	18.1	18.47	18.28
T_{24} ($M_2L_3I_4$)	10.97	12	11.48	14.3	14.67	14.48
SEd (±)	3.42	3.17	3.3	3.17	3.12	3.15
CD (5%)	6.89	6.39	6.64	6.38	6.28	6.33

***DAP – Days after planting**

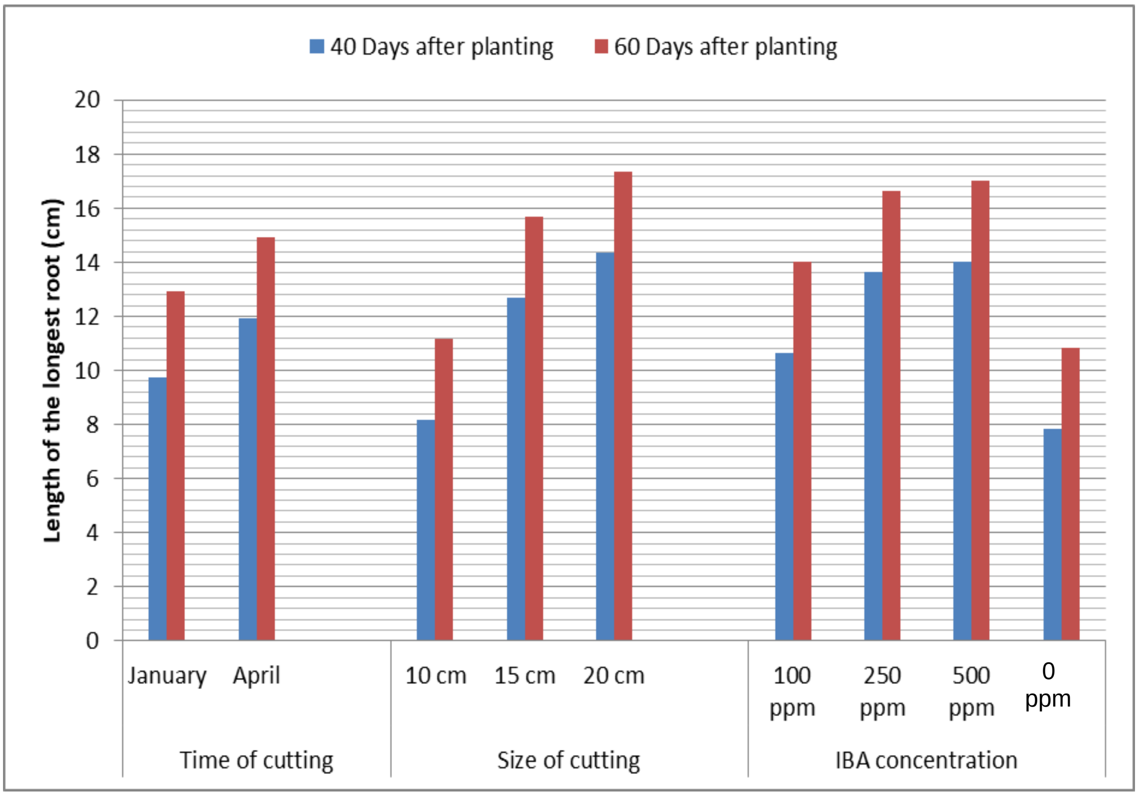


Fig. 4.5 Effect of time and size of cutting and IBA concentration on length of the longest root(cm)

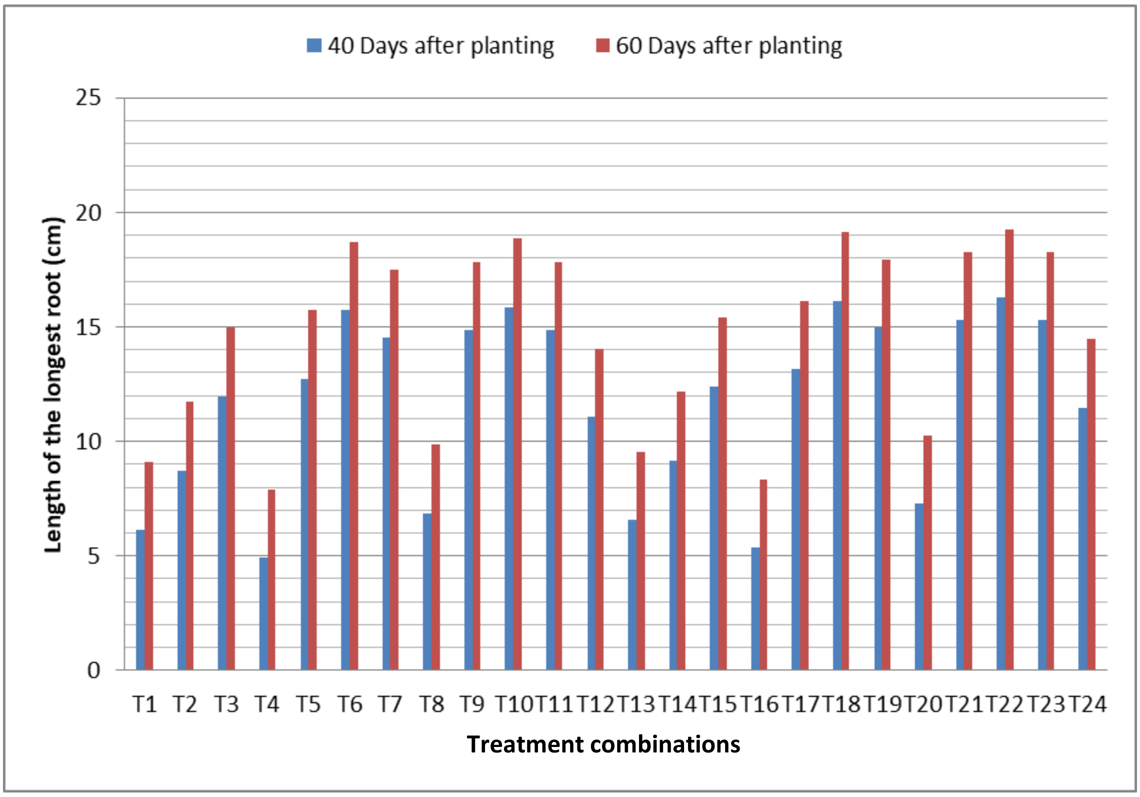


Fig. 4.6 Interaction effect of time and size of cutting and IBA concentration on length of the longest root(cm)

4.1.4 Root Length (cm)

The pooled data depicted in Table 4.7 and Fig. 4.7 revealed that there was significant effect of time and size of cutting and IBA concentration at both 40 DAP and 60 DAP. Highest root length (10.79 cm at 40 DAP; 12.79 cm at 60 DAP) was recorded in the cuttings of April. The pooled analysis data revealed that highest root length (12.81 cm at 40 DAP; 14.81 cm at 60 DAP) was obtained in cuttings of 20 cm size whereas lowest root length (7.25 cm at 40 DAP; 9.25 cm at 60 DAP) was recorded in cuttings of 10 cm size. Moreover, the 20 cm and 15 cm sizes of cuttings were statistically at par with respect to the root length. The IBA concentration of 250 ppm recorded the highest root length (13.97 cm at 40 DAP; 15.97 cm at 60 DAP) whereas the control treatment recorded the lowest root length (5.82 cm at 40 DAP; 7.82 cm at 60 DAP). There was no significant variation of root length between the 500 ppm and 250 ppm IBA treated cuttings.

The data presented on the interaction effect of time and size of cutting and IBA concentration revealed that there was significant variation of root length among the different treatment combinations (Table 4.8, Fig. 4.8). Highest root length (18.83 cm at 40 DAP; 20.83 cm at 60 DAP) was recorded in T_{22} whereas lowest root length (3.63 cm at 40 DAP; 5.63 cm at 60 DAP) was recorded in T_4. The pooled analysis data revealed that the effects of the treatment combinations *viz*., T_{23}, T_{21}, T_{18}, T_{17}, T_{15}, T_{11}, T_{10}, T_6 and T_5 were statistically at par with T_{22}.

Table 4.7 Effect of time and size of cutting and IBA concentration on root length (cm)

Treatment	Root length (cm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	7.57	9.17	8.58	10.06	10.28	10.17
M_2 - April	10.21	11.37	10.79	12.54	13.03	12.79
SEd ($\pm$)	1.28	1.05	1.09	1.19	1.06	1.16
CD (5%)	2.57	2.11	2.15	2.39	2.14	2.27
Size of cutting						
L_1 - 10 cm	6.62	7.88	7.25	8.95	9.54	9.25
L_2 - 15 cm	10.13	10.84	10.48	12.46	12.51	12.49
L_3 - 20 cm	12.15	13.47	12.81	14.48	15.13	14.81
SEd ($\pm$)	1.57	1.28	1.33	1.46	1.3	1.38
CD (5%)	3.16	2.58	2.64	2.94	2.63	2.79
IBA concentration						
I_1 - 100 ppm	9.36	10.29	9.83	11.69	11.96	11.83
I_2 - 250 ppm	13.58	14.37	13.97	15.91	16.03	15.97
I_3 - 500 ppm	10.21	12	11.11	12.54	13.67	13.11
I_4 - 0 ppm	5.38	6.26	5.82	7.71	7.92	7.82
SEd ($\pm$)	1.81	1.48	1.65	1.68	1.51	1.56
CD (5%)	3.65	2.98	3.32	3.39	3.03	3.21

***DAP – Days after planting**

Table 4.8 Interaction effect of time and size of cutting and IBA concentration on root length (cm)

Treatment Combination	Root length (cm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	4.2	5.27	4.73	6.53	6.93	6.73
T_2 ($M_1L_1I_2$)	8.33	8.87	8.6	10.67	10.53	10.6
T_3 ($M_1L_1I_3$)	9	10.8	9.9	11.33	12.47	11.9
T_4 ($M_1L_1I_4$)	2.93	4.33	3.63	5.27	6	5.63
T_5 ($M_1L_2I_1$)	11.2	11.6	11.4	13.53	13.27	13.4
T_6 ($M_1L_2I_2$)	14.2	14.27	14.23	16.53	15.93	16.23
T_7 ($M_1L_2I_3$)	9.47	10.33	9.9	11.8	12	11.9
T_8 ($M_1L_2I_4$)	3.53	4.6	4.07	5.87	6.27	6.07
T_9 ($M_1L_3I_1$)	10.87	12.2	11.53	13.2	13.87	13.53
T_{10} ($M_1L_3I_2$)	16.8	18	17.4	19.13	19.67	19.4
T_{11} ($M_1L_3I_3$)	10.33	12.73	11.53	12.67	14.4	13.53
T_{12} ($M_1L_3I_4$)	7.8	8.07	7.93	10.13	9.73	9.93
T_{13} ($M_2L_1I_1$)	5.2	5.87	5.53	7.53	7.53	7.53
T_{14} ($M_2L_1I_2$)	9.33	9.93	9.63	11.67	11.6	11.63
T_{15} ($M_2L_1I_3$)	10	12.27	11.13	12.33	13.93	13.13
T_{16} ($M_2L_1I_4$)	3.93	5.67	4.8	6.27	7.33	6.8
T_{17} ($M_2L_2I_1$)	12.2	13.2	12.7	14.53	14.87	14.7
T_{18} ($M_2L_2I_2$)	14.53	15.73	15.13	16.87	17.4	17.13
T_{19} ($M_2L_2I_3$)	10.87	11.47	11.17	13.2	13.13	13.17
T_{20} ($M_2L_2I_4$)	5	5.53	5.27	7.33	7.2	7.27
T_{21} ($M_2L_3I_1$)	12.47	13.6	13.03	14.8	15.27	15.03
T_{22} ($M_2L_3I_2$)	18.27	19.4	18.83	20.6	21.07	20.83
T_{23} ($M_2L_3I_3$)	11.6	14.4	13	13.93	16.07	15
T_{24} ($M_2L_3I_4$)	9.07	9.33	9.2	11.4	11	11.2
SEd (±)	4.44	3.63	3.76	4.13	3.38	3.56
CD (5%)	8.94	7.31	7.45	8.3	6.76	7.53

***DAP – Days after planting**

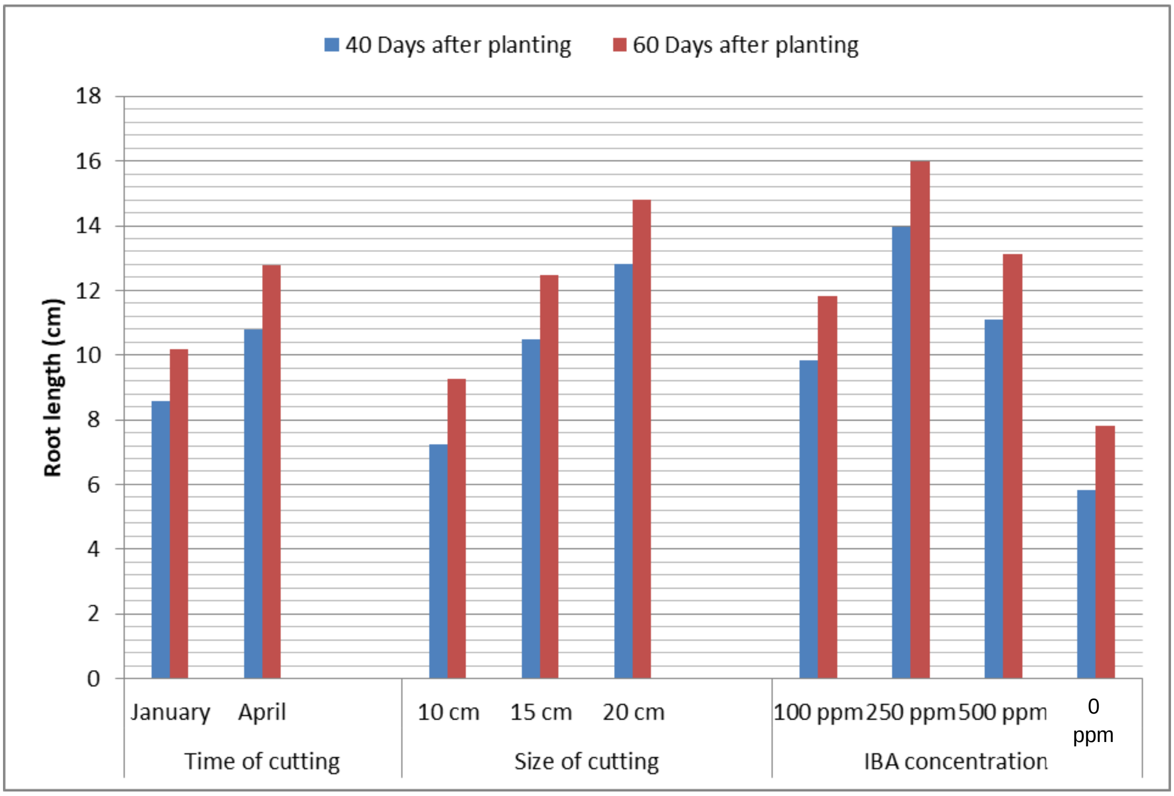


Fig. 4.7 Effect of time and size of cutting and IBA concentration on root length(cm)

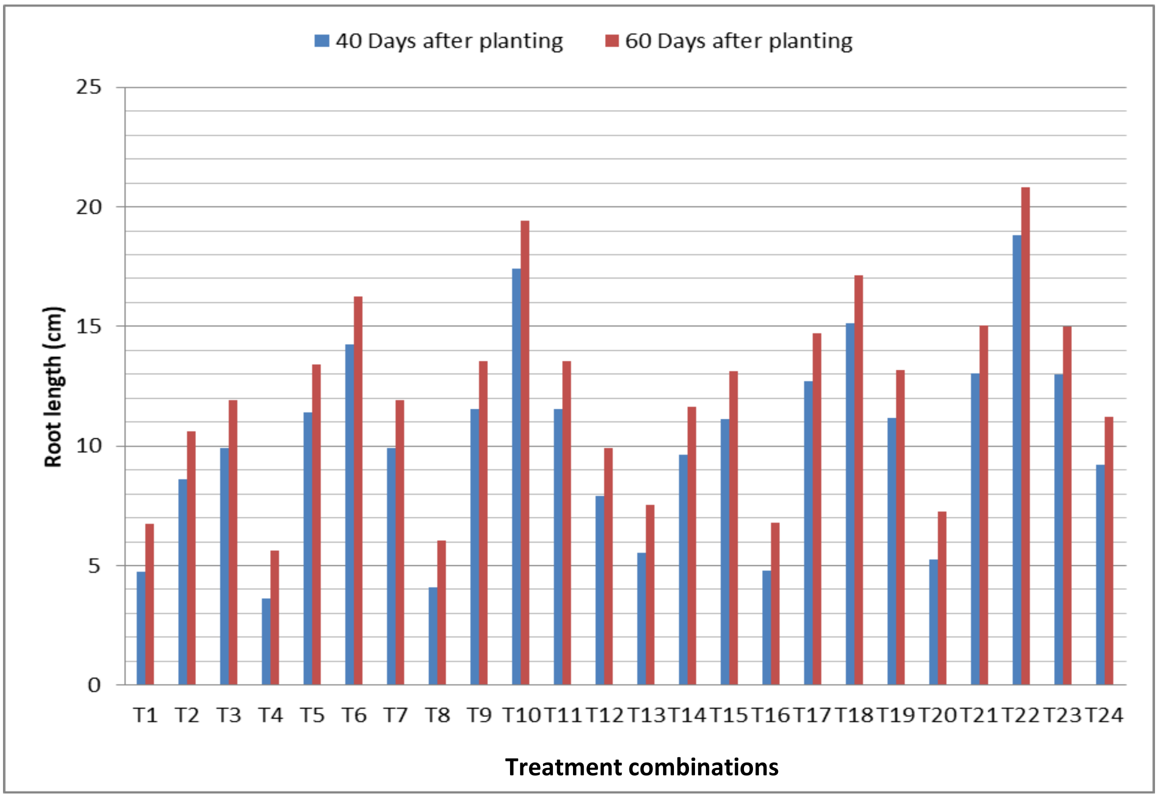


Fig. 4.8 Interaction effect of time and size of cutting and IBA concentration on root length(cm)

4.1.5 Diameter of the longest root (mm)

The effect of time and size of cutting and IBA concentration was pronounced in changes of diameter of the longest root (Table 4.9, Fig. 4.9). The diameter of the longest root was highest (0.52 mm at 40 DAP; 0.77 mm at 60 DAP) in the cuttings taken in April. The pooled analysis data revealed that the diameter of the longest root increased with the increase in size of the cuttings and recorded the highest (0.62 mm at 40 DAP; 0.87 mm at 60 DAP) in cuttings of 20 cm size whereas lowest diameter (0.4 mm at 40 DAP ; 0.65 mm at 60 DAP) was recorded in cuttings of 10 cm size. The 250 ppm IBA treated cuttings recorded the highest diameter (0.66 mm at 40 DAP; 0.91 mm at 60 DAP) of the longest root whereas the non-treated cuttings recorded the lowest diameter (0.29 mm at 40 DAP; 0.54 mm at 60 DAP).

Perusal of pooled data presented in Table 4.10 and Fig. 4.10 revealed that there was significant interaction effect of the different treatment combinations on the diameter of the longest root. The highest diameter (0.78 mm at 40 DAP; 1.04 mm at 60 DAP) of the longest root was obtained in T_{22} whereas lowest diameter (0.23 mm at 40 DAP; 0.48 mm at 60 DAP) was recorded in T_4. The effects of the treatment combinations *viz*., T_{23}, T_{11} and T_{10} were statistically at par with T_{22}.

Table 4.9 Effect of time and size of cutting and IBA concentration on diameter of the longest root (mm)

Treatment	Diameter of the longest root (mm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	0.41	0.43	0.42	0.63	0.65	0.64
M_2 - April	0.51	0.54	0.52	0.77	0.78	0.77
SEd (±)	0.02	0.02	0.02	0.02	0.02	0.02
CD (5%)	0.04	0.05	0.04	0.05	0.04	0.04
Size of cutting						
L_1 - 10 cm	0.39	0.41	0.4	0.64	0.66	0.65
L_2 - 15 cm	0.52	0.54	0.53	0.78	0.79	0.78
L_3 - 20 cm	0.61	0.63	0.62	0.86	0.88	0.87
SEd (±)	0.02	0.02	0.02	0.02	0.02	0.02
CD (5%)	0.05	0.05	0.04	0.05	0.04	0.04
IBA concentration						
I_1 - 100 ppm	0.51	0.53	0.52	0.77	0.79	0.78
I_2 - 250 ppm	0.65	0.67	0.66	0.9	0.92	0.91
I_3 - 500 ppm	0.58	0.6	0.59	0.83	0.85	0.84
I_4 - 0 ppm	0.28	0.31	0.29	0.54	0.55	0.54
SEd (±)	0.03	0.03	0.02	0.03	0.03	0.02
CD (5%)	0.05	0.05	0.05	0.05	0.05	0.05

***DAP – Days after planting**

Table 4.10 Interaction effect of time and size of cutting and IBA concentration on diameter of the longest root (mm)

Treatment Combination	Diameter of the longest root (mm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	0.33	0.35	0.34	0.59	0.6	0.59
T_2 ($M_1L_1I_2$)	0.52	0.54	0.53	0.78	0.79	0.78
T_3 ($M_1L_1I_3$)	0.44	0.47	0.46	0.7	0.72	0.71
T_4 ($M_1L_1I_4$)	0.21	0.24	0.23	0.47	0.49	0.48
T_5 ($M_1L_2I_1$)	0.54	0.58	0.56	0.8	0.83	0.81
T_6 ($M_1L_2I_2$)	0.64	0.66	0.65	0.9	0.91	0.9
T_7 ($M_1L_2I_3$)	0.56	0.58	0.57	0.82	0.83	0.82
T_8 ($M_1L_2I_4$)	0.3	0.32	0.31	0.56	0.57	0.56
T_9 ($M_1L_3I_1$)	0.64	0.66	0.65	0.9	0.91	0.9
T_{10} ($M_1L_3I_2$)	0.75	0.78	0.77	1.01	1.03	1.02
T_{11} ($M_1L_3I_3$)	0.7	0.73	0.72	0.96	0.98	0.97
T_{12} ($M_1L_3I_4$)	0.3	0.33	0.32	0.56	0.58	0.57
T_{13} ($M_2L_1I_1$)	0.34	0.37	0.36	0.6	0.62	0.61
T_{14} ($M_2L_1I_2$)	0.53	0.56	0.55	0.79	0.81	0.8
T_{15} ($M_2L_1I_3$)	0.47	0.48	0.47	0.72	0.73	0.73
T_{16} ($M_2L_1I_4$)	0.23	0.25	0.24	0.49	0.5	0.49
T_{17} ($M_2L_2I_1$)	0.56	0.59	0.58	0.82	0.84	0.83
T_{18} ($M_2L_2I_2$)	0.66	0.67	0.67	0.92	0.92	0.92
T_{19} ($M_2L_2I_3$)	0.57	0.6	0.59	0.83	0.85	0.84
T_{20} ($M_2L_2I_4$)	0.31	0.34	0.33	0.57	0.59	0.58
T_{21} ($M_2L_3I_1$)	0.64	0.68	0.66	0.9	0.93	0.91
T_{22} ($M_2L_3I_2$)	0.77	0.8	0.78	1.03	1.05	1.04
T_{23} ($M_2L_3I_3$)	0.72	0.74	0.73	0.98	0.99	0.98
T_{24} ($M_2L_3I_4$)	0.32	0.35	0.33	0.58	0.6	0.59
SEd (±)	0.05	0.06	0.06	0.05	0.06	0.06
CD (5%)	0.11	0.13	0.12	0.11	0.13	0.12

***DAP – Days after planting**

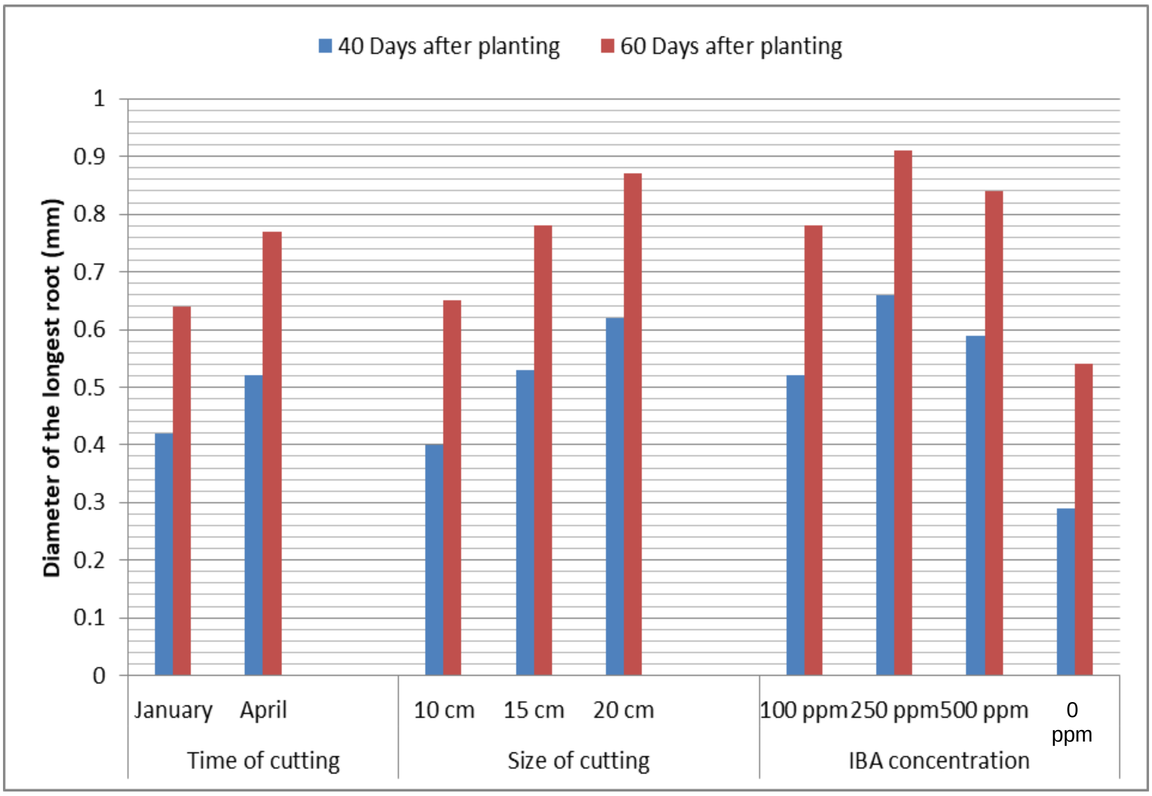


Fig. 4.9 Effect of time and size of cutting and IBA concentration on diameter of the longest root(mm)

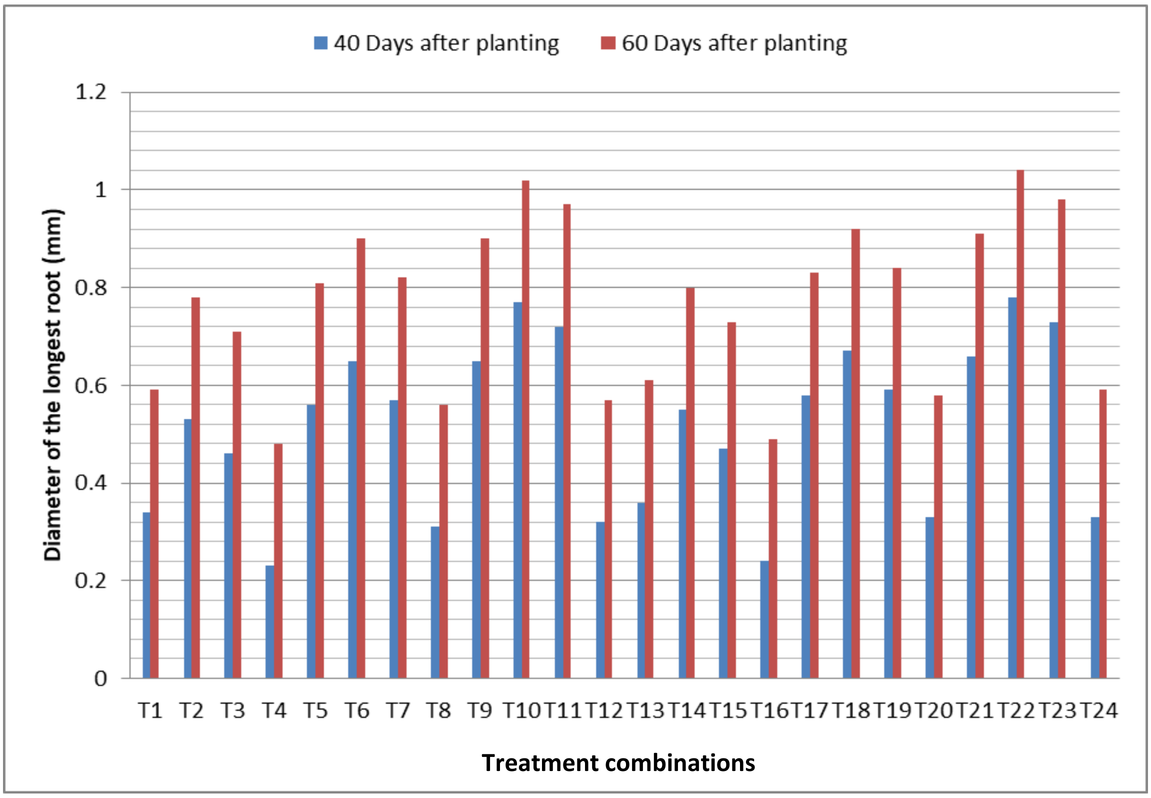


Fig. 4.10 Interaction effect of time and size of cutting and IBA concentration on diameter of the longest root(mm)

4.1.6 Fresh weight of root (g)

The time and size of cutting and IBA concentration had profound effect on the root fresh weight of the cuttings (Table 4.11 and Fig. 4.11). The highest root fresh weight (1.09 g at 40 DAP; 1.42 g at 60 DAP) was obtained in the cuttings taken in April. The pooled analysis data revealed that the root fresh weight was highest (1.26 g at 40 DAP; 1.58 g at 60 DAP) in the cuttings of 20 cm size whereas lowest (0.91 g at 40 DAP; 1.24 g at 60 DAP) root fresh weight was obtained in the cuttings of 10 cm size. The IBA concentration of 250 ppm recorded the highest root fresh weight (1.23 g at 40 DAP; 1.56 g at 60 DAP) whereas the control treatment recorded the lowest root fresh weight (0.79 g at 40 DAP; 1.12 g at 60 DAP). There was no significant variation in root fresh weight between the IBA 250 ppm and 500 ppm treated cuttings.

The treatment combinations had significant interaction effect on the root fresh weight of the cuttings (Table 4.12, Fig. 4.12). The highest root fresh weight (1.46 g at 40 DAP ; 1.79 g at 60 DAP) was recorded in T_{22} whereas lowest root fresh weight (0.72 g at 40 DAP ; 1.05 g at 60 DAP) was recorded in T_4. Moreover, there was no significant variation among the treatment combinations *viz*., T_{22}, T_{23}, T_{11} and T_{10} .

Table 4.11 Effect of time and size of cutting and IBA concentration on root fresh weight (g)

Treatment	Root fresh weight (g)					
	40 DAP			60 DAP		
	2020	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
Time of cutting						
M_1 - January	0.99	1.02	1.01	1.22	1.24	1.23
M_2 - April	1.08	1.11	1.09	1.41	1.43	1.42
SEd (±)	0.02	0.02	0.02	0.02	0.02	0.02
CD (5%)	0.05	0.04	0.05	0.05	0.04	0.05
Size of cutting						
L_1 - 10 cm	0.9	0.92	0.91	1.23	1.25	1.24
L_2 - 15 cm	1.07	1.1	1.09	1.4	1.42	1.41
L_3 - 20 cm	1.24	1.27	1.26	1.57	1.59	1.58
SEd (±)	0.03	0.02	0.03	0.03	0.03	0.02
CD (5%)	0.05	0.05	0.05	0.05	0.05	0.05
IBA concentration						
I_1 - 100 ppm	1.1	1.12	1.11	1.42	1.44	1.43
I_2 - 250 ppm	1.22	1.25	1.23	1.55	1.57	1.56
I_3 - 500 ppm	1.19	1.22	1.21	1.52	1.54	1.53
I_4 - 0 ppm	0.78	0.8	0.79	1.11	1.13	1.12
SEd (±)	0.03	0.03	0.03	0.03	0.03	0.03
CD (5%)	0.06	0.06	0.06	0.06	0.06	0.06

***DAP – Days after planting**

Table 4.12 Interaction effect of time and size of cutting and IBA concentration on root fresh weight (g)

Treatment Combination	Root fresh weight (g)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	0.85	0.88	0.87	1.18	1.2	1.19
T_2 ($M_1L_1I_2$)	1.01	1.03	1.02	1.34	1.35	1.34
T_3 ($M_1L_1I_3$)	0.99	1.01	1	1.32	1.33	1.32
T_4 ($M_1L_1I_4$)	0.71	0.73	0.72	1.04	1.05	1.05
T_5 ($M_1L_2I_1$)	1.1	1.12	1.11	1.43	1.44	1.44
T_6 ($M_1L_2I_2$)	1.2	1.23	1.21	1.53	1.55	1.54
T_7 ($M_1L_2I_3$)	1.18	1.2	1.19	1.51	1.52	1.51
T_8 ($M_1L_2I_4$)	0.79	0.81	0.8	1.12	1.13	1.12
T_9 ($M_1L_3I_1$)	1.3	1.32	1.31	1.63	1.64	1.63
T_{10} ($M_1L_3I_2$)	1.43	1.45	1.44	1.76	1.77	1.76
T_{11} ($M_1L_3I_3$)	1.39	1.42	1.41	1.72	1.74	1.73
T_{12} ($M_1L_3I_4$)	0.82	0.84	0.83	1.15	1.16	1.16
T_{13} ($M_2L_1I_1$)	0.88	0.9	0.89	1.21	1.22	1.22
T_{14} ($M_2L_1I_2$)	1.02	1.04	1.03	1.35	1.36	1.36
T_{15} ($M_2L_1I_3$)	1	1.03	1.02	1.33	1.35	1.34
T_{16} ($M_2L_1I_4$)	0.73	0.75	0.74	1.06	1.07	1.07
T_{17} ($M_2L_2I_1$)	1.12	1.14	1.13	1.45	1.46	1.45
T_{18} ($M_2L_2I_2$)	1.21	1.25	1.23	1.54	1.57	1.56
T_{19} ($M_2L_2I_3$)	1.19	1.22	1.21	1.52	1.54	1.53
T_{20} ($M_2L_2I_4$)	0.8	0.83	0.81	1.13	1.15	1.14
T_{21} ($M_2L_3I_1$)	1.31	1.34	1.32	1.64	1.66	1.65
T_{22} ($M_2L_3I_2$)	1.44	1.48	1.46	1.77	1.8	1.79
T_{23} ($M_2L_3I_3$)	1.41	1.43	1.42	1.74	1.75	1.75
T_{24} ($M_2L_3I_4$)	0.85	0.86	0.86	1.18	1.18	1.18
SEd ($\pm$)	0.07	0.07	0.07	0.08	0.08	0.07
CD (5%)	0.15	0.14	0.13	0.15	0.15	0.14

***DAP – Days after planting**

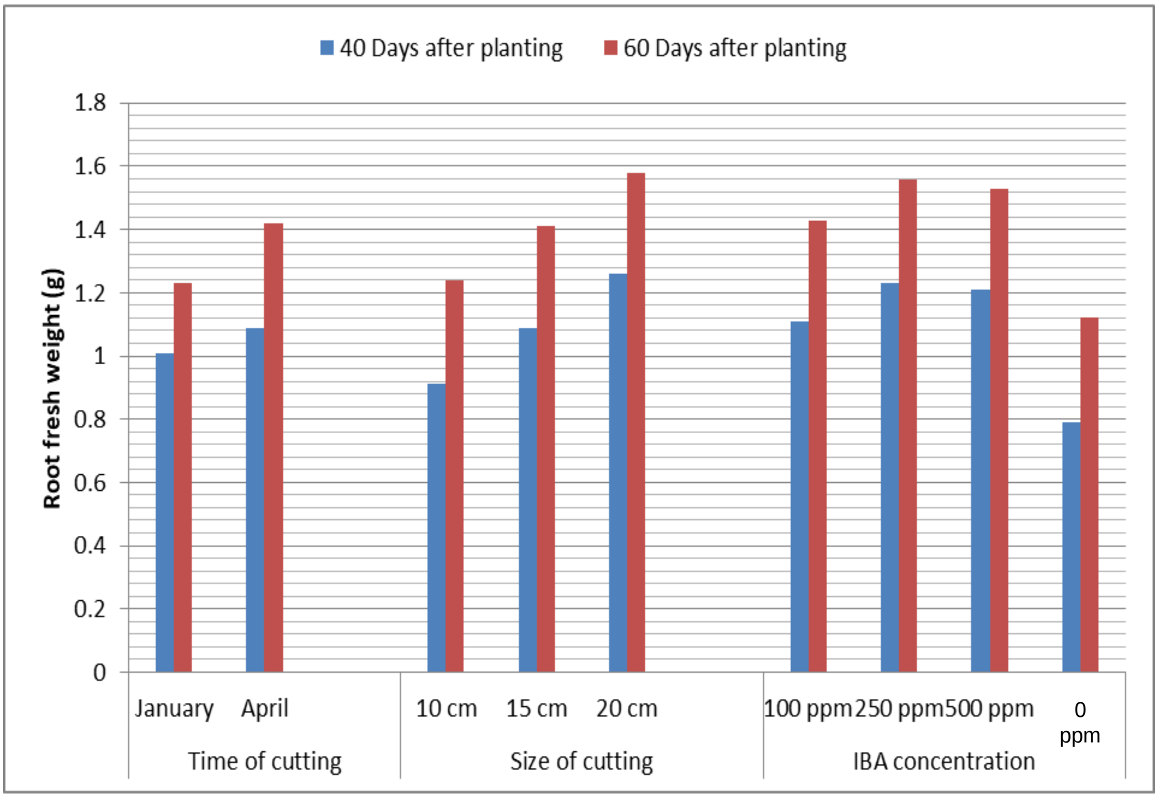


Fig. 4.11 Effect of time and size of cutting and IBA concentration on root fresh weight(g)

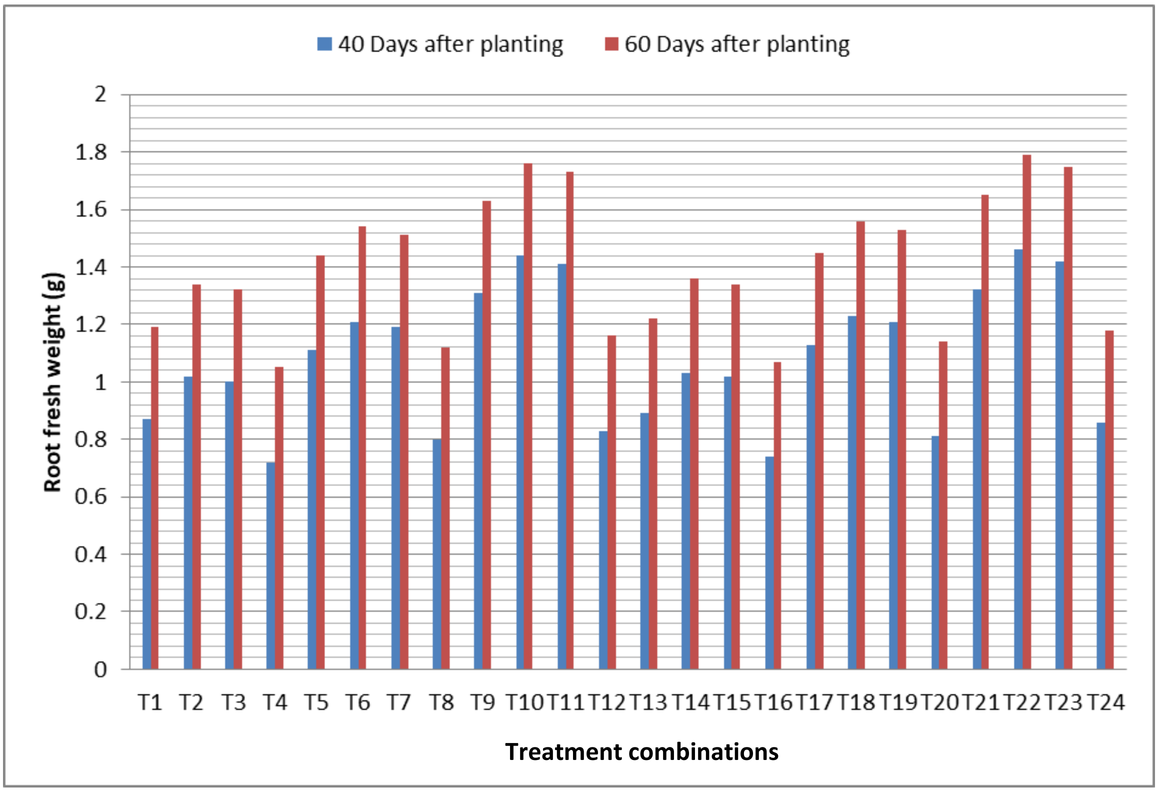


Fig. 4.12 Interaction effect of time and size of cutting and IBA concentration on root fresh weight(g)

4.1.7 Dry weight of roots (g)

Perusal of pooled data depicted in table 4.13 and figure 4.13 revealed that the time and size of cutting and IBA concentration had significant effect on dry weight of roots at both 40 DAP and 60 DAP. The highest root dry weight (0.40 g at 40 DAP; 0.62 g at 60 DAP) was obtained in the cuttings taken in April. The 20 cm size of cuttings recorded highest root dry weight (0.42 g at 40 DAP; 0.63 g at 60 DAP) whereas lowest root dry weight (0.32 g at 40 DAP; 0.53 g at 60 DAP) was obtained in the cuttings of 10 cm size. The 250 ppm IBA concentration recorded the highest root dry weight (0.41 g at 40 DAP; 0.63 g at 60 DAP) whereas the non treated cuttings recorded the lowest root dry weight (0.29 g at 40 DAP; 0.51 g at 60 DAP). The pooled analysis data exhibited that 500 ppm and 250 ppm IBA concentration had no significant differences in dry weight of roots.

The interaction effects of time and size of cuttings and IBA concentrations were found significant on root dry weight during both the years (Table 4.14, Fig. 4.14). The highest root dry weight (0.50 g at 40 DAP ; 0.71 g at 60 DAP) was obtained in T_{22} whereas lowest root dry weight (0.24 g at 40 DAP ; 0.45 g at 60 DAP) was recorded in T_4. However, no significant differences were observed among the treatment combinations *viz*., T_{23}, T_{21} and T_{11} and T_{22}.

Table 4.13 Effect of time and size of cutting and IBA concentration on root dry weight (g)

Treatment	Root dry weight (g)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	0.35	0.36	0.36	0.58	0.57	0.58
M_2 - April	0.39	0.40	0.40	0.62	0.61	0.62
SEd (±)	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.02	0.02	0.02	0.02	0.02
Size of cutting						
L_1 - 10 cm	0.3	0.33	0.32	0.53	0.52	0.53
L_2 - 15 cm	0.36	0.38	0.37	0.58	0.59	0.59
L_3 - 20 cm	0.41	0.43	0.42	0.63	0.63	0.63
SEd (±)	0.01	0.01	0.02	0.02	0.01	0.02
CD (5%)	0.03	0.03	0.03	0.03	0.03	0.03
IBA concentration						
I_1 - 100 ppm	0.35	0.37	0.36	0.58	0.57	0.58
I_2 - 250 ppm	0.40	0.42	0.41	0.63	0.62	0.63
I_3 - 500 ppm	0.40	0.39	0.40	0.62	0.62	0.62
I_4 - 0 ppm	0.28	0.29	0.29	0.51	0.50	0.51
SEd (±)	0.02	0.02	0.02	0.02	0.02	0.02
CD (5%)	0.03	0.03	0.03	0.04	0.03	0.04

***DAP – Days after planting**

Table 4.14 Interaction effect of time and size of cutting and IBA concentration on root dry weight (g)

Treatment Combination	Root dry weight (g)					
	40 DAP			60 DAP		
	2020	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
T_1 ($M_1L_1I_1$)	0.25	0.27	0.26	0.47	0.49	0.48
T_2 ($M_1L_1I_2$)	0.32	0.34	0.33	0.53	0.55	0.54
T_3 ($M_1L_1I_3$)	0.37	0.39	0.38	0.58	0.6	0.59
T_4 ($M_1L_1I_4$)	0.23	0.25	0.24	0.46	0.44	0.45
T_5 ($M_1L_2I_1$)	0.37	0.38	0.38	0.59	0.61	0.6
T_6 ($M_1L_2I_2$)	0.39	0.41	0.40	0.61	0.63	0.62
T_7 ($M_1L_2I_3$)	0.37	0.38	0.38	0.6	0.62	0.61
T_8 ($M_1L_2I_4$)	0.28	0.29	0.29	0.51	0.53	0.52
T_9 ($M_1L_3I_1$)	0.40	0.42	0.42	0.61	0.63	0.62
T_{10} ($M_1L_3I_2$)	0.47	0.49	0.48	0.69	0.71	0.7
T_{11} ($M_1L_3I_3$)	0.42	0.41	0.42	0.64	0.66	0.65
T_{12} ($M_1L_3I_4$)	0.31	0.30	0.31	0.55	0.53	0.54
T_{13} ($M_2L_1I_1$)	0.27	0.26	0.27	0.51	0.49	0.5
T_{14} ($M_2L_1I_2$)	0.33	0.34	0.34	0.57	0.55	0.56
T_{15} ($M_2L_1I_3$)	0.38	0.40	0.39	0.62	0.6	0.61
T_{16} ($M_2L_1I_4$)	0.24	0.26	0.25	0.48	0.46	0.47
T_{17} ($M_2L_2I_1$)	0.39	0.41	0.40	0.63	0.61	0.62
T_{18} ($M_2L_2I_2$)	0.41	0.43	0.42	0.62	0.64	0.63
T_{19} ($M_2L_2I_3$)	0.39	0.41	0.40	0.63	0.61	0.62
T_{20} ($M_2L_2I_4$)	0.3	0.28	0.29	0.51	0.53	0.52
T_{21} ($M_2L_3I_1$)	0.41	0.39	0.40	0.64	0.63	0.64
T_{22} ($M_2L_3I_2$)	0.49	0.51	0.50	0.71	0.70	0.71
T_{23} ($M_2L_3I_3$)	0.44	0.46	0.45	0.65	0.67	0.66
T_{24} ($M_2L_3I_4$)	0.33	0.35	0.34	0.54	0.56	0.55
SEd (±)	0.04	0.04	0.04	0.04	0.04	0.04
CD (5%)	0.08	0.08	0.08	0.09	0.08	0.08

***DAP – Days after planting**

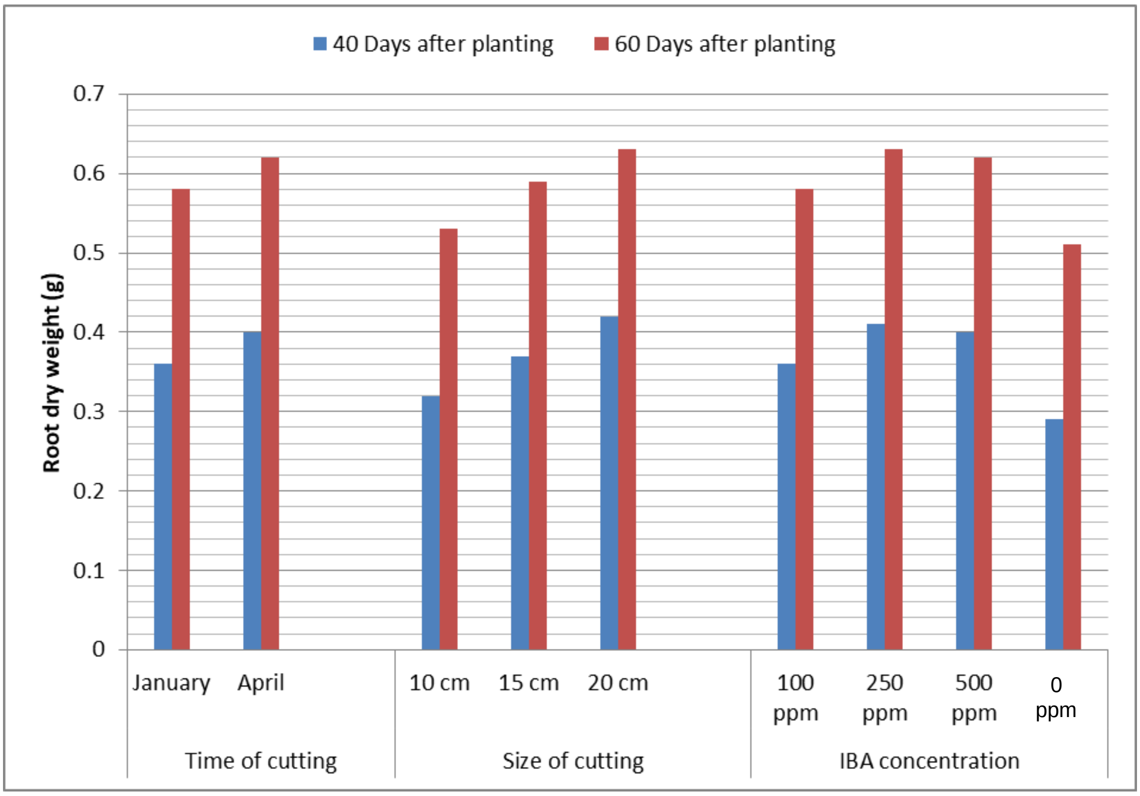


Fig. 4.13 Effect of time and size of cutting and IBA concentration on root dry weight(g)

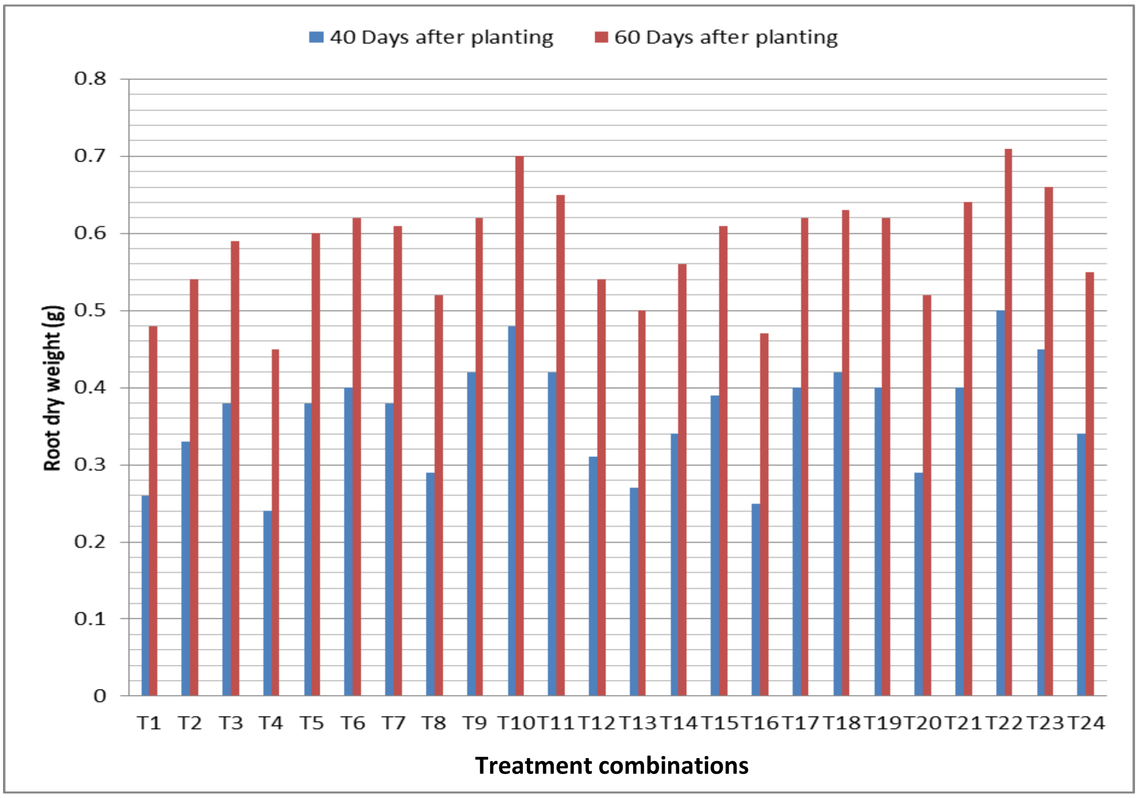


Fig. 4.14 Interaction effect of time and size of cutting and IBA concentration on root dry weight(g)

4.1.8 Rooting percentage

The time and size of cutting and IBA concentration had a significant effect on the rooting percentage at both 40 DAP and 60 DAP (Table 4.15, Fig. 4.15). The highest rooting percentage (82.15 and 97.15 % at 40 DAP and 60 DAP respectively) was obtained in the cuttings taken in April. The rooting percentage was highest (83.75 and 98.75 % at 40 DAP and 60 DAP respectively) in the cuttings of 20 cm size whereas lowest rooting percentage (78.75 and 93.75 % at 40 DAP and 60 DAP respectively) was recorded in the cuttings of 10 cm size. The IBA concentration of 250 ppm led to the highest rooting percentage (85.23 and 99.19 % at 40 DAP and 60 DAP respectively) whereas the control treatment recorded the lowest rooting percentage (77.78 and 92.78 % at 40 DAP and 60 DAP respectively). The pooled analysis data revealed that the effect of 500 ppm IBA concentration is statistically at par with the 250 ppm IBA concentration.

Combined effect of time and size of cuttings and IBA concentrations registered the highest rooting percentage 85 and 100 % at 40 DAP and 60 DAP, respectively in T_{22} which was at par with T_{23}, T_{18}, T_{19}, T_{10} and T_{11} (Table 4.16, Fig. 4.16). Whereas, lowest rooting percentage (72.5 and 87.5 % at 40 DAP and 60 DAP respectively) was obtained in T_4.

Table 4.15 Effect of time and size of cutting and IBA concentration on rooting percentage

Treatment	**Rooting percentage**					
	40 DAP			**60 DAP**		
	2020	**2021**	**Pooled**	**2020**	**2021**	**Pooled**
Time of cutting						
M_1 - January	80.08	80.1	80.09	95.08	95.06	95.07
M_2 - April	81.67	82.64	82.15	96.67	97.64	97.15
SEd (±)	1.02	1.02	1.02	1.02	1.02	1.02
CD (5%)	2.05	2.05	2.05	2.05	2.05	2.05
Size of cutting						
L_1 - 10 cm	77.92	79.58	78.75	92.92	94.58	93.75
L_2 - 15 cm	81.67	82.29	81.98	96.67	97.29	96.98
L_3 - 20 cm	83.33	84.17	83.75	98.33	99.17	98.75
SEd (±)	1.25	1.25	1.25	1.25	1.25	1.25
CD (5%)	2.52	2.52	2.52	2.52	2.52	2.52
IBA concentration						
I_1 - 100 ppm	79.17	80.56	79.87	94.17	95.56	94.87
I_2 - 250 ppm	85.22	85.24	85.23	98.18	99.20	99.19
I_3 - 500 ppm	83.89	84.44	84.17	98.16	99.18	99.17
I_4 - 0 ppm	76.94	78.61	77.78	91.94	93.61	92.78
SEd (±)	1.44	1.44	1.44	1.44	1.44	1.44
CD (5%)	2.91	2.91	2.91	2.91	2.91	2.91

***DAP – Days after planting**

Table 4.16 Interaction effect of time and size of cutting and IBA concentration on rooting percentage

Treatment Combination	Rooting percentage					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	73.33	75	74.17	88.33	90	89.17
T_2 ($M_1L_1I_2$)	83.49	83.51	83.5	96.51	96.49	96.5
T_3 ($M_1L_1I_3$)	81.67	83.33	82.5	96.67	98.33	97.5
T_4 ($M_1L_1I_4$)	71.67	73.33	72.5	86.67	88.33	87.5
T_5 ($M_1L_2I_1$)	80	81.67	80.83	95	96.67	95.83
T_6 ($M_1L_2I_2$)	83.33	82.33	83.33	97.33	98.33	98.33
T_7 ($M_1L_2I_3$)	82.33	83.33	83.33	98.33	97.33	98.33
T_8 ($M_1L_2I_4$)	76.67	78.33	77.5	91.67	93.33	92.5
T_9 ($M_1L_3I_1$)	81.67	83.33	82.5	96.67	98.33	97.5
T_{10} ($M_1L_3I_2$)	85	84	85	100	100	100
T_{11} ($M_1L_3I_3$)	84	85	85	100	100	100
T_{12} ($M_1L_3I_4$)	80	81.67	80.83	95	96.67	95.83
T_{13} ($M_2L_1I_1$)	75	76.67	75.83	90	91.67	90.83
T_{14} ($M_2L_1I_2$)	83.33	85	84.17	98.33	100	99.17
T_{15} ($M_2L_1I_3$)	83.33	85	84.17	100	98.33	99.17
T_{16} ($M_2L_1I_4$)	73.33	75	74.17	88.33	90	89.17
T_{17} ($M_2L_2I_1$)	81.67	81.67	81.67	96.67	96.67	96.67
T_{18} ($M_2L_2I_2$)	85	85	85	100	100	100
T_{19} ($M_2L_2I_3$)	85	85	85	100	100	100
T_{20} ($M_2L_2I_4$)	78.33	80	79.17	93.33	95	94.17
T_{21} ($M_2L_3I_1$)	83.33	85	84.17	98.33	100	99.17
T_{22} ($M_2L_3I_2$)	85	85	85	100	100	100
T_{23} ($M_2L_3I_3$)	85	85	85	100	100	100
T_{24} ($M_2L_3I_4$)	81.67	83.33	82.5	96.67	98.33	97.5
SEd (±)	3.54	3.54	3.54	3.54	3.54	3.54
CD (5%)	7.12	7.12	7.12	7.12	7.12	7.12

***DAP – Days after planting**

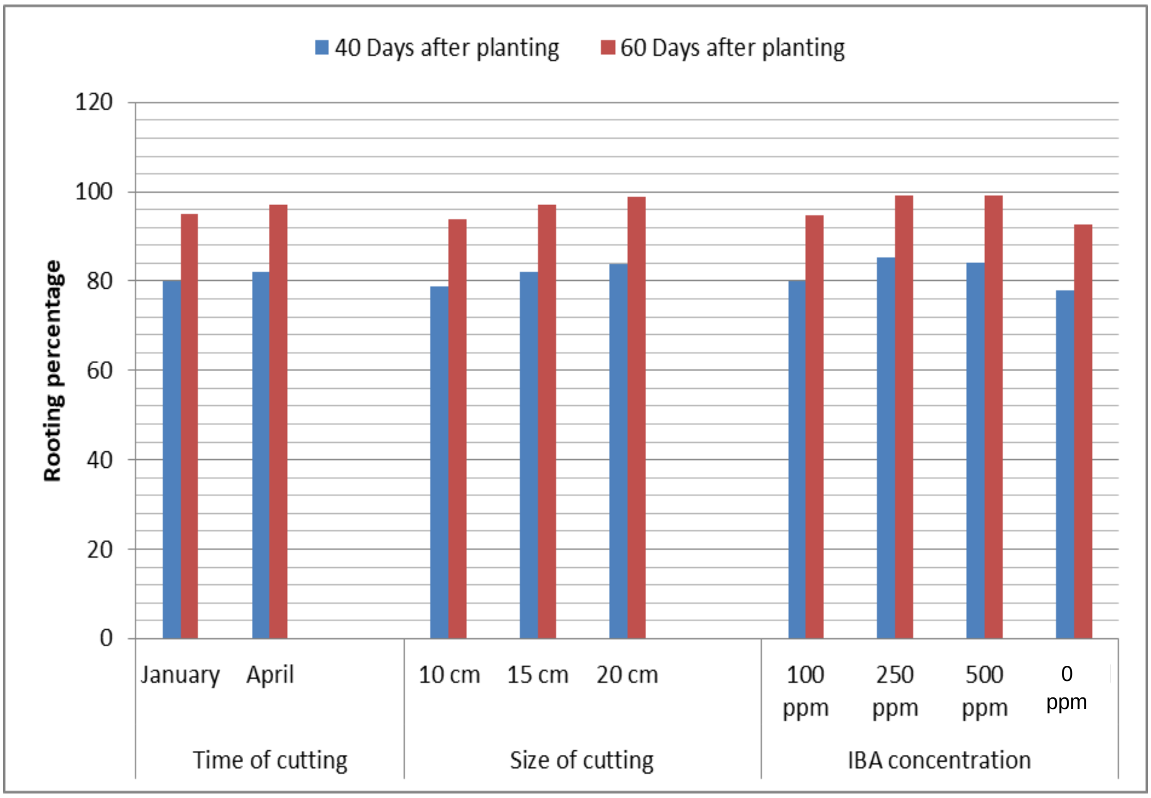


Fig. 4.15 Effect of time and size of cutting and IBA concentration on rooting percentage

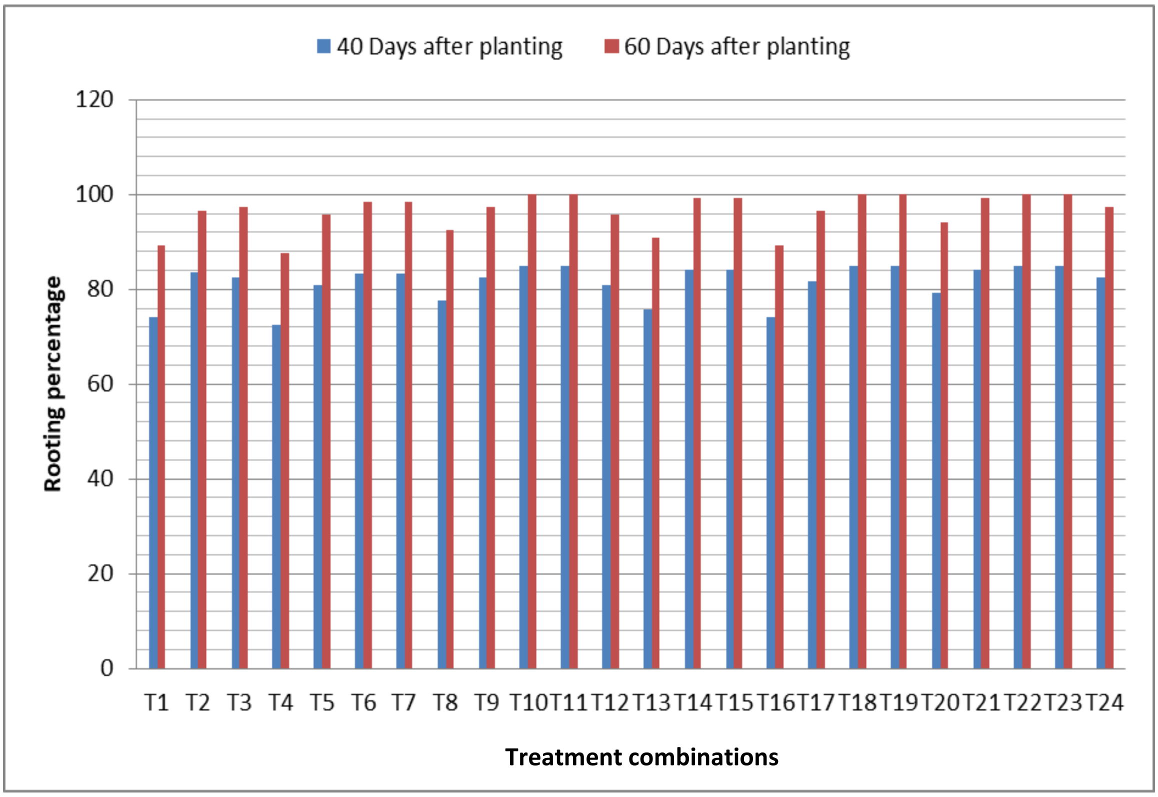


Fig. 4.16 Interaction effect of time and size of cutting and IBA concentration on rooting percentage

4.2 Shoot parameters

4.2.1 Days required for shoot initiation

Perusal of pooled data presented in Table 4.17 and Fig. 4.17 revealed that there was significant effect of time and size of cutting and IBA concentration on days required for shoot initiation. The shoot initiation was early (33.44 days) in the cuttings taken in April. The 20 cm size of cuttings recorded least days (29.58 days) for shoot initiation whereas the cuttings of 10 cm size delayed shoot initiation (38.92 days). The pooled analysis data revealed that the 250 ppm treated cuttings recorded early (29.44 days) shoot initiation whereas the shoot initiation was delayed (41.78 days) in the non-treated cuttings. Moreover, there was no significant variation between the effects of 500 ppm and 250 ppm IBA treatments.

The data pertaining to the interaction effect of time and size of cutting and IBA concentration on the root dry weight as presented in Table 4.18 and Fig. 4.18 revealed that there was significant interaction effect of the different treatment combinations at both 40 DAP and 60 DAP. T_{22} recorded least days (22.33 days) for shoot initiation which was statistically at par with T_{23} whereas T_4 delayed (44 days) shoot initiation. T_{23} was statistically at par with T_{22}.

Table 4.17 Effect of time and size of cutting and IBA concentration on days required for shoot initiation

Treatment	Days required for shoot initiation		
	2020	**2021**	**Pooled**
Time of cutting			
M_1 - January	35.44	34.11	34.78
M_2 - April	34.11	32.78	33.44
SEd ($\pm$)	0.35	0.35	0.43
CD (5%)	0.7	0.71	0.71
Size of cutting			
L_1 - 10 cm	39.58	38.25	38.92
L_2 - 15 cm	34.5	33.17	33.83
L_3 - 20 cm	30.25	28.92	29.58
SEd ($\pm$)	0.42	0.43	0.43
CD (5%)	0.86	0.87	0.87
IBA concentration			
I_1 - 100 ppm	35.44	34.11	34.78
I_2 - 250 ppm	30.11	28.78	29.44
I_3 - 500 ppm	31.11	29.78	30.45
I_4 - 0 ppm	42.44	41.11	41.78
SEd ($\pm$)	0.49	0.5	0.5
CD (5%)	0.99	1.01	1

Table 4.18 Interaction effect of time and size of cutting and IBA concentration on days required for shoot initiation

Treatment Combination	Days required for shoot initiation		
	2020	**2021**	**Pooled**
T_1 ($M_1L_1I_1$)	41.67	40.33	41
T_2 ($M_1L_1I_2$)	38.33	37	37.67
T_3 ($M_1L_1I_3$)	36.33	35	35.67
T_4 ($M_1L_1I_4$)	44.67	43.33	44
T_5 ($M_1L_2I_1$)	35.33	34	34.67
T_6 ($M_1L_2I_2$)	29.67	28.33	29
T_7 ($M_1L_2I_3$)	32.33	31	31.67
T_8 ($M_1L_2I_4$)	43.33	42	42.67
T_9 ($M_1L_3I_1$)	31.33	30	30.67
T_{10} ($M_1L_3I_2$)	24.33	23	23.67
T_{11} ($M_1L_3I_3$)	26.67	25.33	26
T_{12} ($M_1L_3I_4$)	41.33	40	40.67
T_{13} ($M_2L_1I_1$)	40.33	39	39.67
T_{14} ($M_2L_1I_2$)	37	35.67	36.33
T_{15} ($M_2L_1I_3$)	35	33.67	34.33
T_{16} ($M_2L_1I_4$)	43.33	42	42.67
T_{17} ($M_2L_2I_1$)	34	32.67	33.33
T_{18} ($M_2L_2I_2$)	28.33	27	27.67
T_{19} ($M_2L_2I_3$)	31	29.67	30.33
T_{20} ($M_2L_2I_4$)	42	40.67	41.33
T_{21} ($M_2L_3I_1$)	30	28.67	29.33
T_{22} ($M_2L_3I_2$)	23	21.67	22.33
T_{23} ($M_2L_3I_3$)	25.33	24	24.67
T_{24} ($M_2L_3I_4$)	40	38.67	39.33
SEd (±)	1.2	1.22	1.21
CD (5%)	2.42	2.47	2.45

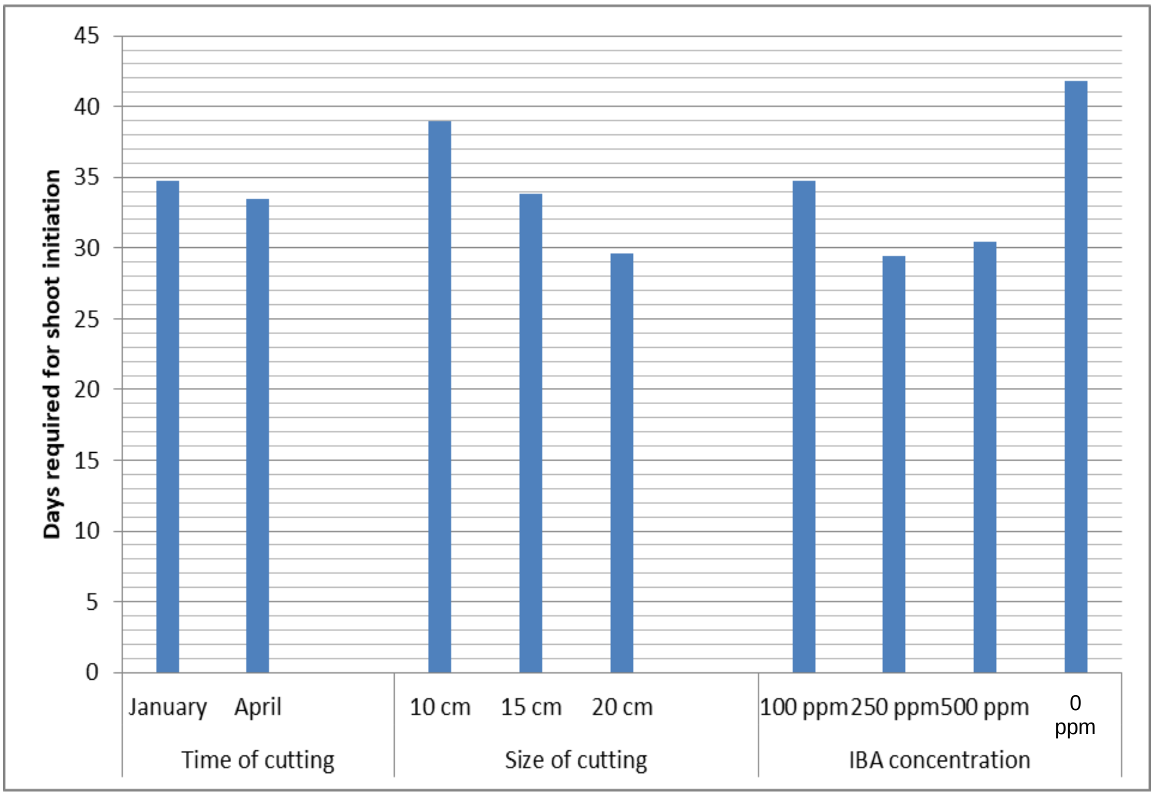


Fig. 4.17 Effect of time and size of cutting and IBA concentration on days required for shoot initiation

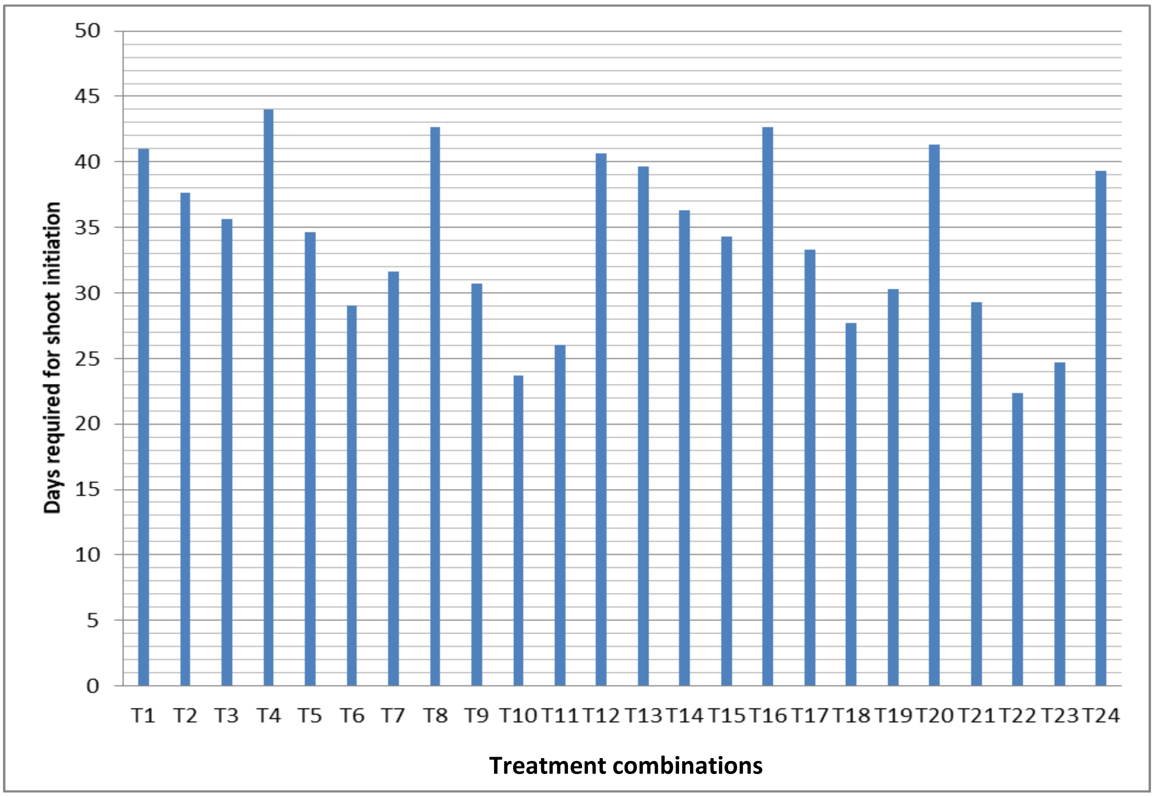


Fig. 4.18 Interaction effect of time and size of cutting and IBA concentration on days required for shoot initiation

4.2.2 Number of shoots

The time and size of cutting and IBA concentration had significant effect on the number of shoots at both 40 DAP and 60 DAP (Table 4.19, Fig. 4.19). The highest number of shoots (3.32 and 4.66 at 40 DAP and 60 DAP, respectively) was recorded in the cuttings taken in April. The 20 cm size of cuttings recorded highest number of shoots (3.1 and 4.43 at 40 DAP and 60 DAP respectively) whereas the 10 cm size of cuttings recorded lowest (1.97 and 2.71 at 40 DAP and 60 DAP respectively) number of shoots. The pooled analysis data revealed that the effect of 15 cm size of cutting was statistically at par with the 20 cm size of cutting. The IBA concentration of 250 ppm recorded highest numbers of shoots (3.18 and 5.01 at 40 DAP and 60 DAP respectively) whereas the control treatment recorded lowest numbers of shoots (1.78 and 2.54 at 40 DAP and 60 DAP respectively). Moreover, there was no significant difference in shoot number between the 250 ppm and 500 ppm IBA treated cuttings.

The interaction among time and size of cuttings and IBA concentrations was significant on shoot number in both the years of experimentation and in pooled analysis (Table 4.20 and Fig. 4.20). Combination of 20 cm size cuttings treated with 250 ppm IBA planted in April (T_{22}) recorded the highest shoot number (4.4 and 5.73 at 40 DAP and 60 DAP respectively). Whereas, T_4 recorded lowest shoot numbers (0.87 and 1.2 at 40 DAP and 60 DAP respectively). The pooled analysis data revealed that the effects of treatment combinations *viz*., T_{23}, T_{21}, T_{19}, T_{18}, T_{17}, T_{15}, T_{14}, T_{10} and T_6 were statistically at par with T_{22}.

Table 4.19 Effect of time and size of cutting and IBA concentration on number of shoots

Treatment	Number of shoots					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	1.32	2.66	1.99	2.66	3.99	3.33
M_2 - April	2.66	3.99	3.32	3.99	5.32	4.66
SEd (±)	0.24	0.43	0.43	0.43	0.66	0.58
CD (5%)	0.48	0.87	0.86	0.87	1.32	1.15
Size of cutting						
L_1 - 10 cm	1.3	2.63	1.97	2.72	2.7	2.71
L_2 - 15 cm	2.23	3.57	2.9	3.57	4.9	4.23
L_3 - 20 cm	2.43	3.77	3.1	3.77	5.1	4.43
SEd (±)	0.29	0.53	0.43	0.53	0.81	0.71
CD (5%)	0.58	1.07	1.05	1.07	1.62	1.42
IBA concentration						
I_1 - 100 ppm	1.91	3.24	2.58	3.24	4.58	3.91
I_2 - 250 ppm	2.51	3.84	3.18	4.84	5.18	5.01
I_3 - 500 ppm	2.2	3.53	2.87	3.53	4.87	4.2
I_4 - 0 ppm	1.77	1.79	1.78	2.53	2.55	2.54
SEd (±)	0.34	0.61	0.51	0.61	0.93	0.82
CD (5%)	0.67	1.24	1.21	1.24	1.86	1.64

***DAP – Days after planting**

Table 4.20 Interaction effect of time and size of cutting and IBA concentration on number of shoots

Treatment Combination	Number of shoots					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	0.53	1.87	1.2	1.87	1.2	1.56
T_2 ($M_1L_1I_2$)	1	2.33	1.67	2.33	3.67	3
T_3 ($M_1L_1I_3$)	0.8	2.13	1.47	2.13	3.47	2.8
T_4 ($M_1L_1I_4$)	0.2	1.53	0.87	0.53	1.87	1.2
T_5 ($M_1L_2I_1$)	1.47	2.8	2.13	2.8	4.13	3.47
T_6 ($M_1L_2I_2$)	2.13	3.47	2.8	3.47	4.8	4.13
T_7 ($M_1L_2I_3$)	1.87	3.2	2.53	3.2	4.53	3.87
T_8 ($M_1L_2I_4$)	1.06	1.08	1.07	1.27	1.29	1.28
T_9 ($M_1L_3I_1$)	1.73	3.07	2.4	3.07	4.4	3.73
T_{10} ($M_1L_3I_2$)	2.4	3.73	3.07	3.73	5.07	4.4
T_{11} ($M_1L_3I_3$)	1.93	3.27	2.6	3.27	4.6	3.93
T_{12} ($M_1L_3I_4$)	1.16	1.18	1.17	1.3	1.32	1.31
T_{13} ($M_2L_1I_1$)	1.87	3.2	2.53	3.2	4.53	3.87
T_{14} ($M_2L_1I_2$)	2.33	3.67	3	3.67	5	4.33
T_{15} ($M_2L_1I_3$)	2.13	3.47	2.8	3.47	4.8	4.13
T_{16} ($M_2L_1I_4$)	0.53	1.87	1.2	1.52	1.54	1.53
T_{17} ($M_2L_2I_1$)	2.8	4.13	3.47	4.13	5.47	4.8
T_{18} ($M_2L_2I_2$)	3.47	4.8	4.13	4.8	6.13	5.47
T_{19} ($M_2L_2I_3$)	3.2	4.53	3.87	4.53	5.87	5.2
T_{20} ($M_2L_2I_4$)	1.13	1.11	1.12	1.32	1.34	1.33
T_{21} ($M_2L_3I_1$)	3.07	4.4	3.73	4.4	5.73	5.07
T_{22} ($M_2L_3I_2$)	3.73	5.07	4.4	5.07	6.4	5.73
T_{23} ($M_2L_3I_3$)	3.27	4.6	3.93	4.6	5.93	5.27
T_{24} ($M_2L_3I_4$)	1.33	1.3	1.31	1.42	1.44	1.43
SEd (±)	0.82	0.84	0.83	0.83	0.85	0.84
CD (5%)	1.64	1.68	1.66	1.66	1.7	1.68

***DAP – Days after planting**

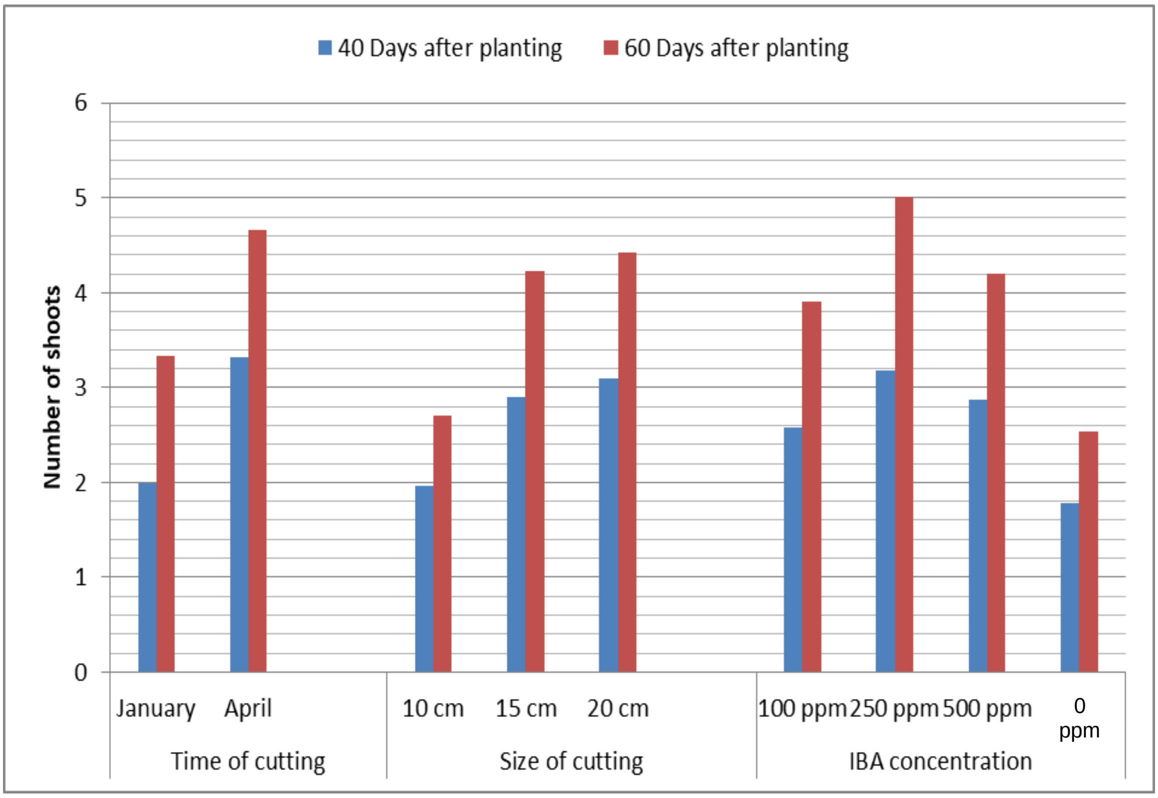


Fig. 4.19 Effect of time and size of cutting and IBA concentration on number of shoots

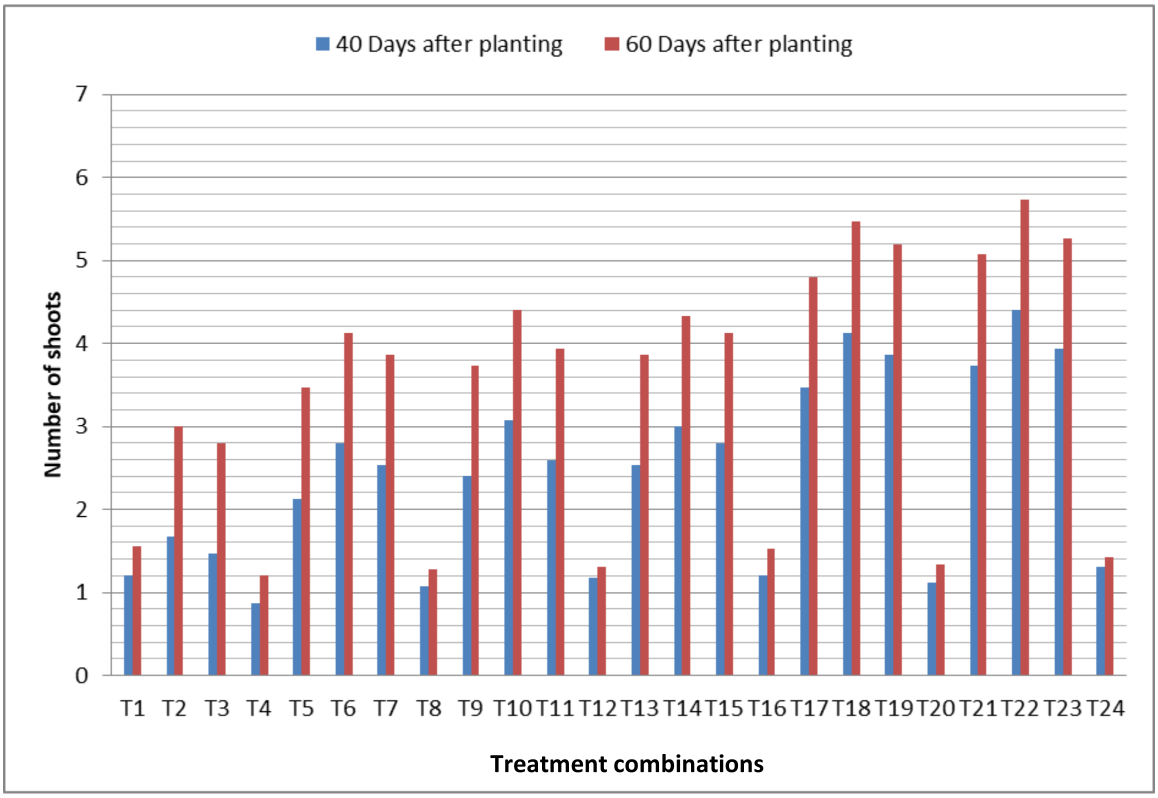


Fig. 4.20 Interaction effect of time and size of cutting and IBA concentration on number of shoots

4.2.3 Length of primary shoots (cm)

There was significant effect of time and size of cutting and IBA concentration on the length of the primary shoots (Table 4.21, Fig. 4.21). The longest of primary shoots (13.29 and 14.63 cm at 40 DAP and 60 DAP respectively) was recorded in the cuttings taken in April. The 20 cm size of cuttings recorded highest length (16.73and 18.06 cm at 40 DAP and 60 DAP respectively) of primary shoots whereas the 10 cm size of cutting recorded lowest length of primary shoots (9.68 and 11.01 cm at 40 DAP and 60 DAP respectively). The IBA concentration of 250 ppm recorded highest length (14.97 and 16.3 cm at 40 DAP and 60 DAP respectively) of primary shoots whereas the control treatment recorded lowest length (8.57 and 9.9 cm at 40 DAP and 60 DAP) of primary shoots. The pooled analysis data revealed that the effect of 500 ppm IBA concentration was statistically at par with the 250 ppm IBA concentration.

The treatment combinations imparted a significant interaction effect on the length of the primary shoots (Table 4.22, Fig. 4.22). T_{22} recorded highest length (21.37 and 22.7 cm at 40 DAP and 60 DAP respectively) of primary shoots whereas T_4 recorded the shortest primary shoots (7.2 and 8.53 cm at 40 DAP and 60 DAP, respectively). The pooled analysis data revealed that the effects of treatment combinations *viz*., T_{23}, T_{21}, T_{11} and T_{10} were statistically at par with T_{22}.

Table 4.21 Effect of time and size of cutting and IBA concentration on length of the primary shoots (cm)

Treatment	Length of the primary shoots (cm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	11.13	12.79	11.96	12.46	14.13	13.3
M_2 - April	12.46	14.13	13.29	13.79	15.46	14.63
SEd (±)	0.31	0.4	0.39	0.46	0.58	0.56
CD (5%)	0.63	0.81	0.78	0.93	1.16	1.08
Size of cutting						
L_1 - 10 cm	8.84	10.51	9.68	10.18	11.84	11.01
L_2 - 15 cm	10.64	12.31	11.48	11.98	13.64	12.81
L_3 - 20 cm	15.89	17.56	16.73	17.23	18.89	18.06
SEd (±)	0.38	0.49	0.46	0.56	0.71	0.63
CD (5%)	0.77	0.99	0.92	1.14	1.42	1.35
IBA concentration						
I_1 - 100 ppm	12.09	13.76	12.93	13.42	15.09	14.26
I_2 - 250 ppm	14.13	15.8	14.97	15.47	17.13	16.3
I_3 - 500 ppm	13.21	14.88	14.04	14.54	16.21	15.38
I_4 - 0 ppm	7.73	9.4	8.57	9.07	10.73	9.9
SEd (±)	0.44	0.57	0.53	0.65	0.81	0.74
CD (5%)	0.89	1.15	1.08	1.31	1.64	1.47

***DAP – Days after planting**

Table 4.22 Interaction effect of time and size of cutting and IBA concentration on length of the primary shoots (cm)

Treatment Combination	Length of the primary shoots (cm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	8.33	10	9.17	9.67	11.33	10.5
T_2 ($M_1L_1I_2$)	9.2	10.87	10.03	10.53	12.2	11.37
T_3 ($M_1L_1I_3$)	8.8	10.47	9.63	10.13	11.8	10.97
T_4 ($M_1L_1I_4$)	6.37	8.03	7.2	7.7	9.37	8.53
T_5 ($M_1L_2I_1$)	9.67	11.33	10.5	11	12.67	11.83
T_6 ($M_1L_2I_2$)	12	13.67	12.83	13.33	15	14.17
T_7 ($M_1L_2I_3$)	11.3	12.97	12.13	12.63	14.3	13.47
T_8 ($M_1L_2I_4$)	6.93	8.6	7.77	8.27	9.93	9.1
T_9 ($M_1L_3I_1$)	16.27	17.93	17.1	17.6	19.27	18.43
T_{10} ($M_1L_3I_2$)	19.2	20.87	20.03	20.53	22.2	21.37
T_{11} ($M_1L_3I_3$)	17.53	19.2	18.37	18.87	20.53	19.7
T_{12} ($M_1L_3I_4$)	7.9	9.57	8.73	9.23	10.9	10.07
T_{13} ($M_2L_1I_1$)	9.67	11.33	10.5	11	12.67	11.83
T_{14} ($M_2L_1I_2$)	10.53	12.2	11.37	11.87	13.53	12.7
T_{15} ($M_2L_1I_3$)	10.13	11.8	10.97	11.47	13.13	12.3
T_{16} ($M_2L_1I_4$)	7.7	9.37	8.53	9.03	10.7	9.87
T_{17} ($M_2L_2I_1$)	11	12.67	11.83	12.33	14	13.17
T_{18} ($M_2L_2I_2$)	13.33	15	14.17	14.67	16.33	15.5
T_{19} ($M_2L_2I_3$)	12.63	14.3	13.47	13.97	15.63	14.8
T_{20} ($M_2L_2I_4$)	8.27	9.93	9.1	9.6	11.27	10.43
T_{21} ($M_2L_3I_1$)	17.6	19.27	18.43	18.93	20.6	19.77
T_{22} ($M_2L_3I_2$)	20.53	22.2	21.37	21.87	23.53	22.7
T_{23} ($M_2L_3I_3$)	18.87	20.53	19.7	20.2	21.87	21.03
T_{24} ($M_2L_3I_4$)	9.23	10.9	10.07	10.57	12.23	11.4
SEd (±)	1.09	1.4	1.25	1.6	1.99	1.8
CD (5%)	2.19	2.81	2.5	3.21	4.02	3.6

***DAP – Days after planting**

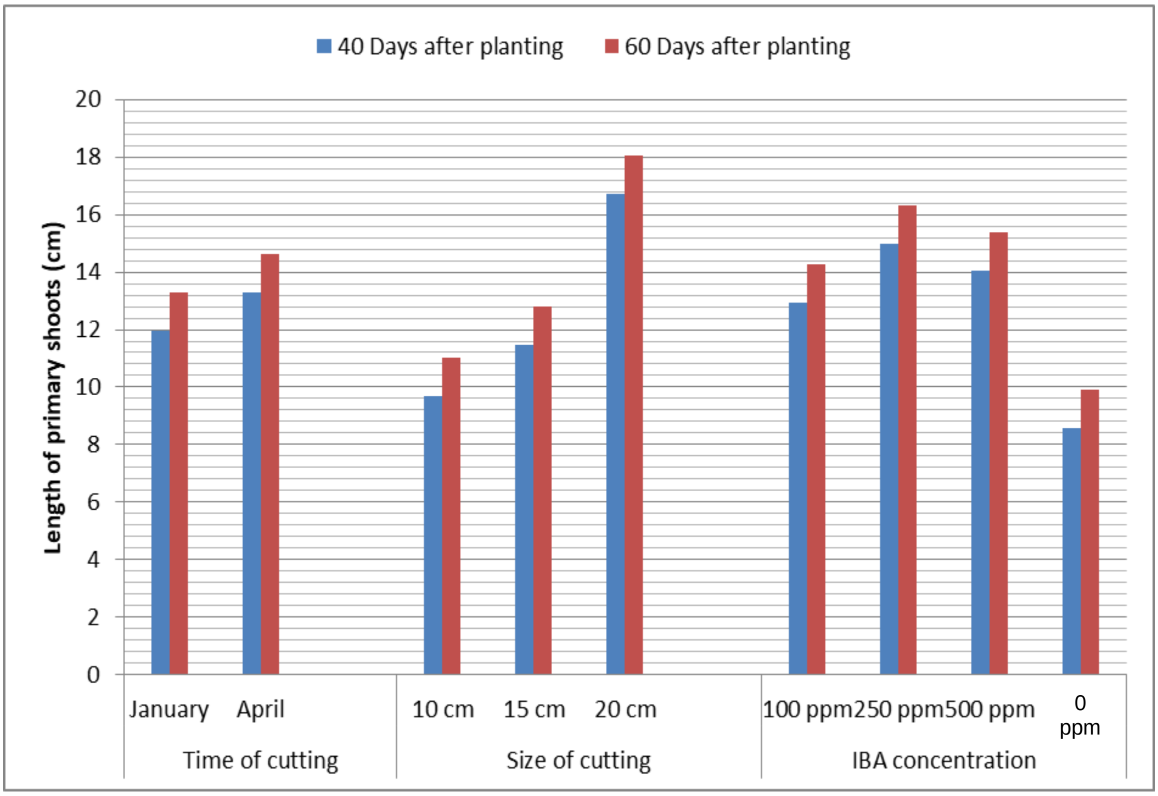


Fig. 4.21 Effect of time and size of cutting and IBA concentration on length of the primary shoots(cm)

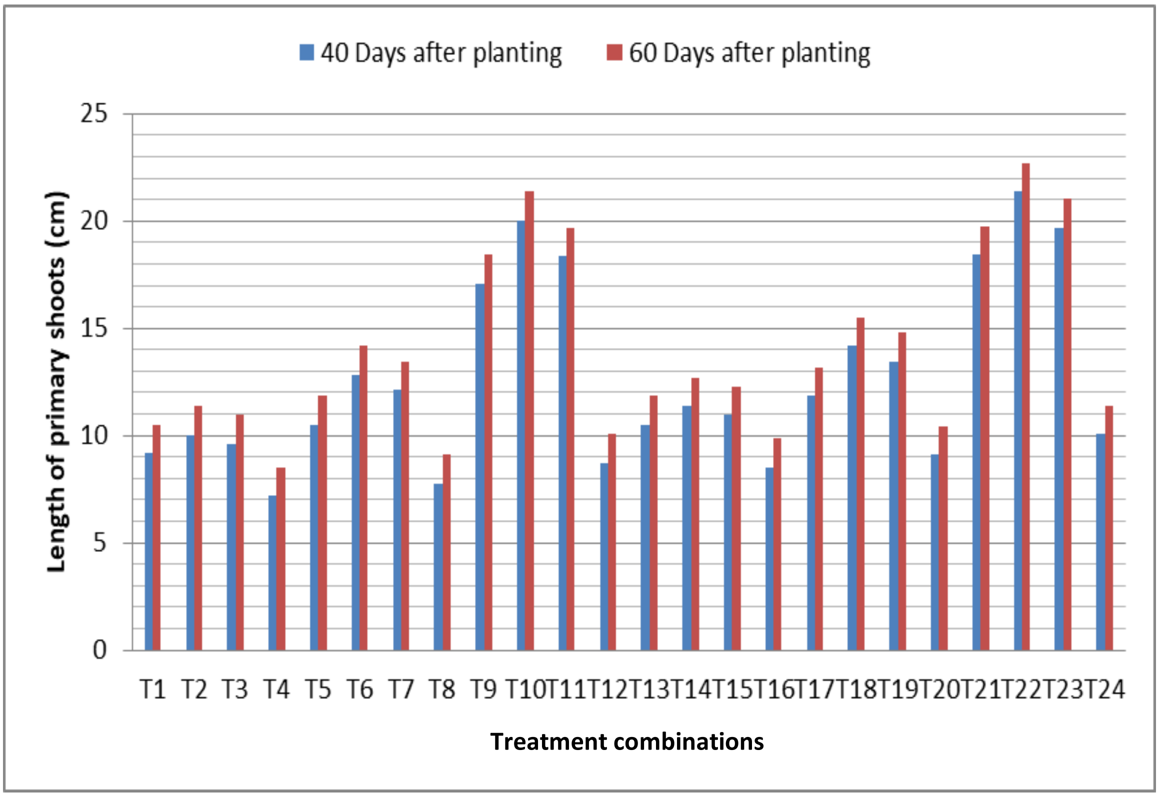


Fig. 4.22 Interaction effect of time and size of cutting and IBA concentration on length of the primary shoots(cm)

4.2.4 Length of secondary shoots (cm)

The length of the secondary shoots varied significantly with the time and size of cutting and IBA concentration at both 40 DAP and 60 DAP (Table 4.23, Fig. 4.23). The highest length (8.36 and 9.7 cm at 40 DAP and 60 DAP, respectively) of secondary shoots was recorded in the cuttings taken in April. The pooled analysis data revealed that 20 cm size of cuttings recorded highest length (9.18 and 10.52 cm at 40 DAP and 60 DAP, respectively) of secondary shoots whereas the 10 cm size of cutting recorded the lowest length (6.16 and 7.49 cm at 40 DAP and 60 DAP, respectively) of secondary shoots. The 250 ppm IBA treated cuttings recorded highest length (8.69 and 10.02 cm at 40 DAP and 60 DAP respectively) of secondary shoots whereas the non-treated cuttings recorded lowest length (5.29 and 6.62 cm at 40 DAP and 60 DAP respectively) of secondary shoots. Moreover, the 500 ppm and 100 ppm IBA treatments were found similar with the 250 ppm IBA treatment.

The interaction effect among time and size of cuttings and IBA concentrations was significant recording the highest secondary shoot length (11.33 and 12.67 cm at 40 DAP and 60 DAP, respectively) in T_{22} whereas T_4 recorded lowest length of secondary shoots (3.87 and 5.2 cm at 40 DAP and 60 DAP, respectively). However, interaction effects of the treatment combinations *viz.*, T_{23}, T_{21}, T_{11} and T_{10} treatments were statistically at par with T_{22}.

Table 4.23 Effect of time and size of cutting and IBA concentration on length of the secondary shoots (cm)

Treatment	Length of the secondary shoots (cm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	6.2	7.86	7.03	7.53	9.2	8.36
M_2 - April	7.53	9.2	8.36	8.86	10.53	9.7
SEd (±)	0.22	0.36	0.26	0.26	0.55	0.54
CD (5%)	0.45	0.73	0.64	0.53	1.12	1.07
Size of cutting						
L_1 - 10 cm	5.33	6.99	6.16	6.66	8.33	7.49
L_2 - 15 cm	6.92	8.58	7.75	8.25	9.92	9.08
L_3 - 20 cm	8.35	10.02	9.18	9.68	11.35	10.52
SEd (±)	0.27	0.45	0.36	0.32	0.68	0.66
CD (5%)	0.55	0.9	0.72	0.65	1.37	1.3
IBA concentration						
I_1 - 100 ppm	6.98	8.64	7.81	8.31	9.98	9.14
I_2 - 250 ppm	7.86	9.52	8.69	9.19	10.86	10.02
I_3 - 500 ppm	8.17	9.83	9	9.5	11.17	10.33
I_4 - 0 ppm	4.46	6.12	5.29	5.79	7.46	6.62
SEd (±)	0.32	0.52	0.45	0.37	0.78	0.76
CD (5%)	0.64	1.04	0.79	0.75	1.58	0.91

***DAP – Days after planting**

Table 4.24 Interaction effect of time and size of cutting and IBA concentration on length of the secondary shoots (cm)

Treatment Combination	Length of the secondary shoots (cm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	4.17	5.83	5	5.5	7.17	6.33
T_2 ($M_1L_1I_2$)	5	6.67	5.83	6.33	8	7.17
T_3 ($M_1L_1I_3$)	6.43	8.1	7.27	7.77	9.43	8.6
T_4 ($M_1L_1I_4$)	3.03	4.7	3.87	4.37	6.03	5.2
T_5 ($M_1L_2I_1$)	6.63	8.3	7.47	7.97	9.63	8.8
T_6 ($M_1L_2I_2$)	7.4	9.07	8.23	8.73	10.4	9.57
T_7 ($M_1L_2I_3$)	7.17	8.83	8	8.5	10.17	9.33
T_8 ($M_1L_2I_4$)	3.8	5.47	4.63	5.13	6.8	5.97
T_9 ($M_1L_3I_1$)	8.13	9.8	8.97	9.47	11.13	10.3
T_{10} ($M_1L_3I_2$)	9.17	10.83	10	10.5	12.17	11.33
T_{11} ($M_1L_3I_3$)	8.9	10.57	9.73	10.23	11.9	11.07
T_{12} ($M_1L_3I_4$)	4.53	6.2	5.37	5.87	7.53	6.7
T_{13} ($M_2L_1I_1$)	5.5	7.17	6.33	6.83	8.5	7.67
T_{14} ($M_2L_1I_2$)	6.33	8	7.17	7.67	9.33	8.5
T_{15} ($M_2L_1I_3$)	7.77	9.43	8.6	9.1	10.77	9.93
T_{16} ($M_2L_1I_4$)	4.37	6.03	5.2	5.7	7.37	6.53
T_{17} ($M_2L_2I_1$)	7.97	9.63	8.8	9.3	10.97	10.13
T_{18} ($M_2L_2I_2$)	8.73	10.4	9.57	10.07	11.73	10.9
T_{19} ($M_2L_2I_3$)	8.5	10.17	9.33	9.83	11.5	10.67
T_{20} ($M_2L_2I_4$)	5.13	6.8	5.97	6.47	8.13	7.3
T_{21} ($M_2L_3I_1$)	9.47	11.13	10.3	10.8	12.47	11.63
T_{22} ($M_2L_3I_2$)	10.5	12.17	11.33	11.83	13.5	12.67
T_{23} ($M_2L_3I_3$)	10.23	11.9	11.07	11.57	13.23	12.4
T_{24} ($M_2L_3I_4$)	5.87	7.53	6.7	7.2	8.87	8.03
SEd (±)	0.77	1.26	1.19	0.92	1.92	1.86
CD (5%)	1.56	2.54	2.16	1.84	3.86	2.69

***DAP – Days after planting**

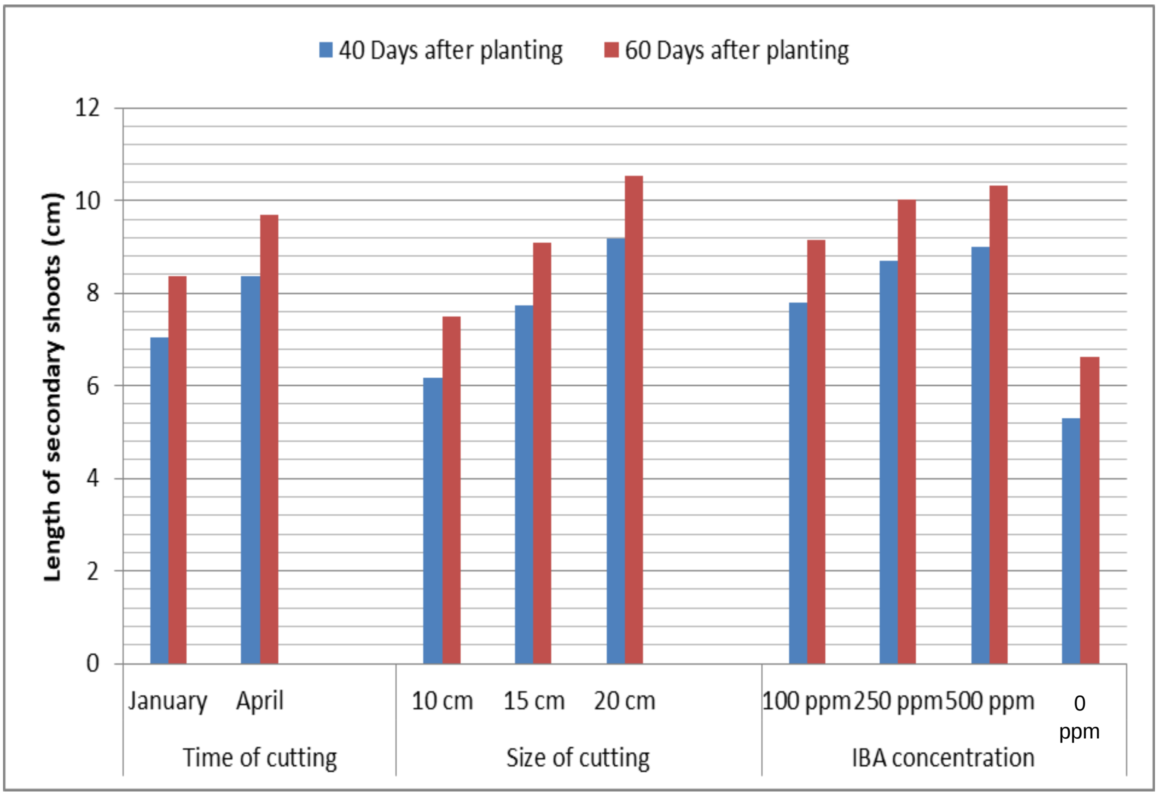


Fig. 4.23 Effect of time and size of cutting and IBA concentration on length of the secondary shoots(cm)

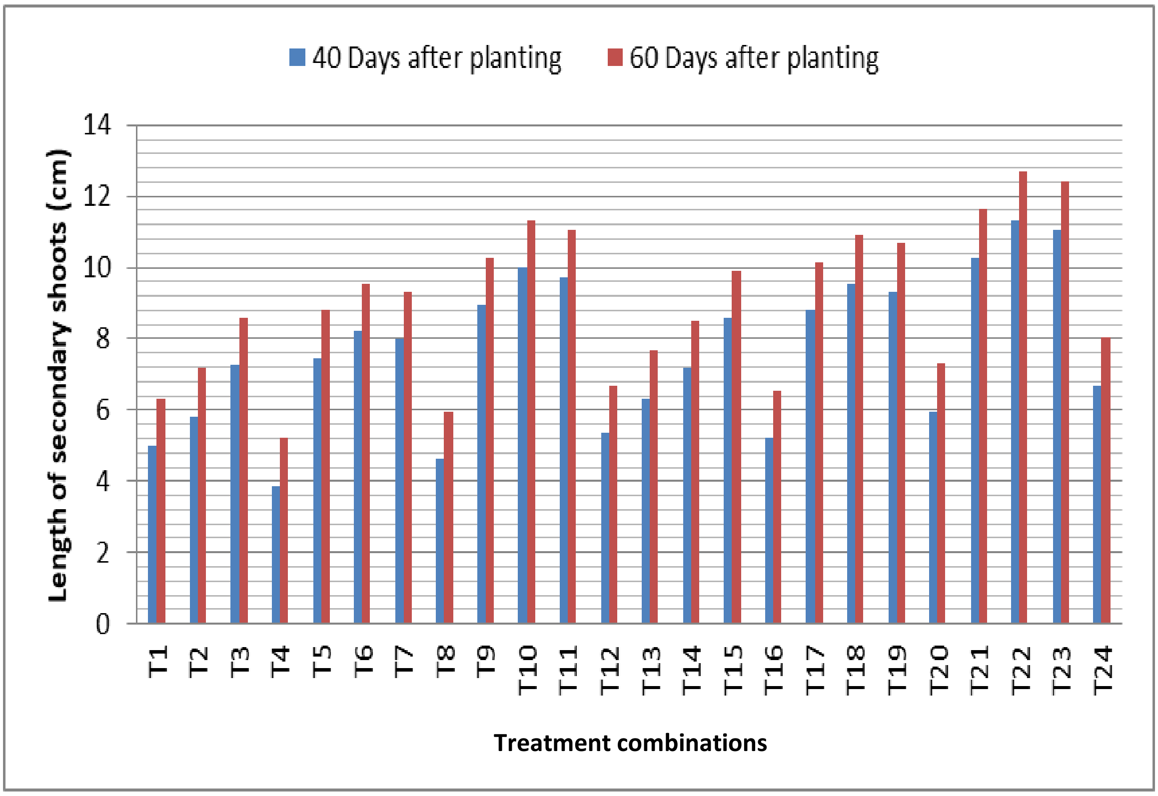


Fig. 4.24 Interaction effect of time and size of cutting and IBA concentration on length of the secondary shoots(cm)

4.2.5 Fresh weight of shoots (g)

The data pertaining to the fresh weight of shoots presented in Table 4. 25 and Fig. 4.25 revealed that there was significant effect of time and size of cutting and IBA concentration at both 40 DAP and 60 DAP. The highest shoot fresh weight (61.44 and 64.27 g at 40 DAP and 60 DAP, respectively) was recorded in the cuttings taken in April. The 20 cm size of cuttings recorded highest shoot fresh weight (71.68 and 74.52 g at 40 DAP and 60 DAP respectively) whereas the 10 cm size of cutting recorded lowest shoot fresh weight (51.52 and 54.35 g at 40 DAP and 60 DAP respectively). The pooled data analysis revealed that IBA concentration of 250 ppm recorded highest (70.02 and 72.86 g at 40 DAP and 60 DAP respectively) shoot fresh weight whereas the control treatment recorded lowest (43.36 and 46.19 g at 40 DAP and 60 DAP respectively) shoot fresh weight.

Combined effects of time and size of cuttings and IBA concentration (Table 4.26, Fig. 4.26) recorded significantly the highest shoot fresh weight (84.07 and 86.9 g at 40 DAP and 60 DAP respectively) whereas T_4 recorded the lowest (39.87 and 42.7 g at 40 DAP and 60 DAP respectively) shoot fresh weight. The interaction effects among T_{23}, T_{21}, T_{11} and T_{10} were statistically at par with T_{22}.

Table 4.25 Effect of time and size of cutting and IBA concentration on shoot fresh weight (g)

Treatment	Shoot fresh weight (g)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	58.71	60.23	59.47	61.02	63.41	62.22
M_2 - April	60.77	62.1	61.44	63.1	65.43	64.27
SEd (±)	0.89	0.88	0.89	0.99	0.93	0.96
CD (5%)	1.8	1.76	1.77	1.99	1.87	1.92
Size of cutting						
L_1 - 10 cm	50.85	52.18	51.52	53.18	55.52	54.35
L_2 - 15 cm	58.43	59.77	59.1	60.77	63.1	61.93
L_3 - 20 cm	71.02	72.35	71.68	73.35	75.68	74.52
SEd (±)	1.09	1.07	1.08	1.21	1.14	1.18
CD (5%)	2.2	2.16	2.18	2.43	2.29	2.33
IBA concentration						
I_1 - 100 ppm	61.78	63.11	62.44	64.11	66.44	65.28
I_2 - 250 ppm	69.36	70.69	70.02	71.69	74.02	72.86
I_3 - 500 ppm	66.58	67.91	67.25	68.91	71.11	70.01
I_4 - 0 ppm	42.69	44.02	43.36	45.02	47.36	46.19
SEd (±)	1.26	1.24	1.25	1.39	1.31	1.37
CD (5%)	2.54	2.49	2.51	2.81	2.64	2.71

***DAP – Days after planting**

Table 4.26 Interaction effect of time and size of cutting and IBA concentration on shoot fresh weight (g)

Treatment Combination	Shoot fresh weight (g)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	48.07	49.4	48.73	50.4	52.73	51.57
T_2 ($M_1L_1I_2$)	58	59.33	58.67	60.33	62.67	61.5
T_3 ($M_1L_1I_3$)	55.47	56.8	56.13	57.8	60.13	58.97
T_4 ($M_1L_1I_4$)	39.2	40.53	39.87	41.53	43.87	42.7
T_5 ($M_1L_2I_1$)	60.33	61.67	61	62.67	65	63.83
T_6 ($M_1L_2I_2$)	66	67.33	66.67	68.33	70.67	69.5
T_7 ($M_1L_2I_3$)	63.07	64.4	63.73	65.4	67.73	66.57
T_8 ($M_1L_2I_4$)	41.67	43	42.33	44	46.33	45.17
T_9 ($M_1L_3I_1$)	74.93	76.27	75.6	77.27	79.6	78.43
T_{10} ($M_1L_3I_2$)	82.07	83.4	82.73	84.4	86.73	85.57
T_{11} ($M_1L_3I_3$)	79.2	80.53	79.87	81.53	83.87	82.7
T_{12} ($M_1L_3I_4$)	45.2	46.53	45.87	47.53	49.87	48.7
T_{13} ($M_2L_1I_1$)	49.4	50.73	50.07	51.73	54.07	52.9
T_{14} ($M_2L_1I_2$)	59.33	60.67	60	61.67	64	62.83
T_{15} ($M_2L_1I_3$)	56.8	58.13	57.47	59.13	61.47	60.3
T_{16} ($M_2L_1I_4$)	40.53	41.87	41.2	42.87	45.2	44.03
T_{17} ($M_2L_2I_1$)	61.67	63	62.33	64	66.33	65.17
T_{18} ($M_2L_2I_2$)	67.33	68.67	68	69.67	72	70.83
T_{19} ($M_2L_2I_3$)	64.4	65.73	65.07	66.73	69.07	67.9
T_{20} ($M_2L_2I_4$)	43	44.33	43.67	45.33	47.67	46.5
T_{21} ($M_2L_3I_1$)	76.27	77.6	76.93	78.6	80.93	79.77
T_{22} ($M_2L_3I_2$)	83.4	84.73	84.07	85.73	88.07	86.9
T_{23} ($M_2L_3I_3$)	80.53	81.87	81.2	82.87	85.2	84.03
T_{24} ($M_2L_3I_4$)	46.53	47.87	47.2	48.87	51.2	50.03
SEd (±)	3.09	3.03	3.06	3.42	3.22	3.32
CD (5%)	6.23	6.11	6.22	6.88	6.47	6.64

***DAP – Days after planting**

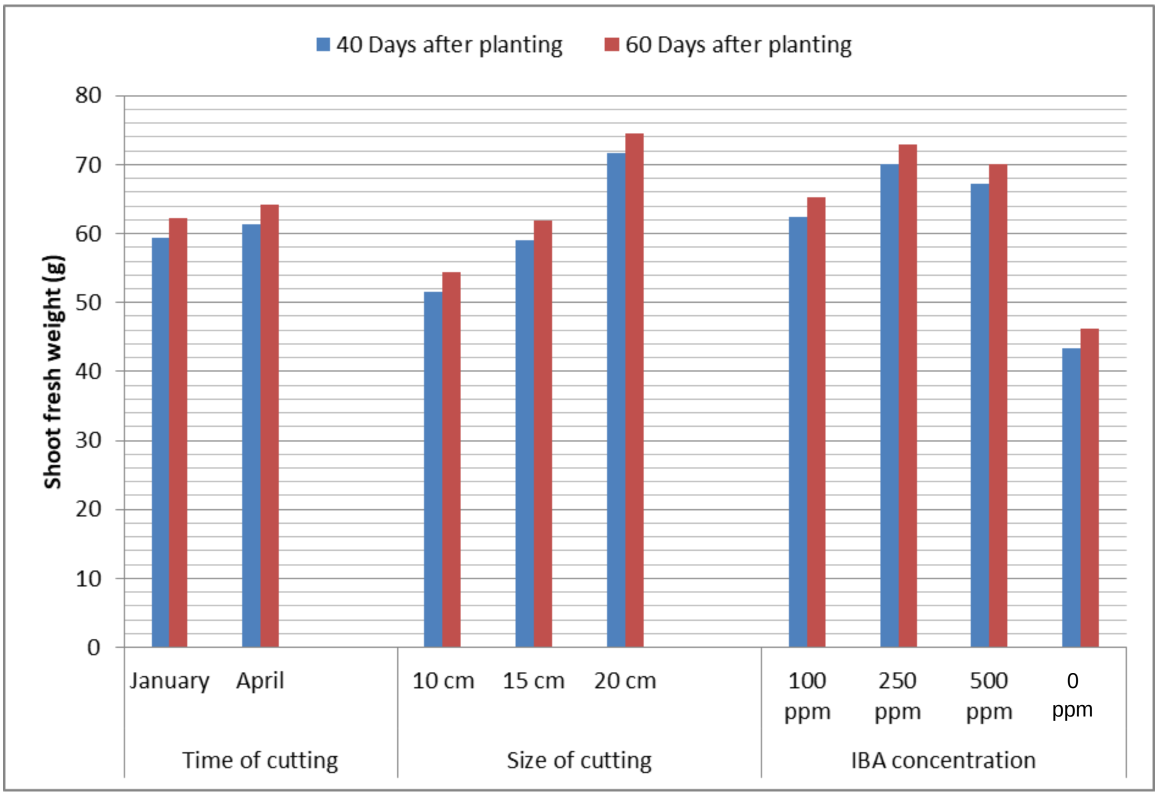


Fig. 4.25 Effect of time and size of cutting and IBA concentration on shoot fresh weight(g)

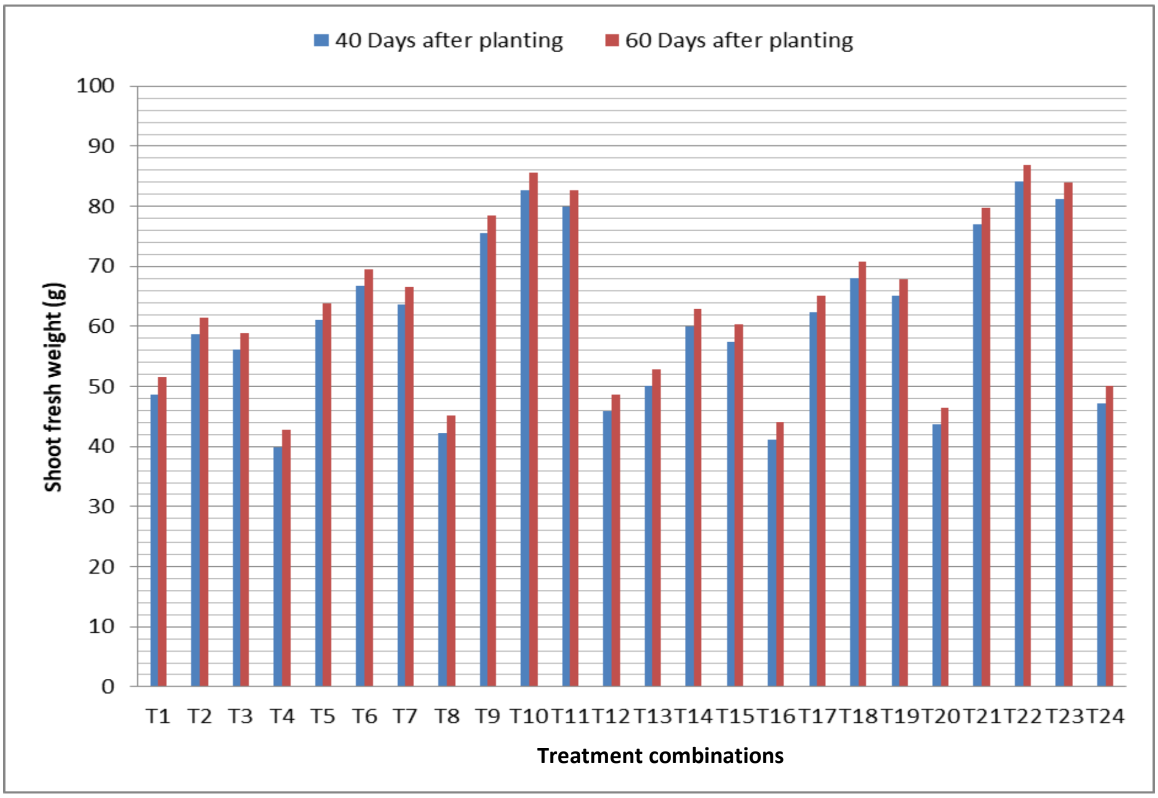


Fig. 4.26 Interaction effect of time and size of cutting and IBA concentration on shoot fresh weight(g)

4.2.6 Dry weight of shoot (g)

Perusal of pooled data presented in Table 4.27 and Fig. 4.27 revealed that time and size of cutting and IBA concentration had significant effects on shoot dry weight. The highest shoot dry weight (9.38 and 10.88 g at 40 and 60 DAP, respectively) was recorded in the cuttings taken in April. The 20 cm size of cuttings recorded the highest shoot dry weight (10.02 and 11.52 g at 40 DAP and 60 DAP, respectively) whereas the 10 cm size of cutting recorded lowest shoot dry weight (7.52 and 9.02 g at 40 DAP and 60 DAP respectively) . The IBA concentration of 250 ppm recorded highest (9.71 and 11.21 g at 40 DAP and 60 DAP respectively) shoot dry weight whereas the control treatment recorded lowest (7.04 and 8.54 g at 40 DAP and 60 DAP respectively) shoot dry weight. The pooled analysis data revealed that the effect of 500 ppm IBA concentration was statistically at par with the 250 ppm IBA concentration.

The data pertaining to the interaction effect of time and size of cutting and IBA concentration on the shoot dry weight as depicted in Table 4.28 and Fig. 4.28 revealed that there was significant interaction effect of the different treatment combinations at both 40 DAP and 60 DAP. T_{22} recorded highest (11.93 and 13.43 g at 40 DAP and 60 DAP, respectively) shoot dry weight whereas T_4 recorded lowest (5.53 and 7.03 g at 40 DAP and 60 DAP, respectively) shoot dry weight. The pooled data analysis reveals that the effects of the treatment combinations *viz*., T_{23}, T_{21}, T_{19}, T_{18}, T_{11} and T_{10} treatments were statistically at par with T_{22}.

Table 4.27 Effect of time and size of cutting and IBA concentration on shoot dry weight (g)

Treatment	Shoot dry weight (g)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	7.04	9.04	8.04	8.71	10.38	9.54
M_2 - April	8.38	10.38	9.38	10.04	11.71	10.88
SEd (±)	0.22	0.33	0.28	0.37	0.26	0.32
CD (5%)	0.44	0.67	0.55	0.74	0.52	0.63
Size of cutting						
L_1 - 10 cm	6.52	8.52	7.52	8.18	9.85	9.02
L_2 - 15 cm	7.6	9.6	8.6	9.27	10.93	10.1
L_3 - 20 cm	9.02	11.02	10.02	10.68	12.35	11.52
SEd (±)	0.27	0.41	0.34	0.45	0.32	0.39
CD (5%)	0.54	0.82	0.68	0.91	0.64	0.78
IBA concentration						
I_1 - 100 ppm	7.76	9.76	8.76	9.42	11.09	10.26
I_2 - 250 ppm	8.71	10.71	9.71	10.38	12.04	11.21
I_3 - 500 ppm	8.33	10.33	9.33	10	11.67	10.83
I_4 - 0 ppm	6.04	8.04	7.04	7.71	9.38	8.54
SEd (±)	0.31	0.47	0.39	0.52	0.37	0.45
CD (5%)	0.62	0.95	0.78	1.05	0.74	0.9

***DAP – Days after planting**

Table 4.28 Interaction effect of time and size of cutting and IBA concentration on shoot dry weight (g)

Treatment Combination	Shoot dry weight (g)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	5.73	7.73	6.73	7.4	9.07	8.23
T_2 ($M_1L_1I_2$)	6.73	8.73	7.73	8.4	10.07	9.23
T_3 ($M_1L_1I_3$)	6.4	8.4	7.4	8.07	9.73	8.9
T_4 ($M_1L_1I_4$)	4.53	6.53	5.53	6.2	7.87	7.03
T_5 ($M_1L_2I_1$)	7.33	9.33	8.33	9	10.67	9.83
T_6 ($M_1L_2I_2$)	7.8	9.8	8.8	9.47	11.13	10.3
T_7 ($M_1L_2I_3$)	7.47	9.47	8.47	9.13	10.8	9.97
T_8 ($M_1L_2I_4$)	5.13	7.13	6.13	6.8	8.47	7.63
T_9 ($M_1L_3I_1$)	8.2	10.2	9.2	9.87	11.53	10.7
T_{10} ($M_1L_3I_2$)	9.6	11.6	10.6	11.27	12.93	12.1
T_{11} ($M_1L_3I_3$)	9.13	11.13	10.13	10.8	12.47	11.63
T_{12} ($M_1L_3I_4$)	6.47	8.47	7.47	8.13	9.8	8.97
T_{13} ($M_2L_1I_1$)	7.07	9.07	8.07	8.73	10.4	9.57
T_{14} ($M_2L_1I_2$)	8.07	10.07	9.07	9.73	11.4	10.57
T_{15} ($M_2L_1I_3$)	7.73	9.73	8.73	9.4	11.07	10.23
T_{16} ($M_2L_1I_4$)	5.87	7.87	6.87	7.53	9.2	8.37
T_{17} ($M_2L_2I_1$)	8.67	10.67	9.67	10.33	12	11.17
T_{18} ($M_2L_2I_2$)	9.13	11.13	10.13	10.8	12.47	11.63
T_{19} ($M_2L_2I_3$)	8.8	10.8	9.8	10.47	12.13	11.3
T_{20} ($M_2L_2I_4$)	6.47	8.47	7.47	8.13	9.8	8.97
T_{21} ($M_2L_3I_1$)	9.53	11.53	10.53	11.2	12.87	12.03
T_{22} ($M_2L_3I_2$)	10.93	12.93	11.93	12.6	14.27	13.43
T_{23} ($M_2L_3I_3$)	10.47	12.47	11.47	12.13	13.8	12.97
T_{24} ($M_2L_3I_4$)	7.8	9.8	8.8	9.47	11.13	10.3
SEd (±)	0.75	1.16	0.96	1.27	0.9	1.09
CD (5%)	1.52	2.33	1.92	2.54	1.8	2.18

***DAP – Days after planting**

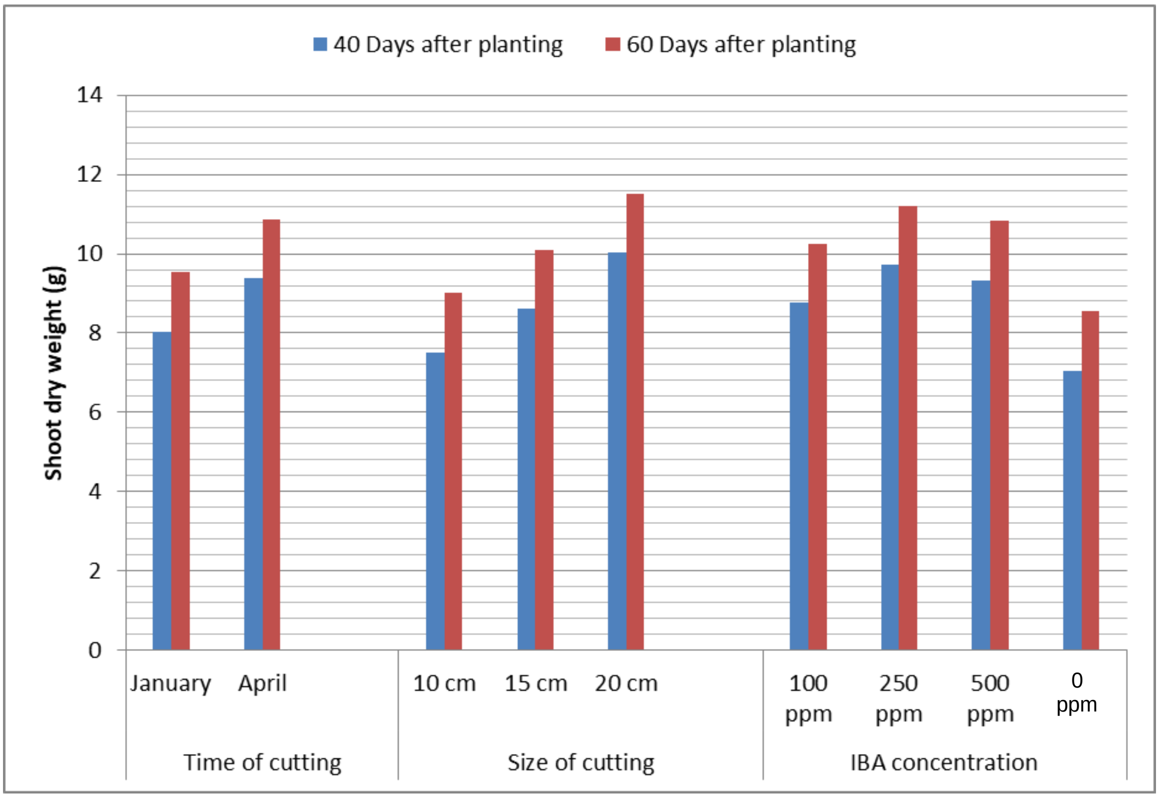


Fig. 4.27 Effect of time and size of cutting and IBA concentration on shoot dry weight(g)

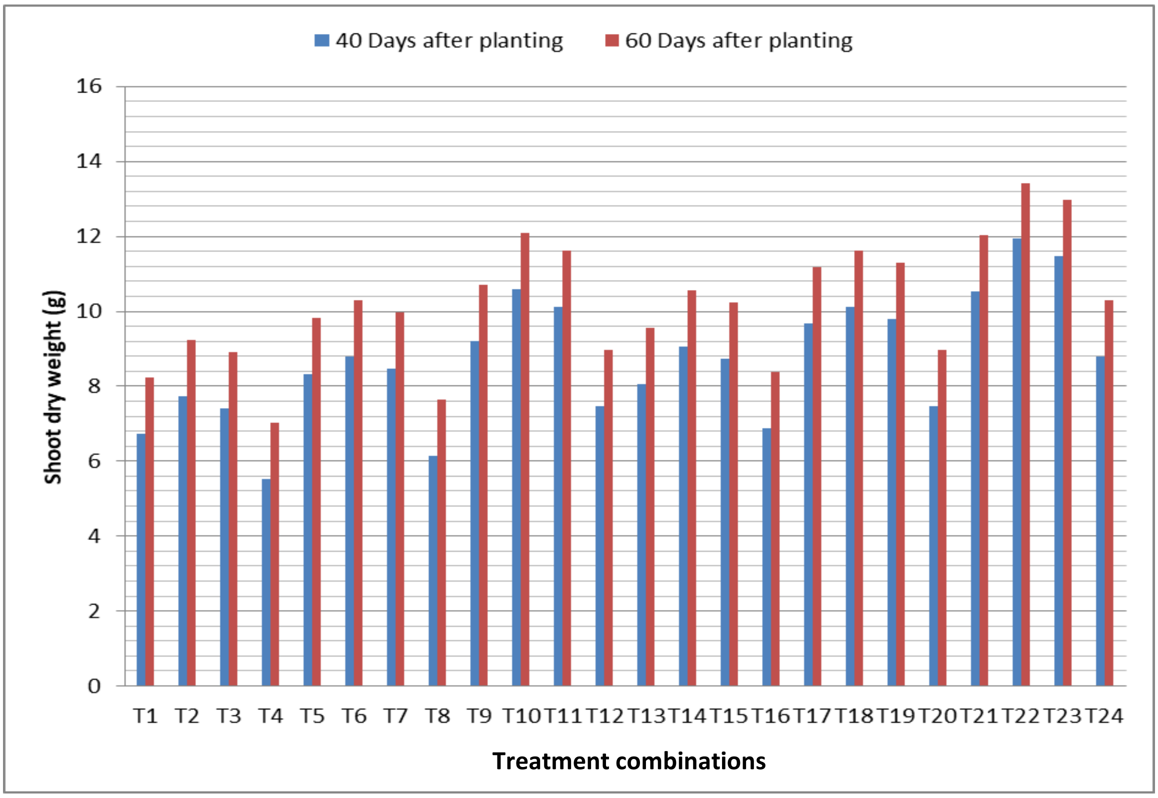


Fig. 4.28 Interaction effect of time and size of cutting and IBA concentration on shoot dry weight(g)

4.2.7 Root to shoot ratio

The root to shoot ratio varied significantly with the change in time and size of cutting and IBA concentration (Table 4.29, Fig. 4.29). The highest root to shoot ratio (0.09 and 0.10 at 40 DAP and 60 DAP, respectively) was recorded in the cuttings taken in April. The 20 cm size of cuttings recorded the highest root to shoot ratio (0.09 and 0.10 at 40 DAP and 60 DAP, respectively) whereas the 10 cm size of cutting recorded lowest (0.06 and 0.07 at 40 DAP and 60 DAP, respectively) root to shoot ratio. The IBA concentration of 250 ppm recorded highest root to shoot ratio (0.11 and 0.12 at 40 DAP and 60 DAP respectively) whereas the control treatment recorded lowest root to shoot ratio (0.07 and 0.08 at 40 DAP and 60 DAP, respectively). The pooled analysis data revealed that the effect of 500 ppm IBA concentration was statistically at par with the 250 ppm IBA concentration.

Perusal of pooled data presented in Table 4.30 and Fig. 4.30 revealed that there was significant effect of the treatment combinations on the root to shoot ratio. The treatment combinations *viz*., $T_{23,}$ T_{22}, T_{18} and T_{19} treatments recorded highest root to shoot ratio (0.09 and 0.1 at 40 DAP and 60 DAP respectively) whereas the treatment combinations *viz*., $T_{1,}$ T_4, T_{12} T_{20} and T_{21} treatments recorded lowest root to shoot ratio (0.06 and 0.07 at 40 DAP and 60 DAP, respectively).

Table 4.29 Effect of time and size of cutting and IBA concentration on root to shoot ratio

Treatment	Root to shoot ratio					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	0.04	0.08	0.06	0.07	0.06	0.07
M_2 - April	0.07	0.11	0.09	0.10	0.09	0.10
SEd (±)	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.02	0.02	0.02	0.02	0.02
Size of cutting						
L_1 - 10 cm	0.05	0.08	0.06	0.07	0.06	0.07
L_2 - 15 cm	0.06	0.09	0.07	0.08	0.07	0.08
L_3 - 20 cm	0.09	0.11	0.09	0.10	0.09	0.10
SEd (±)	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.02	0.02	0.02	0.02	0.02
IBA concentration						
I_1 - 100 ppm	0. 06	0.09	0.08	0.09	0.08	0.09
I_2 - 250 ppm	0.1	0.12	0.11	0.12	0.11	0.12
I_3 - 500 ppm	0.09	0.11	0.1	0.11	0.10	0.11
I_4 - 0 ppm	0.05	0.08	0.07	0.08	0.07	0.08
SEd (±)	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.02	0.02	0.02	0.02	0.02

***DAP – Days after planting**

Table 4.30 Interaction effect of time and size of cutting and IBA concentration on root to shoot ratio

Treatment	Root to shoot ratio					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	0.04	0.08	0.06	0.05	0.09	0.07
T_2 ($M_1L_1I_2$)	0.05	0.09	0.07	0.06	0.1	0.08
T_3 ($M_1L_1I_3$)	0.06	0.09	0.08	0.07	0.1	0.09
T_4 ($M_1L_1I_4$)	0.05	0.06	0.06	0.06	0.07	0.07
T_5 ($M_1L_2I_1$)	0.05	0.08	0.08	0.06	0.09	0.09
T_6 ($M_1L_2I_2$)	0.05	0.09	0.07	0.06	0.1	0.08
T_7 ($M_1L_2I_3$)	0.05	0.1	0.08	0.06	0.11	0.09
T_8 ($M_1L_2I_4$)	0.06	0.07	0.07	0.07	0.08	0.08
T_9 ($M_1L_3I_1$)	0.05	0.08	0.07	0.06	0.09	0.08
T_{10} ($M_1L_3I_2$)	0.05	0.09	0.07	0.06	0.1	0.08
T_{11} ($M_1L_3I_3$)	0.05	0.08	0.07	0.06	0.09	0.08
T_{12} ($M_1L_3I_4$)	0.05	0.07	0.06	0.06	0.08	0.07
T_{13} ($M_2L_1I_1$)	0.05	0.08	0.07	0.06	0.09	0.08
T_{14} ($M_2L_1I_2$)	0.07	0.09	0.08	0.08	0.1	0.09
T_{15} ($M_2L_1I_3$)	0.09	0.07	0.08	0.08	0.1	0.09
T_{16} ($M_2L_1I_4$)	0.04	0.09	0.07	0.05	0.1	0.08
T_{17} ($M_2L_2I_1$)	0.05	0.08	0.07	0.06	0.09	0.08
T_{18} ($M_2L_2I_2$)	0.07	0.1	0.09	0.08	0.11	0.1
T_{19} ($M_2L_2I_3$)	0.1	0.7	0.09	0.08	0.11	0.1
T_{20} ($M_2L_2I_4$)	0.05	0.07	0.06	0.06	0.08	0.07
T_{21} ($M_2L_3I_1$)	0.04	0.08	0.06	0.05	0.09	0.07
T_{22} ($M_2L_3I_2$)	0.07	0.1	0.09	0.08	0.11	0.1
T_{23} ($M_2L_3I_3$)	0.1	0.7	0.09	0.08	0.11	0.1
T_{24} ($M_2L_3I_4$)	0.04	0.08	0.06	0.05	0.09	0.07
SEd (±)	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.02	0.02	0.02	0.02	0.02

***DAP – Days after planting**

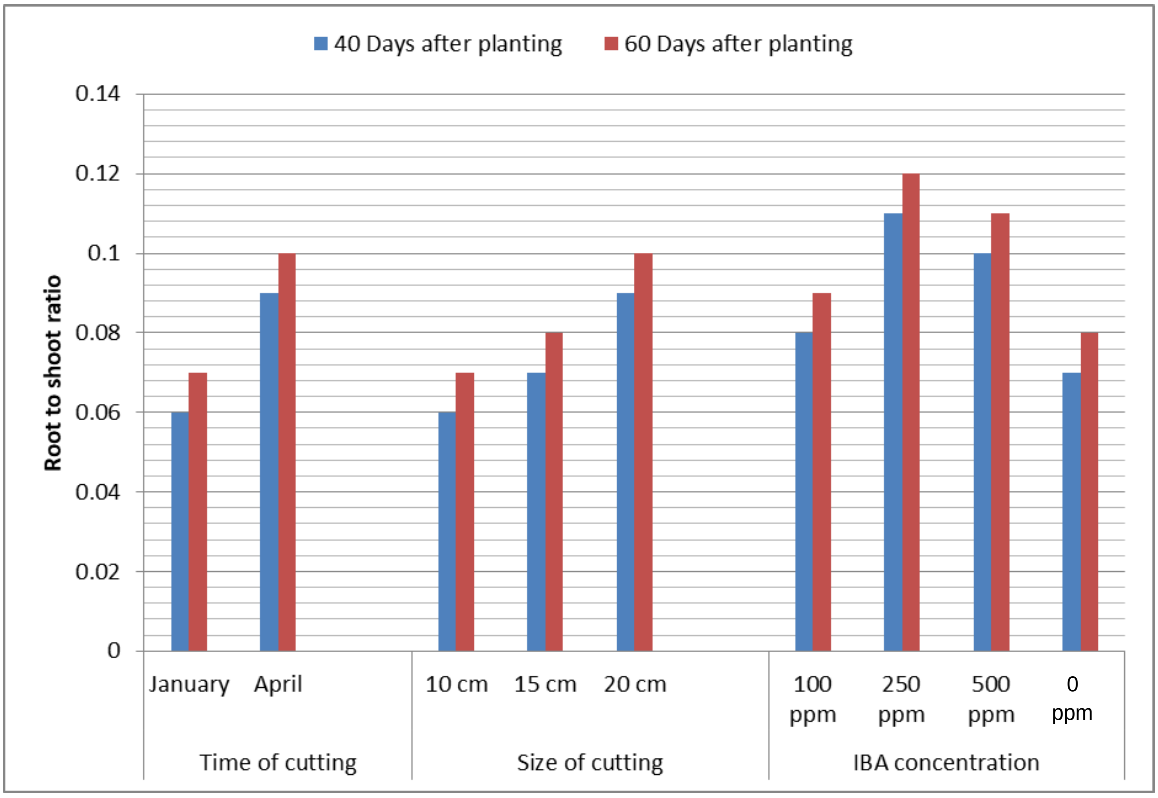


Fig. 4.29 Effect of time and size of cutting and IBA concentration on root to shoot ratio

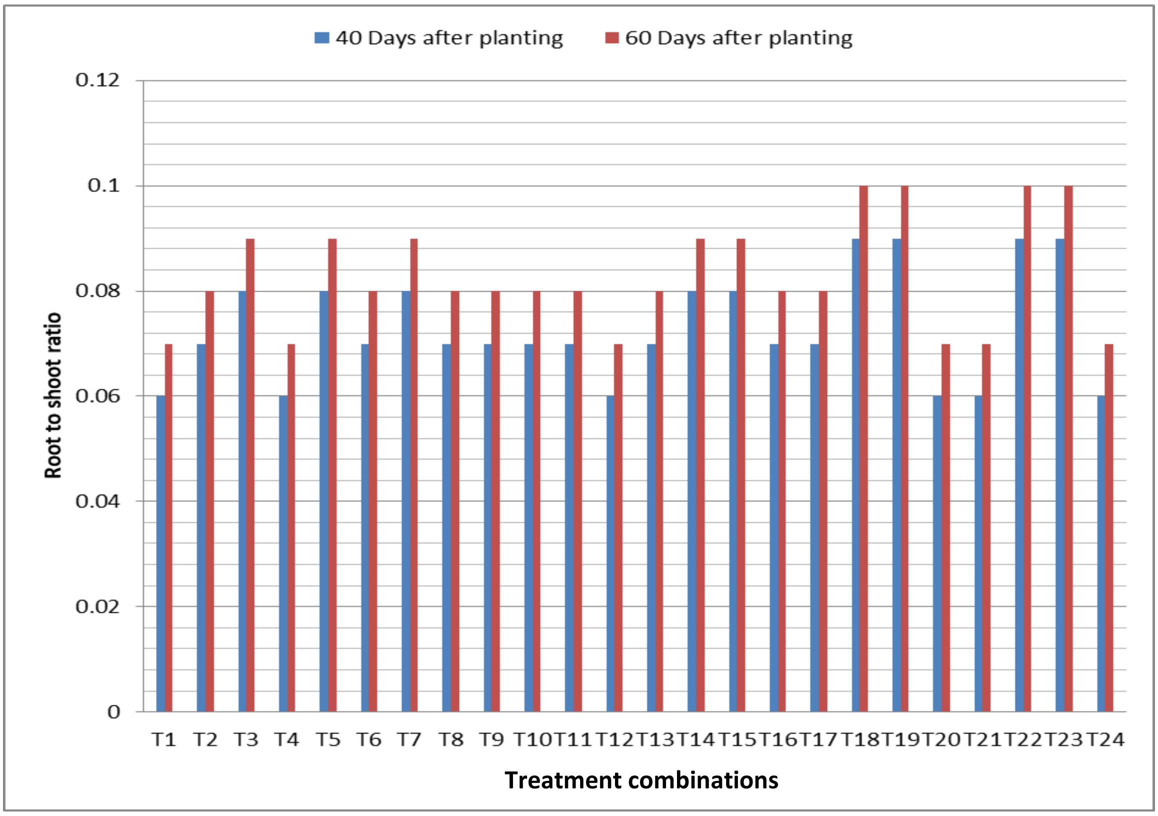


Fig. 4.30 Interaction effect of time and size of cutting and IBA concentration on root to shoot ratio

4.2.8 Nitrogen content in shoot (%)

Perusal of pooled data presented in Table 4.31 and Fig. 4.31 revealed that there was significant effect of time and size of cutting and IBA concentration on the nitrogen content in shoot. The highest nitrogen percentage (2.5 and 2.53 % at 40 DAP and 60 DAP respectively) of shoot was recorded in the cuttings taken in April. The 20 cm size of cuttings recorded highest nitrogen content (2.59 and 2.63 % at 40 DAP and 60 DAP respectively) of shoot whereas the 10 cm size of cutting recorded lowest nitrogen content (2.4 and 2.44 % at 40 DAP and 60 DAP respectively). The IBA concentration of 250 ppm recorded highest nitrogen content (2.56 and 2.6 % at 40 DAP and 60 DAP respectively) of shoot whereas the control treatment recorded lowest nitrogen content (2.36 and 2.4 % at 40 DAP and 60 DAP respectively) of shoot. The pooled analysis data revealed that the effect of 500 ppm IBA concentration was statistically at par with the 250 ppm IBA concentration.

The data pertaining to the interaction effect of time and size of cutting and IBA concentration on the nitrogen content of shoot as presented in Table 4.32 and Fig. 4.32 revealed that there was significant interaction effect of the different treatment combinations at both 40 DAP and 60 DAP. T_{22} recorded the highest nitrogen content (2.71 and 2.75 % at 40 DAP and 60 DAP respectively) of shoot whereas T_4 recorded lowest nitrogen (2.32 and 2.36 % at 40 DAP and 60 DAP respectively). The pooled analysis data revealed that the effects of the treatment combinations viz., T_{23}, T_{21}, T_{10} and T_{11} were statistically at par with T_{22}.

Table 4.31 Effect of time and size of cutting and IBA concentration on the nitrogen content in shoot (%)

Treatment	Nitrogen content in shoot (%)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	2.45	2.47	2.46	2.44	2.49	2.47
M_2 - April	2.47	2.52	2.5	2.5	2.57	2.53
SEd (±)	0.02	0.02	0.02	0.02	0.02	0.02
CD (5%)	0.03	0.04	0.04	0.04	0.04	0.04
Size of cutting						
L_1 - 10 cm	2.37	2.42	2.4	2.4	2.47	2.44
L_2 - 15 cm	2.44	2.5	2.47	2.48	2.54	2.51
L_3 - 20 cm	2.56	2.62	2.59	2.6	2.66	2.63
SEd (±)	0.02	0.02	0.02	0.02	0.02	0.02
CD (5%)	0.04	0.04	0.04	0.04	0.05	0.05
IBA concentration						
I_1 - 100 ppm	2.46	2.51	2.48	2.49	2.55	2.52
I_2 - 250 ppm	2.53	2.59	2.56	2.57	2.63	2.6
I_3 - 500 ppm	2.51	2.57	2.54	2.55	2.61	2.58
I_4 - 0 ppm	2.33	2.38	2.36	2.36	2.43	2.4
SEd (±)	0.02	0.02	0.02	0.02	0.03	0.03
CD (5%)	0.05	0.05	0.05	0.05	0.05	0.05

***DAP – Days after planting**

Table 4.32 Interaction effect of time and size of cutting and IBA concentration on the nitrogen content in shoot (%)

Treatment Combination	Nitrogen content in shoot (%)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	2.34	2.39	2.37	2.37	2.44	2.41
T_2 ($M_1L_1I_2$)	2.4	2.45	2.42	2.43	2.49	2.46
T_3 ($M_1L_1I_3$)	2.4	2.46	2.43	2.44	2.5	2.47
T_4 ($M_1L_1I_4$)	2.29	2.35	2.32	2.33	2.39	2.36
T_5 ($M_1L_2I_1$)	2.44	2.49	2.47	2.47	2.54	2.51
T_6 ($M_1L_2I_2$)	2.5	2.56	2.53	2.54	2.6	2.57
T_7 ($M_1L_2I_3$)	2.46	2.52	2.49	2.5	2.56	2.53
T_8 ($M_1L_2I_4$)	2.31	2.37	2.34	2.35	2.41	2.38
T_9 ($M_1L_3I_1$)	2.56	2.61	2.58	2.59	2.65	2.62
T_{10} ($M_1L_3I_2$)	2.66	2.71	2.69	2.69	2.76	2.73
T_{11} ($M_1L_3I_3$)	2.63	2.69	2.66	2.67	2.73	2.7
T_{12} ($M_1L_3I_4$)	2.35	2.4	2.38	2.38	2.45	2.42
T_{13} ($M_2L_1I_1$)	2.36	2.42	2.39	2.4	2.46	2.43
T_{14} ($M_2L_1I_2$)	2.42	2.47	2.45	2.45	2.52	2.49
T_{15} ($M_2L_1I_3$)	2.43	2.48	2.45	2.46	2.52	2.49
T_{16} ($M_2L_1I_4$)	2.32	2.37	2.34	2.35	2.41	2.38
T_{17} ($M_2L_2I_1$)	2.46	2.52	2.49	2.5	2.56	2.53
T_{18} ($M_2L_2I_2$)	2.53	2.58	2.55	2.56	2.62	2.59
T_{19} ($M_2L_2I_3$)	2.49	2.54	2.51	2.52	2.58	2.55
T_{20} ($M_2L_2I_4$)	2.34	2.39	2.36	2.37	2.43	2.4
T_{21} ($M_2L_3I_1$)	2.58	2.63	2.61	2.61	2.68	2.65
T_{22} ($M_2L_3I_2$)	2.68	2.74	2.71	2.72	2.78	2.75
T_{23} ($M_2L_3I_3$)	2.66	2.71	2.68	2.69	2.75	2.72
T_{24} ($M_2L_3I_4$)	2.37	2.43	2.4	2.41	2.47	2.44
SEd (±)	0.06	0.06	0.06	0.06	0.06	0.06
CD (5%)	0.12	0.12	0.12	0.12	0.13	0.13

***DAP – Days after planting**

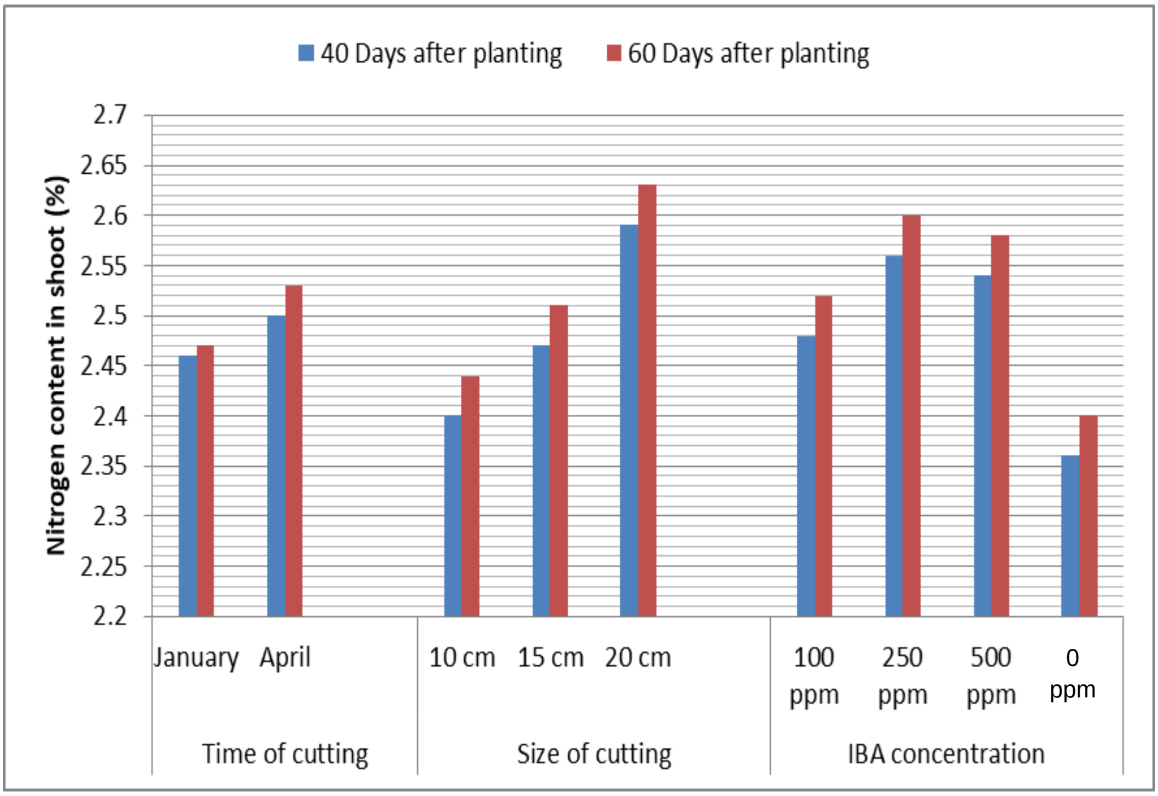


Fig. 4.31 Effect of time and size of cutting and IBA concentration on nitrogen content in shoot (%)

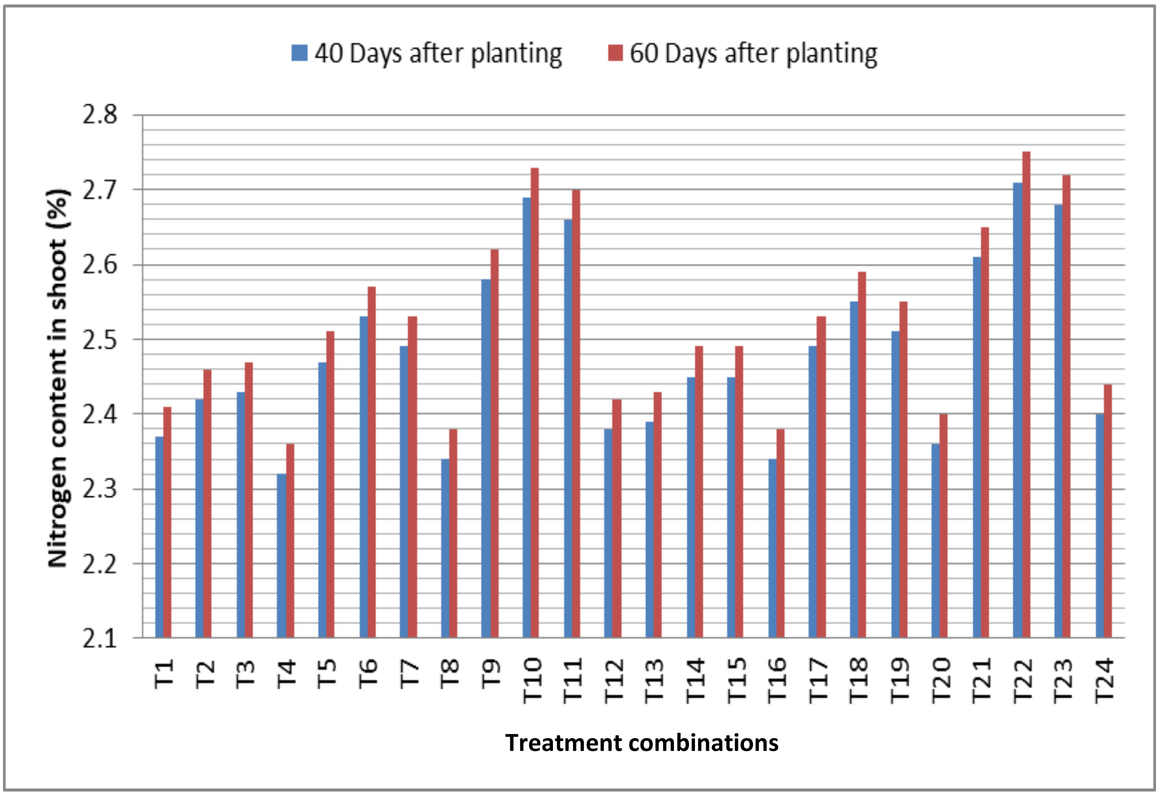


Fig. 4.32 Interaction effect of time and size of cutting and IBA concentration on nitrogen content in shoot (%)

4.2.9 Protein content in shoot (%)

The protein content in shoot was significantly affected by time and size of cutting and IBA concentration at both 40 DAP and 60 DAP (Table 4.33 and Fig. 4.33). The highest protein content (15.6 and 15.84 % at 40 DAP and 60 DAP, respectively) of shoot was recorded in the cuttings of April month. The 20 cm size of cuttings recorded highest protein content (16.18 and 16.42 % at 40 DAP and 60 DAP, respectively) of shoot whereas the 10 cm size of cutting recorded lowest protein content (14.98 and 15.22 % at 40 DAP and 60 DAP, respectively). The IBA concentration of 250 ppm recorded highest protein content (15.99 and 16.23 % at 40 DAP and 60 DAP, respectively) of shoot whereas the control treatment recorded lowest protein content (14.73 and 14.97 % at 40 DAP and 60 DAP, respectively) of shoot. The pooled data analysis revealed that the effect of 500 ppm IBA concentration is statistically at par with the 250 ppm IBA concentration.

The data pertaining to the interaction effect of time and size of cutting and IBA concentration on the protein content of shoot as depicted in table 4.34 and figure 4.34 revealed that there was significant interaction effect of the different treatment combinations at both 40 DAP and 60 DAP. T_{22} recorded highest protein content (16.94 and 17.18 % at 40 DAP and 60 DAP, respectively) of shoot whereas T_4 recorded lowest protein content (14.5 and 14.74 % at 40 DAP and 60 DAP, respectively). However, the effects of treatment combinations *viz*., T_{23}, T_{21}, T_{10} and T_{11} were statistically at par with T_{22}.

Table 4.33 Effect of time and size of cutting and IBA concentration on the protein content in shoot (%)

Treatment	Protein content in shoot (%)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	15.14	15.16	15.15	15.29	15.27	15.28
M_2 - April	15.43	15.77	15.6	15.64	16.04	15.84
SEd (±)	0.1	0.11	0.11	0.11	0.12	0.12
CD (5%)	0.21	0.22	0.22	0.22	0.23	0.23
Size of cutting						
L_1 - 10 cm	14.81	15.15	14.98	15.02	15.42	15.22
L_2 - 15 cm	15.26	15.59	15.43	15.47	15.86	15.67
L_3 - 20 cm	16.01	16.34	16.18	16.22	16.61	16.42
SEd (±)	0.13	0.13	0.13	0.13	0.14	0.14
CD (5%)	0.25	0.27	0.26	0.27	0.29	0.28
IBA concentration						
I_1 - 100 ppm	15.36	15.69	15.52	15.57	15.96	15.76
I_2 - 250 ppm	15.82	16.16	15.99	16.03	16.43	16.23
I_3 - 500 ppm	15.7	16.03	15.86	15.91	16.3	16.1
I_4 - 0 ppm	14.57	14.9	14.73	14.77	15.17	14.97
SEd (±)	0.15	0.15	0.15	0.15	0.16	0.16
CD (5%)	0.29	0.31	0.30	0.31	0.33	0.32

***DAP – Days after planting**

Table 4.34 Interaction effect of time and size of cutting and IBA concentration on the protein content in shoot (%)

Treatment	Protein content in shoot (%)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	14.63	14.96	14.79	14.83	15.23	15.03
T_2 ($M_1L_1I_2$)	14.98	15.31	15.15	15.19	15.58	15.39
T_3 ($M_1L_1I_3$)	15.02	15.35	15.19	15.23	15.63	15.43
T_4 ($M_1L_1I_4$)	14.33	14.67	14.5	14.54	14.94	14.74
T_5 ($M_1L_2I_1$)	15.25	15.58	15.42	15.46	15.85	15.66
T_6 ($M_1L_2I_2$)	15.65	15.98	15.81	15.85	16.25	16.05
T_7 ($M_1L_2I_3$)	15.4	15.73	15.56	15.6	16	15.8
T_8 ($M_1L_2I_4$)	14.46	14.79	14.63	14.67	15.06	14.86
T_9 ($M_1L_3I_1$)	15.98	16.31	16.15	16.19	16.58	16.39
T_{10} ($M_1L_3I_2$)	16.63	16.96	16.79	16.83	17.23	17.03
T_{11} ($M_1L_3I_3$)	16.46	16.79	16.63	16.67	17.06	16.86
T_{12} ($M_1L_3I_4$)	14.69	15.02	14.85	14.9	15.29	15.09
T_{13} ($M_2L_1I_1$)	14.77	15.1	14.94	14.98	15.38	15.18
T_{14} ($M_2L_1I_2$)	15.13	15.46	15.29	15.33	15.73	15.53
T_{15} ($M_2L_1I_3$)	15.17	15.5	15.33	15.38	15.77	15.57
T_{16} ($M_2L_1I_4$)	14.48	14.81	14.65	14.69	15.08	14.89
T_{17} ($M_2L_2I_1$)	15.4	15.73	15.56	15.6	16	15.8
T_{18} ($M_2L_2I_2$)	15.79	16.13	15.96	16	16.4	16.2
T_{19} ($M_2L_2I_3$)	15.54	15.88	15.71	15.75	16.15	15.95
T_{20} ($M_2L_2I_4$)	14.6	14.94	14.77	14.81	15.21	15.01
T_{21} ($M_2L_3I_1$)	16.13	16.46	16.29	16.33	16.73	16.53
T_{22} ($M_2L_3I_2$)	16.77	17.1	16.94	16.98	17.38	17.18
T_{23} ($M_2L_3I_3$)	16.6	16.94	16.77	16.81	17.21	17.01
T_{24} ($M_2L_3I_4$)	14.83	15.17	15	15.04	15.44	15.24
SEd (±)	0.36	0.38	0.37	0.38	0.4	0.39
CD (5%)	0.72	0.76	0.74	0.76	0.81	0.79

***DAP – Days after planting**

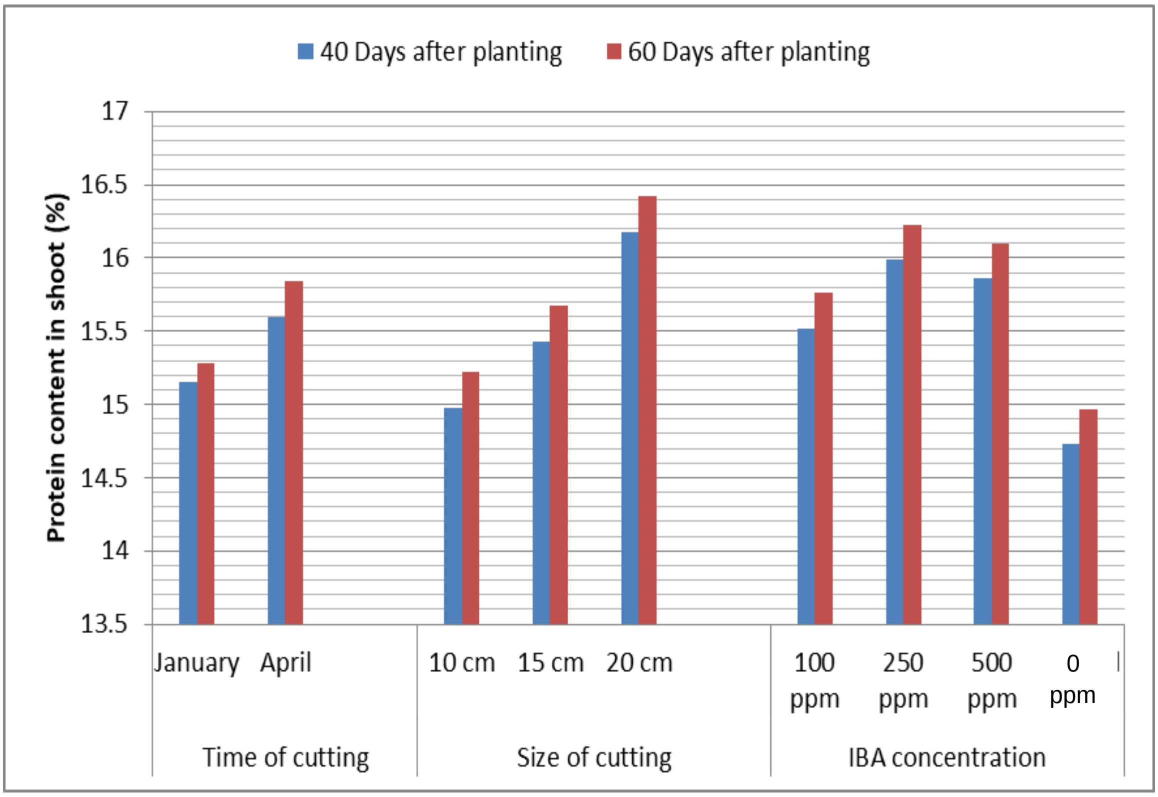


Fig. 4.33 Effect of time and size of cutting and IBA concentration on the protein content in shoot (%)

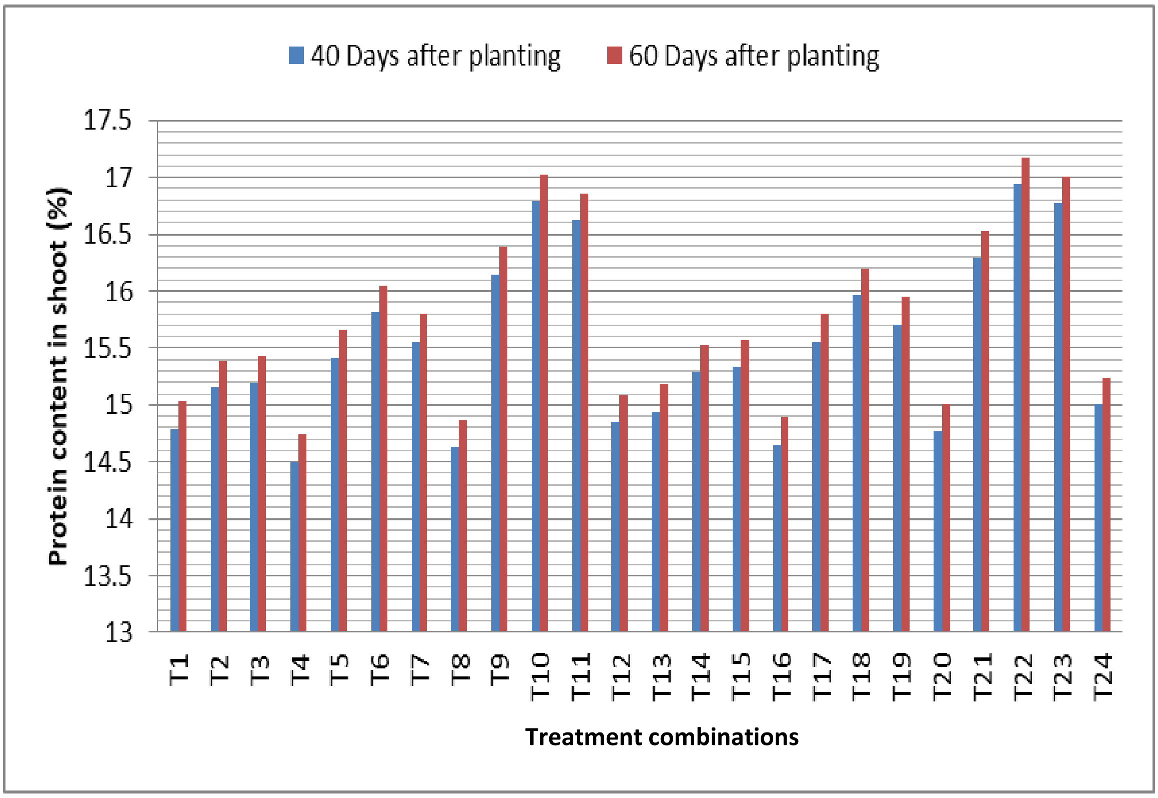


Fig. 4.34 Interaction effect of time and size of cutting and IBA concentration on the protein content in shoot (%)

4.2.10 Total chlorophyll content in shoot (mg/g)

The data presented in Table 4.35 and Fig. 4.35 revealed that there was significant effect of time and size of cutting and IBA concentration on the total chlorophyll content. The highest chlorophyll content of shoot (0.38 and 0.44 mg/g at 40 DAP and 60 DAP, respectively) was recorded in the cuttings taken in April. The 20 cm size of cuttings recorded the highest chlorophyll content of shoot (0.39 and 0.45 mg/g at 40 DAP and 60 DAP, respectively) whereas the 10 cm size of cutting recorded lowest chlorophyll content (0.33 and 0.39 mg/g at 40 DAP and 60 DAP, respectively) of shoot. Moreover, it was found that the effect of 15 cm size of cutting was statistically at par with the 20 cm size of cutting. The 250 ppm IBA treated cuttings recorded highest chlorophyll content (0.39 and 0.45 mg/g at 40 DAP and 60 DAP, respectively) of shoot whereas the non-treated cuttings recorded lowest chlorophyll content (0.32 and 0.33 mg/g at 40 DAP and 60 DAP respectively) of shoot. The pooled analysis data revealed that the effect of 500 ppm IBA concentration was statistically at par with the 250 ppm IBA concentration.

The treatment combinations had significant interaction effect on the chlorophyll content in shoot (Table 4.36, Fig. 4.36). T_{22} recorded the highest total chlorophyll content (0.45 and 0.51 mg/g at 40 DAP and 60 DAP, respectively) of shoot whereas T_4 recorded the lowest total chlorophyll content (0.27 and 0.28 mg/g at 40 DAP and 60 DAP, respectively) of shoot. The pooled analysis data revealed that the effects of the treatment combinations *viz*., T_{23}, T_{21}, T_{19}, T_{18}, T_{17}, T_{14}, T_{15}, T_{11}, T_{10} and T_9 were statistically at par with T_{22}.

Table 4.35 Effect of time and size of cutting and IBA concentration on the total chlorophyll content of shoot (mg/g)

Treatment	Total chlorophyll content of shoot (mg/g)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	0.3	0.37	0.34	0.34	0.41	0.38
M_2 - April	0.35	0.42	0.38	0.39	0.49	0.44
SEd (±)	0.01	0.01	0.01	0.01	0.02	0.02
CD (5%)	0.02	0.02	0.02	0.04	0.04	0.04
Size of cutting						
L_1 - 10 cm	0.29	0.36	0.33	0.36	0.38	0.37
L_2 - 15 cm	0.32	0.39	0.36	0.37	0.47	0.42
L_3 - 20 cm	0.36	0.43	0.39	0.41	0.5	0.45
SEd (±)	0.01	0.02	0.02	0.01	0.03	0.02
CD (5%)	0.02	0.04	0.03	0.02	0.06	0.04
IBA concentration						
I_1 - 100 ppm	0.33	0.4	0.36	0.33	0.35	0.34
I_2 - 250 ppm	0.35	0.42	0.39	0.4	0.5	0.45
I_3 - 500 ppm	0.34	0.41	0.37	0.38	0.48	0.43
I_4 - 0 ppm	0.28	0.35	0.32	0.33	0.32	0.33
SEd (±)	0.01	0.02	0.02	0.01	0.03	0.02
CD (5%)	0.02	0.04	0.03	0.02	0.06	0.04

***DAP – Days after planting**

Table 4.36 Interaction effect of time and size of cutting and IBA concentration on the total chlorophyll content of shoot (mg/g)

Treatment Combination	Total chlorophyll content of shoot (mg/g)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	0.27	0.34	0.3	0.23	0.35	0.29
T_2 ($M_1L_1I_2$)	0.28	0.35	0.32	0.33	0.43	0.38
T_3 ($M_1L_1I_3$)	0.27	0.35	0.31	0.32	0.42	0.37
T_4 ($M_1L_1I_4$)	0.25	0.29	0.27	0.23	0.34	0.28
T_5 ($M_1L_2I_1$)	0.3	0.37	0.33	0.34	0.44	0.39
T_6 ($M_1L_2I_2$)	0.33	0.4	0.37	0.38	0.47	0.43
T_7 ($M_1L_2I_3$)	0.31	0.38	0.35	0.36	0.46	0.41
T_8 ($M_1L_2I_4$)	0.26	0.33	0.29	0.24	0.35	0.29
T_9 ($M_1L_3I_1$)	0.34	0.41	0.38	0.39	0.49	0.44
T_{10} ($M_1L_3I_2$)	0.37	0.44	0.4	0.41	0.51	0.46
T_{11} ($M_1L_3I_3$)	0.35	0.43	0.39	0.4	0.5	0.45
T_{12} ($M_1L_3I_4$)	0.27	0.34	0.31	0.32	0.42	0.37
T_{13} ($M_2L_1I_1$)	0.31	0.38	0.35	0.36	0.46	0.41
T_{14} ($M_2L_1I_2$)	0.33	0.4	0.37	0.38	0.48	0.43
T_{15} ($M_2L_1I_3$)	0.32	0.39	0.36	0.37	0.47	0.42
T_{16} ($M_2L_1I_4$)	0.3	0.37	0.33	0.34	0.44	0.39
T_{17} ($M_2L_2I_1$)	0.34	0.41	0.38	0.39	0.49	0.44
T_{18} ($M_2L_2I_2$)	0.38	0.45	0.41	0.42	0.52	0.47
T_{19} ($M_2L_2I_3$)	0.36	0.43	0.39	0.41	0.5	0.46
T_{20} ($M_2L_2I_4$)	0.31	0.38	0.34	0.35	0.45	0.4
T_{21} ($M_2L_3I_1$)	0.39	0.46	0.43	0.44	0.53	0.49
T_{22} ($M_2L_3I_2$)	0.41	0.48	0.45	0.46	0.56	0.51
T_{23} ($M_2L_3I_3$)	0.4	0.47	0.44	0.45	0.55	0.5
T_{24} ($M_2L_3I_4$)	0.32	0.39	0.36	0.37	0.47	0.42
SEd (±)	0.02	0.05	0.04	0.03	0.08	0.06
CD (5%)	0.04	0.09	0.07	0.09	0.16	0.12

***DAP – Days after planting**

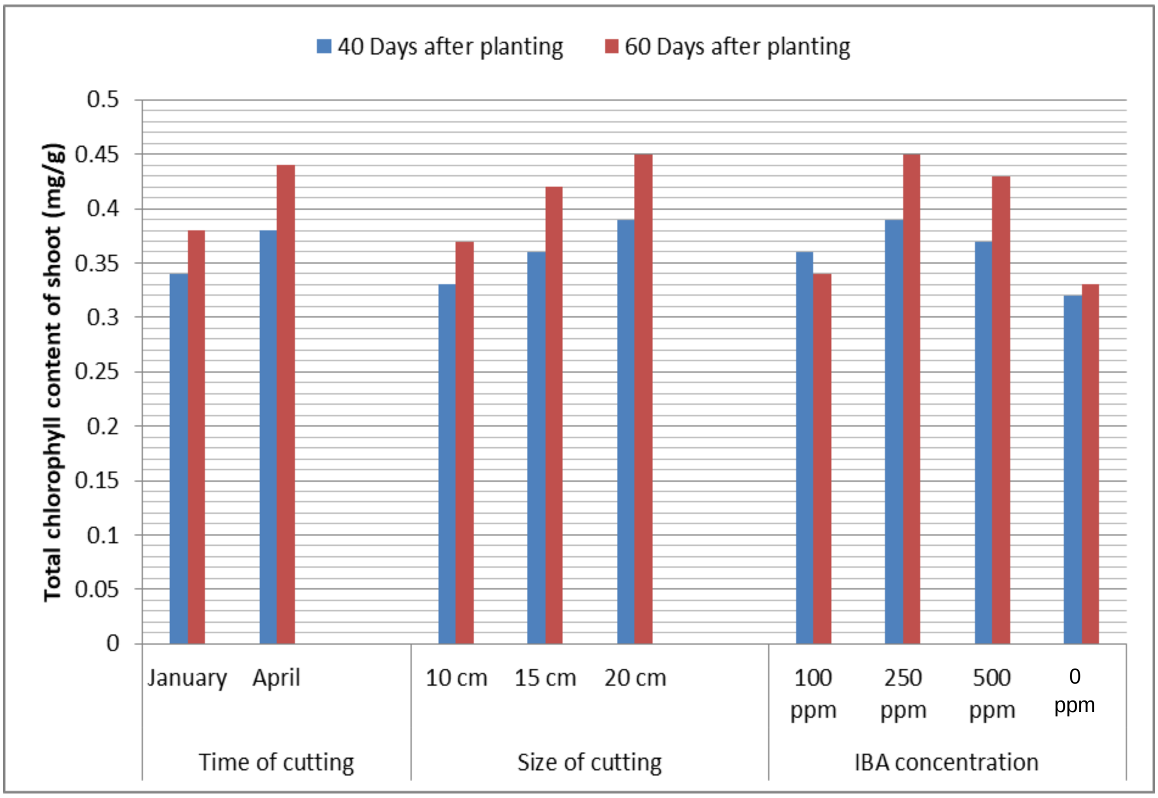


Fig. 4.35 Effect of time and size of cutting and IBA concentration on the total chlorophyll content of shoot(mg/g)

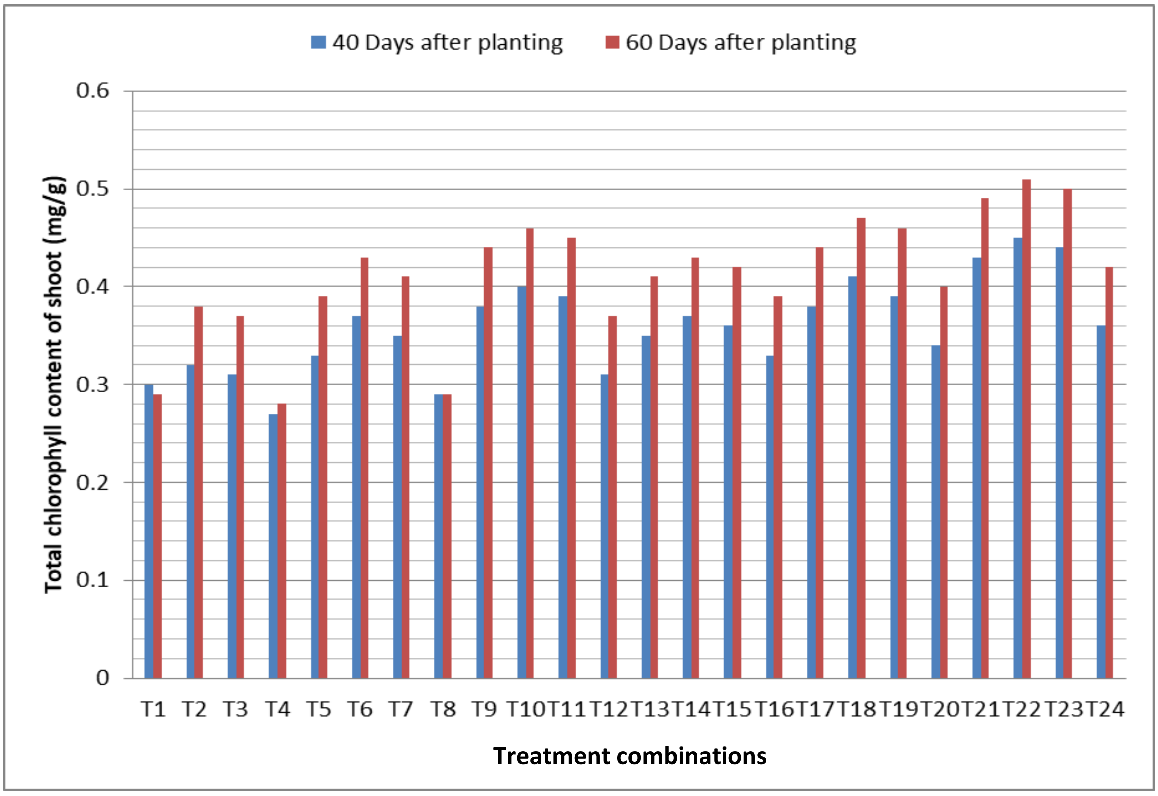


Fig. 4.36 Interaction effect of time and size of cutting and IBA concentration on the total chlorophyll content of shoot(mg/g)

4.2.11 Thickness of vascular cambium of shoot (mm)

The thickness of the vascular cambium of shoot varied significantly with the time and size of cutting and IBA concentration (Table 4.37, Fig. 4.37). The highest thickness (0.07 and 0.08 mm at 40 DAP and 60 DAP respectively) of the vascular cambium of shoot was recorded in the cuttings taken in April. The pooled analysis data revealed that, 20 cm size of cuttings recorded highest vascular cambium thickness (0.1 and 0.11 mm at 40 DAP and 60 DAP, respectively) of shoot whereas the 10 cm size of cuttings recorded lowest vascular cambium thickness of shoot (0.04 and 0.05 mm at 40 DAP and 60 DAP, respectively). The IBA concentration of 250 ppm recorded highest vascular cambium thickness of shoot (0.08 and 0.1 mm at 40 DAP and 60 DAP, respectively) whereas the control treatment recorded lowest vascular cambium thickness of shoot (0.04 and 0.06 mm at 40 DAP and 60 DAP. respectively).

Perusal of pooled data presented in Table 4.38 and Fig. 4.38 revealed that there was significant interaction effect of the different treatment combinations at both 40 DAP and 60 DAP. T_{22} recorded highest thickness (0.12 mm at 40 DAP; 0.15 mm at 60 DAP) of vascular cambium of shoot whereas T_4 recorded the least thickness (0.03 mm at 40 DAP; 0.04 mm at 60 DAP). Moreover, it was found that the effect of T_{23} was statistically at par with T_{22}.

Table 4.37 Effect of time and size of cutting and IBA concentration on the vascular cambium thickness of shoot (mm)

Treatment	Vascular cambium thickness of shoot (mm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
Time of cutting						
M_1 - January	0.03	0.04	0.04	0.04	0.05	0.05
M_2 - April	0.06	0.07	0.07	0.08	0.08	0.08
SEd (±)	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.02	0.02	0.02	0.02	0.02
Size of cutting						
L_1 - 10 cm	0.03	0.04	0.04	0.04	0.05	0.05
L_2 - 15 cm	0.05	0.06	0.06	0.06	0.07	0.07
L_3 - 20 cm	0.09	0.1	0.1	0.11	0.11	0.11
SEd (±)	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.03	0.03	0.02	0.02	0.02
IBA concentration						
I_1 - 100 ppm	0.05	0.04	0.05	0.06	0.07	0.07
I_2 - 250 ppm	0.07	0.08	0.08	0.09	0.1	0.1
I_3 - 500 ppm	0.05	0.06	0.06	0.07	0.08	0.08
I_4 - 0 ppm	0.04	0.05	0.04	0.05	0.07	0.06
SEd (±)	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.02	0.02	0.02	0.03	0.02	0.02

***DAP – Days after planting**

Table 4.38 Interaction effect of time and size of cutting and IBA concentration on the vascular cambium thickness of shoot (mm)

Treatment Combination	Vascular cambium thickness of shoot (mm)					
	40 DAP			60 DAP		
	2020	2021	Pooled	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	0.03	0.04	0.04	0.04	0.05	0.04
T_2 ($M_1L_1I_2$)	0.04	0.03	0.04	0.05	0.06	0.05
T_3 ($M_1L_1I_3$)	0.03	0.04	0.04	0.05	0.05	0.05
T_4 ($M_1L_1I_4$)	0.02	0.03	0.03	0.04	0.04	0.04
T_5 ($M_1L_2I_1$)	0.04	0.05	0.05	0.06	0.06	0.06
T_6 ($M_1L_2I_2$)	0.07	0.07	0.07	0.08	0.09	0.09
T_7 ($M_1L_2I_3$)	0.05	0.06	0.06	0.07	0.08	0.08
T_8 ($M_1L_2I_4$)	0.04	0.05	0.05	0.06	0.06	0.06
T_9 ($M_1L_3I_1$)	0.08	0.09	0.09	0.1	0.1	0.1
T_{10} ($M_1L_3I_2$)	0.1	0.11	0.11	0.12	0.13	0.13
T_{11} ($M_1L_3I_3$)	0.1	0.09	0.1	0.11	0.12	0.12
T_{12} ($M_1L_3I_4$)	0.07	0.08	0.07	0.09	0.09	0.09
T_{13} ($M_2L_1I_1$)	0.03	0.04	0.03	0.04	0.05	0.05
T_{14} ($M_2L_1I_2$)	0.04	0.05	0.04	0.05	0.06	0.06
T_{15} ($M_2L_1I_3$)	0.04	0.04	0.04	0.05	0.06	0.06
T_{16} ($M_2L_1I_4$)	0.03	0.03	0.03	0.04	0.05	0.05
T_{17} ($M_2L_2I_1$)	0.05	0.04	0.05	0.06	0.07	0.07
T_{18} ($M_2L_2I_2$)	0.07	0.08	0.08	0.09	0.08	0.09
T_{19} ($M_2L_2I_3$)	0.06	0.07	0.07	0.07	0.08	0.08
T_{20} ($M_2L_2I_4$)	0.05	0.04	0.05	0.06	0.07	0.07
T_{21} ($M_2L_3I_1$)	0.08	0.09	0.09	0.1	0.11	0.11
T_{22} ($M_2L_3I_2$)	0.11	0.12	0.12	0.14	0.15	0.15
T_{23} ($M_2L_3I_3$)	0.1	0.11	0.1	0.11	0.12	0.12
T_{24} ($M_2L_3I_4$)	0.08	0.08	0.08	0.09	0.1	0.1
SEd (±)	0.01	0.02	0.02	0.01	0.03	0.02
CD (5%)	0.02	0.04	0.03	0.02	0.06	0.04

***DAP – Days after planting**

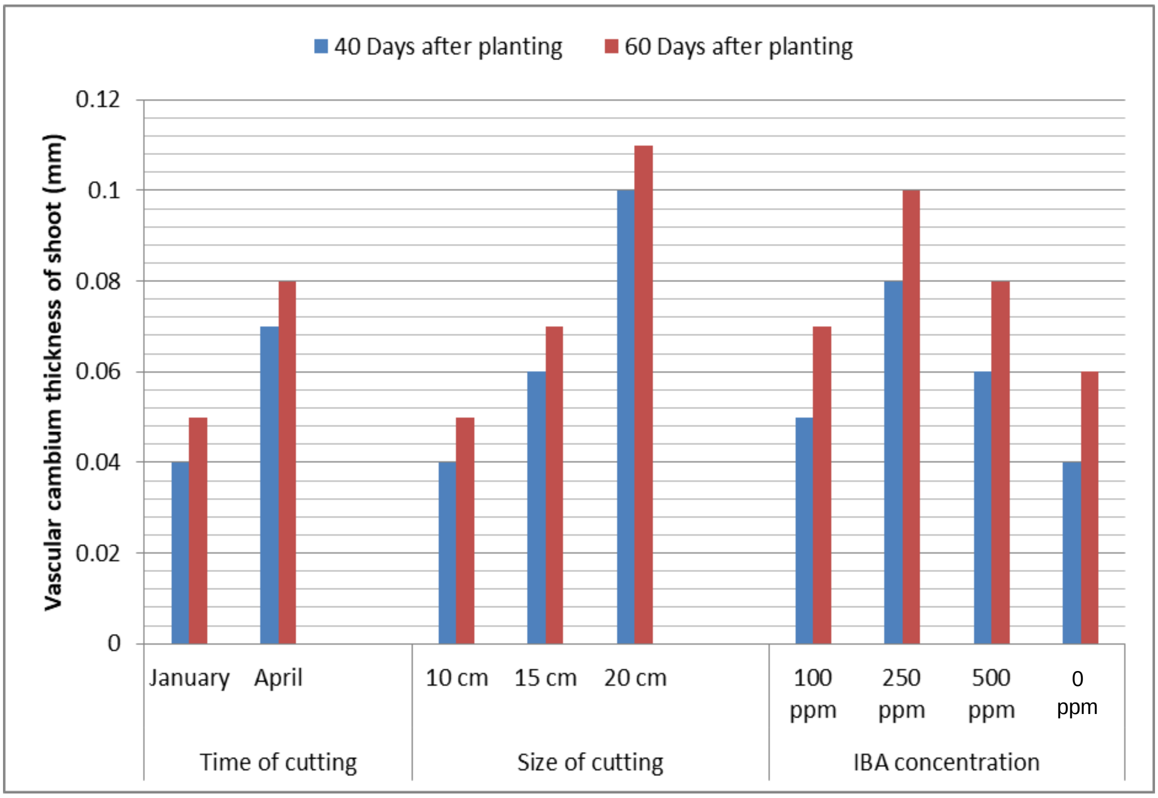


Fig. 4.37 Effect of time and size of cutting and IBA concentration on the vascular cambium thickness of shoot(mm)

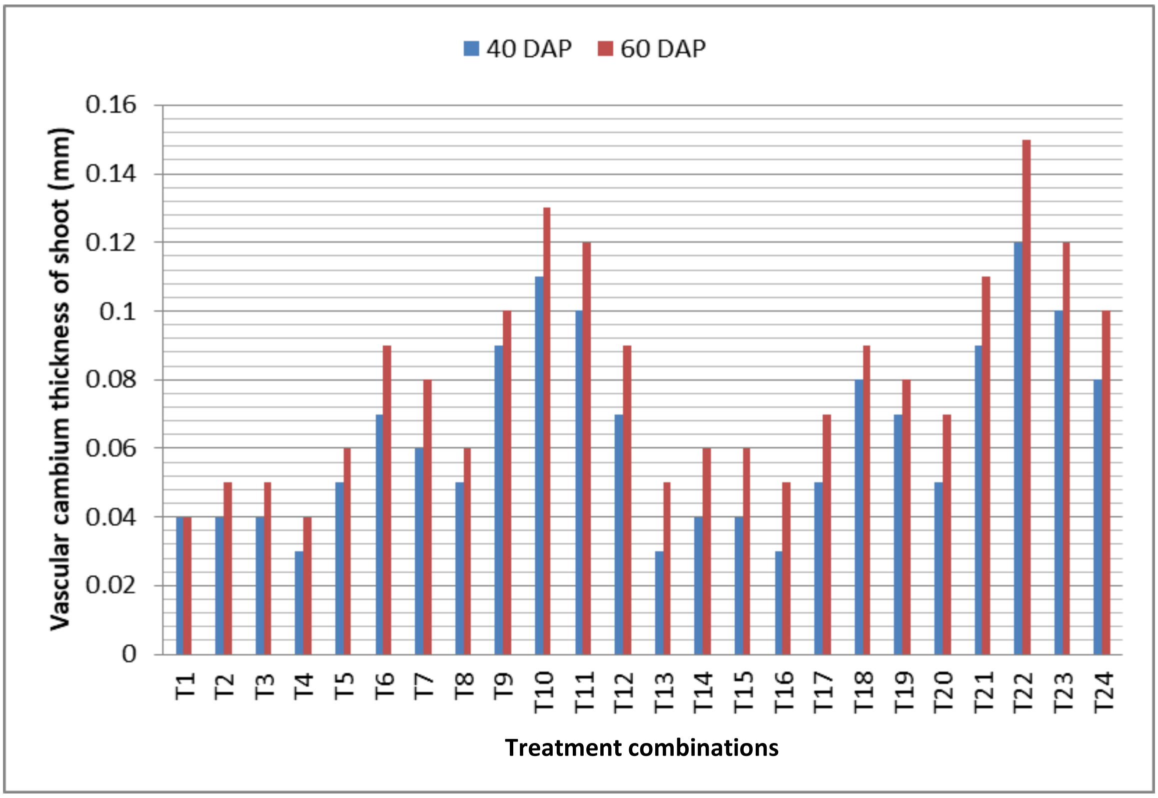


Fig. 4.38 Interaction effect of time and size of cutting and IBA concentration on the vascular cambium thickness of shoot(mm)

4.3 Survival of the saplings (%)

The survival of the saplings were significantly affected by the time and size of cutting and IBA concentration (Table 4.39, Fig. 4.39). The highest survival (98.13 %) was recorded in the cuttings taken in April. The 20 cm size of cuttings recorded highest survival (99.17 %) whereas the 10 cm size of cuttings recorded lowest survival (95.42 %). Moreover, it was observed that the survival of 15 cm size of cuttings was statistically at par with the 20 cm size of cuttings. The IBA concentration of 250 ppm recorded the highest survival (99.17 %) whereas the control treatment recorded lowest survival (95.83 %). The pooled analysis data revealed that the effect of 500 ppm IBA concentration was statistically at par with the 250 ppm IBA concentration.

The treatment combinations had a significant interaction effect on the survival of the saplings (Table 4.40, Fig. 4.40). The treatment combinations *viz*., T_{23}, T_{22}, T_{19}, T_{18}, T_{11} and T_{10} recorded highest survival (100 %) of the saplings whereas T_4 recorded lowest survival (92.5%) of the saplings.

Table 4.39 Effect of time and size of cutting and IBA concentration on the survival of the saplings (%)

Treatment	Survival of saplings (%)		
	2020	**2021**	**Pooled**
Time of cutting			
M_1 - January	94.98	96.02	95.01
M_2 - April	97.64	98.61	98.13
SEd (±)	1.13	1.2	1.17
CD (5%)	2.26	2.4	2.33
Size of cutting			
L_1 - 10 cm	94.58	96.25	95.42
L_2 - 15 cm	97.92	98.33	98.13
L_3 - 20 cm	98.75	99.58	99.17
SEd (±)	1.38	1.47	1.43
CD (5%)	2.78	2.97	2.88
IBA concentration			
I_1 - 100 ppm	95.66	97.68	95.67
I_2 - 250 ppm	98.89	99.44	99.17
I_3 - 500 ppm	98.33	98.89	98.61
I_4 - 0 ppm	95.04	95.02	95.03
SEd (±)	1.6	1.7	1.65
CD (5%)	3.21	3.42	3.32

***DAP – Days after planting**

Table 4.40 Interaction effect of time and size of cutting and IBA concentration on the survival of the saplings (%)

Treatment	Survival of saplings (%)		
	2020	2021	Pooled
T_1 ($M_1L_1I_1$)	90	90.17	90.09
T_2 ($M_1L_1I_2$)	96.67	98.33	97.5
T_3 ($M_1L_1I_3$)	95	96.67	95.83
T_4 ($M_1L_1I_4$)	90	90	90
T_5 ($M_1L_2I_1$)	90	91.17	90.09
T_6 ($M_1L_2I_2$)	98.33	98.33	98.33
T_7 ($M_1L_2I_3$)	98.33	98.33	98.33
T_8 ($M_1L_2I_4$)	91.17	90.67	90.92
T_9 ($M_1L_3I_1$)	98.33	100	99.17
T_{10} ($M_1L_3I_2$)	100	100	100
T_{11} ($M_1L_3I_3$)	100	100	100
T_{12} ($M_1L_3I_4$)	91.17	91.17	91.17
T_{13} ($M_2L_1I_1$)	93.33	95	94.17
T_{14} ($M_2L_1I_2$)	98.33	100	99.17
T_{15} ($M_2L_1I_3$)	96.67	98.33	97.5
T_{16} ($M_2L_1I_4$)	93.33	95	94.17
T_{17} ($M_2L_2I_1$)	98.33	98.33	98.33
T_{18} ($M_2L_2I_2$)	100	100	100
T_{19} ($M_2L_2I_3$)	100	100	100
T_{20} ($M_2L_2I_4$)	96.67	98.33	97.5
T_{21} ($M_2L_3I_1$)	98.33	100	99.17
T_{22} ($M_2L_3I_2$)	100	100	100
T_{23} ($M_2L_3I_3$)	100	100	100
T_{24} ($M_2L_3I_4$)	96.67	98.33	97.5
SEd (±)	3.91	4.17	4.04
CD (5%)	7.82	8.34	8.08

***DAP – Days after planting**

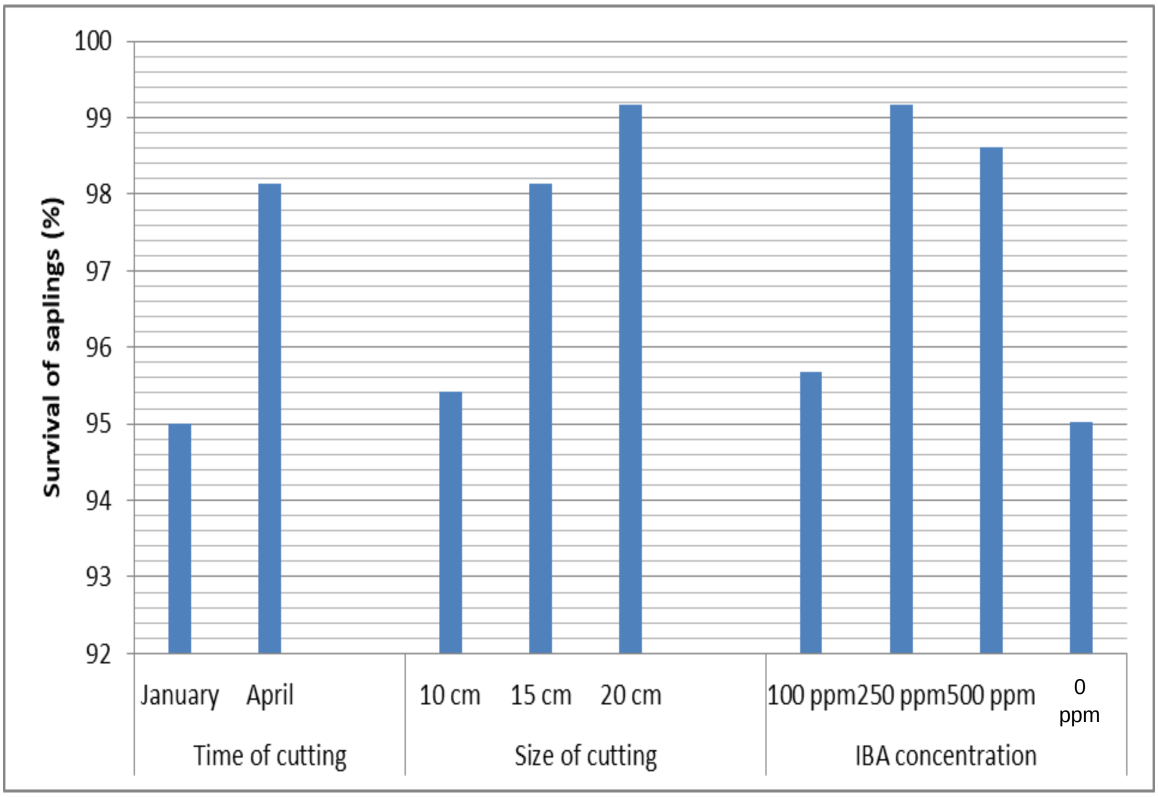


Fig. 4.39 Effect of time and size of cutting and IBA concentration on the survival of the saplings (%)

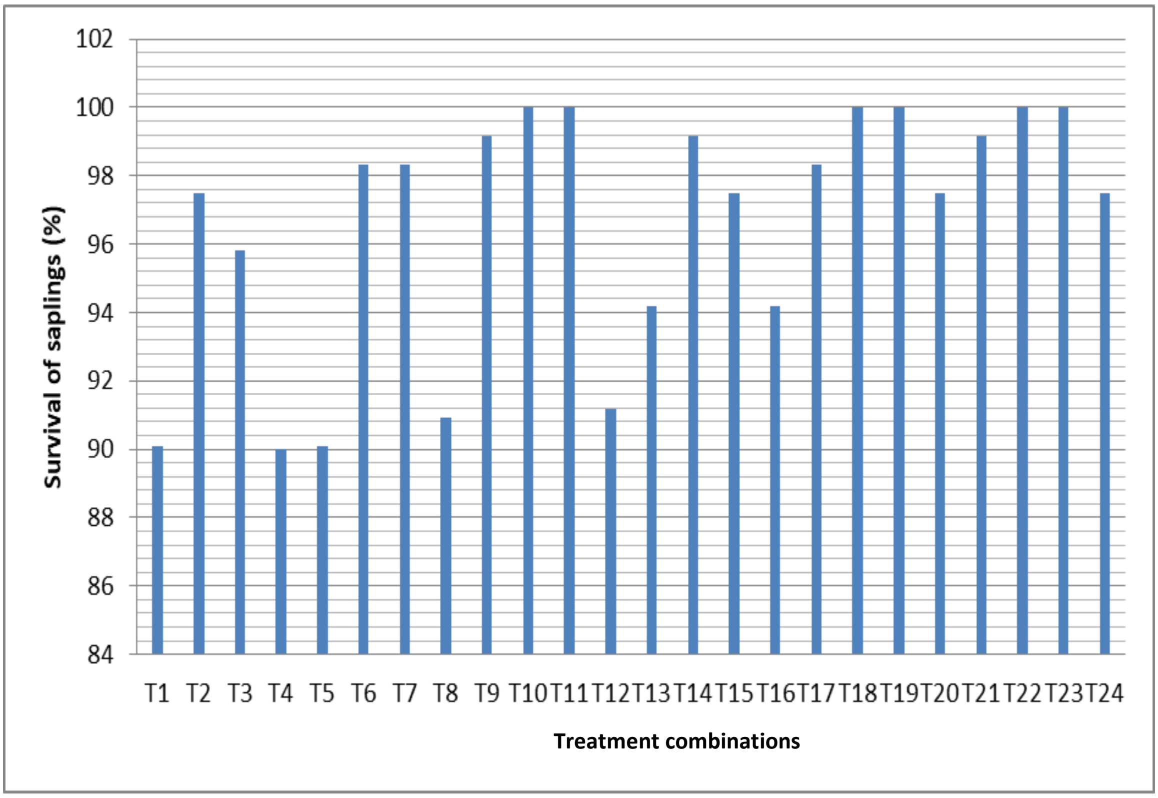


Fig. 4.40 Interaction effect of time and size of cutting and IBA concentration on the survival of the saplings (%)

4.4 Cost analysis

Computation of individual treatment combination cost analysis (Table 4.41) showed that the highest cost (Rs. 26.12/-) was involved in L_3I_3 which was followed by L_3I_2 whereas the lowest cost was recorded in L_1I_4(Rs.15.82/-) followed by L_1I_1. Though the treatment combination cost was the lowest in L_1I_4, it required more days for root formation (26 and 28 days in April and January cuttings, respectively). Although the cost involvement in L_3I_3 and L_3I_2 was the highest, it took minimum days for root formation (14 and 18 days, in April and January cuttings respectively).

Table 4.41 Estimation of individual treatment combination cost (Rs per sapling)

Treatment Combination	Cost of Polybag (Rs)	Cost of Cutting (Rs)	Cost of Polybag Mixture (Rs)	Labour cost (Rs)	Cost of IBA (Rs)	Cost of Other operations (Rs)	Total Cost (Rs)
L_1I_1	1.23	10	0.21	3.38	0.06	1	15.88
L_1I_2	1.23	10	0.21	3.38	0.15	1	15.97
L_1I_3	1.23	10	0.21	3.38	0.3	1	16.12
L_1I_4	1.23	10	0.21	3.38	0	1	15.82
L_2I_1	1.23	15	0.21	3.38	0.06	1	20.88
L_2I_2	1.23	15	0.21	3.38	0.15	1	20.97
L_2I_3	1.23	15	0.21	3.38	0.3	1	21.12
L_2I_4	1.23	15	0.21	3.38	0	1	20.82
L_3I_1	1.23	20	0.21	3.38	0.06	1	25.88
L_3I_2	1.23	20	0.21	3.38	0.15	1	25.97
L_3I_3	1.23	20	0.21	3.38	0.3	1	26.12
L_3I_4	1.23	20	0.21	3.38	0	1	25.82

CHAPTER V

DISCUSSION

In the present chapter, an attempt has been made to justify the causes of variability among different treatments. Changes in root and shoot growth of dragon fruit saplings were observed to be affected by the time and size of cutting and IBA concentration. Moreover, the climatic conditions also supplemented to the variation in growth and development among the different treatments. Thus, the standardisation of appropriate time and size of cutting and IBA concentration for a particular agro climatic region is a critical factor for successful commercial propagation of dragon fruit cuttings.

The salient findings of the present investigation are discussed critically with logistic views under the following heads:

5.1 Changes in root growth parameters

5.2 Changes in shoot growth parameters

5.3 Biochemical changes in shoot

5.4 Changes in vascular cambium

5.5 Survival of saplings

5.1 Changes in root growth parameters

There was significant variation in days required for root formation among the different treatments. Early root formation was obtained in the cuttings of April month (18.09 days). This may be due to higher levels of carbohydrates, shoot RNA, proteins and endogenous auxins in the cuttings of the April month. For the initiation of the cell division of the root initials, a certain level of protein and DNA synthesis is required and the gene regulation for protein and DNA synthesis is regulated by increased shoot RNA activity (Davies, 1984). Moreover, higher endogenous auxins in the cuttings may increase the cambial activity, resulting in the early root initiation (Wodzicki, 1978). A relatively higher temperature (Table 3.1) may also be responsible for the early root formation in the April cuttings (Almeida *et al*., 2017). The cuttings of 20 cm size recorded early root formation (18.46 days) whereas late root formation was obtained in cuttings of 10 cm size (22 days). The 20 cm size of cuttings may have more carbohydrate reserves as compared to the smaller size of cuttings. Moreover, due to the larger surface area in 20 cm size of cuttings as compared to the smaller sizes, the 20 cm sized cuttings may have more chlorophyll concentration as a result of which more photosynthates may be produced in the 20 cm size of cuttings. The IBA concentration of 500 ppm led to early root formation (15.06 days). This may be ascribed to the rapid hydrolysis of reserve carbohydrates in the cuttings by the higher concentration of IBA (Chandramouli, 2001). The hydrolysed carbohydrates provide energy through respiratory activity for the initiation of the roots. The treatment without IBA delayed root formation (25.89 days). Among the interaction effects T_{23} recorded early root formation (14 days) and T_4 delayed root formation (28 days) This may be due to the combined effect of the levels of the three factors in the experiment that led to early root formation. Similar, results were reported in dragon fruit stem cuttings by Minz (2020) and Siddiqua and Thippesha (2018) .

The treatments showed significant difference with respect to number of roots. Highest root number was recorded in the cuttings of April (10.79 at 40 DAP ; 12.79 at 60 DAP). The cuttings of April month may have higher levels of carbohydrates, shoot RNA, proteins and endogenous auxins which may favour in the formation of more root initials (Wodzicki, 1978). Cuttings taken in the month of April having more C:N ratio, total carbohydrate and total nitrogen levels have been reported to influence the adventitious rooting of plant species (Druege *et al.*, 2004). Highest root number (12.81 at 40 DAP ; 14.81 at 60 DAP) was recorded in cuttings of 20 cm size whereas lowest root number (7.25 at 40 DAP ; 9.25 at 60 DAP) was recorded in cuttings of 10 cm size. A relatively higher levels of carbohydrate reserves and more photosynthates production due to higher chlorophyll content may be responsible for higher number of roots in the 20 cm sized cuttings. The IBA concentration of 250 ppm recorded highest root numbers (13.97 at 40 DAP ; 15.97 at 60 DAP) whereas the control treatment recorded lowest root numbers (5.82 at 40 DAP ; 7.82 at 60 DAP). Rapid hydrolysis of stored carbohydrates into physiologically active forms of sugars by the higher concentration of IBA may be responsible for higher number of roots in the 250 ppm IBA treated cuttings (Chandramouli, 2001). There exists a correlation between primordia division in root initiation and endogenous or exogenous auxin level. The roots are vital organ for anchorage and absorption of water and nutrients from the soil for better growth of cuttings. This finding is supported by Fathi and Ismailpor (2000) who reported that auxin enhances the root formation in cuttings. Relatively lower numbers (11.11 at 40 DAP ; 13.11 at 60 DAP) of roots were recorded in 500 ppm treated cutting which may be due to the toxicity produced by auxins at higher concentrations (Tien *et al*., 2020 ; Aminah *et al*., 1995 ; Karimi and Yadollahi, 2012 ; Eliasson and Areblad, 1984). T_{22} recorded the highest root number (18.84 at 40 DAP ; 20.83 at 60 DAP) whereas T_4 recorded the lowest root number (3.63 at 40 DAP ; 5.63 at 60 DAP). The results obtained were in concurrence with the results of Malswamkimi *et al*. (2019) and Ahmad *et al*. (2016).

The treatments showed profound difference with respect to the root length. Highest root length (10.79 cm at 40 DAP ; 12.79 cm at 60 DAP) was recorded in the cuttings of April month. The cuttings of April month may have higher levels of carbohydrates and endogenous auxins which may cause rapid cell division in the meristematic tissues of the root tip thus leading to the elongation of the roots (Molnar and Croix, 1972) . Highest root length (12.81 cm at 40 DAP ; 14.81 cm at 60 DAP) was recorded in cuttings of 20 cm size whereas lowest root length (7.25 cm at 40 DAP ; 9.25 cm at 60 DAP) was recorded in cuttings of 10 cm size. A relatively higher levels of carbohydrate reserves and more photosynthates production due to higher chlorophyll content as a result of higher surface area may be responsible for the higher root length in the 20 cm sized cuttings. The IBA concentration of 250 ppm recorded the highest root length (13.97 cm at 40 DAP ; 15.97 cm at 60 DAP) whereas the control treatment recorded the lowest root length (5.82 cm at 40 DAP ; 7.82 cm at 60 DAP). Rapid hydrolysis of stored carbohydrates in the cuttings by the higher concentration of IBA may be responsible for higher length of the roots in the 250 ppm IBA treated cuttings (Chandramouli, 2001). Relatively lower length (11.11 cm at 40 DAP ; 13.11 cm at 60 DAP) of the roots were recorded in 500 ppm treated cutting which may be due to the toxicity produced by auxins at higher concentrations (Tien *et al*., 2020 ; Aminah *et al*., 1995 ; Karimi and Yadollahi, 2012 ; Eliasson and Areblad, 1984). Highest root length (18.83 cm at 40 DAP ; 20.83 cm at 60 DAP) was recorded in T_{22} whereas lowest root length (3.63 cm at 40 DAP ; 5.63 cm at 60 DAP) was recorded in T_4. The combination of the specific levels of the three factors that led to higher length of the roots may be responsible for the higher length of the roots in T_{22}. Similar results were also reported by Ahmad *et al*. (2016) and Minz (2020).

The treatments revealed remarkable variation in respect of the length of the longest root. Longest root (11.94 cm at 40 DAP ; 14.94 cm at 60 DAP) was recorded in the cuttings of April month. The higher levels of carbohydrates and endogenous auxins in the April cuttings may supplement in the increased cell division in the meristematic tissues of the root tip thus helping in elongation of the root (Davies, 1984). Longest root (14.37 cm at 40 DAP ; 17.37 cm at 60 DAP) was achieved in cuttings of 20 cm size whereas the lowest length of the longest root (8.15 cm at 40 DAP ; 11.15 cm at 60 DAP) was obtained in cuttings of 10 cm size. More photosynthates production due to higher chlorophyll content as a result of higher surface area and higher levels of carbohydrate reserves in the April cuttings may attribute to the length of the longest root. The IBA concentration of 500 ppm recorded the longest root (14 cm at 40 DAP ; 17 cm at 60 DAP) whereas the control treatment recorded the shortest length (7.82 cm at 40 DAP ; 10.82 cm at 60 DAP) of the longest root. At 500 ppm IBA concentration there may be rapid hydrolysis of the stored carbohydrates which may have supplemented to the longest root length. Among the interaction effects, T_{22} recorded longest root (16.28 cm at 40 DAP ; 19.28 cm at 60 DAP) and T_4 recorded shortest length of the longest root (4.92 cm at 40 DAP ; 7.92 cm at 60 DAP***)***. This may be due to the combined effect of the levels of the three factors in the experiment that led to the longest roots. The results were in agreement with the previous works by Malswamkimi *et al*. (2019) and Siddiqua and Thippesha (2018).

A significant variation in the diameter of the longest root was noticed among the different treatments. The diameter of the longest root was highest (0.52 mm at 40 DAP ; 0.77 mm at 60 DAP) in the cuttings of April month. The higher levels of carbohydrates and endogenous auxins in the April cuttings may increase the cell division in the lateral meristem of roots thus leading to thicker roots with increased diameter (Wodzicki, 1978). The diameter of the longest root was highest (0.62 mm at 40 DAP ; 0.87 mm at 60 DAP) in cuttings of 20 cm size whereas lowest diameter (0.4 mm at 40 DAP ; 0.65 mm at 60 DAP) was recorded in cuttings of 10 cm size. The 20 cm size of cuttings may have more carbohydrate reserves as compared to the smaller size of cuttings. Moreover, due to the larger surface area in

20 cm size of cuttings as compared to the smaller sizes, the 20 cm sized cuttings may have more chlorophyll concentration as a result of which more photosynthates may be produced in the 20 cm size of cuttings. The IBA concentration of 250 ppm recorded the highest diameter (0.66 mm at 40 DAP ; 0.91 mm at 60 DAP) of the longest root whereas the control treatment recorded the lowest diameter (0.29 mm at 40 DAP 0.54 mm at 60 DAP). This may be attributed to the rapid hydrolysis of stored carbohydrates into physiologically active forms of sugars by the higher concentration of IBA (Chandramouli, 2001). The hydrolysed carbohydrates provides energy through respiratory activity for the cell division in the lateral meristematic tissues of the roots. Among the interaction effects T_{22} recorded highest root diameter (0.78 mm at 40 DAP ; 1.04 mm at 60 DAP) whereas the T_4 recorded lowest root diameter (0.23 mm at 40 DAP ; 0.48 mm at 60 DAP). This may be due to the combined effect of the levels of the three factors in the experiment that led to the increased root diameter. Similar results were reported in dragon fruit stem cuttings by Ahmad *et al*. (2016), Siddiqua and Thippesha (2018) and Malswamkimi *et al.* (2019).

The treatments revealed significant variation for the fresh weight of the roots. The highest root fresh weight (1.09 g at 40 DAP; 1.42 g at 60 DAP) was obtained in the cuttings of April month. The higher number of roots as a result of higher cambial activity brought about by higher levels of endogenous auxins may be responsible for the higher root fresh weight in April month cuttings (Davies, 1984). Due to higher number of roots there may be higher absorption of water and minerals which may also increase the root fresh weight. The root fresh weight was highest (1.26 g at 40 DAP ; 1.58 g at 60 DAP) in the cuttings of 20 cm size whereas lowest (0.91 g at 40 DAP ; 1.24 g at 60 DAP) root fresh weight was achieved in the cuttings of 10 cm size. A relatively higher levels of carbohydrate reserves and more photosynthates production due to higher chlorophyll content as a result of higher surface area may be responsible for higher fresh weight of the roots in the 20 cm sized cuttings. The IBA concentration of 250 ppm recorded the highest root fresh weight (1.23 g at 40 DAP ; 1.56 g at 60 DAP) whereas the control treatment recorded the lowest root fresh weight (0.79 g at 40 DAP ; 1.12 g at 60 DAP). Rapid hydrolysis of stored carbohydrates into physiologically active forms of sugars by the higher concentration of IBA may increase the plant metabolism thus supplementing to the root fresh weight. Relatively lower root fresh weight (1.21 g at 40 DAP ; 1.53 g at 60

DAP) was recorded in 500 ppm IBA treated cutting which may be attributed to the toxic symptoms produced by auxins at higher concentrations (Tien *et al.*, 2020 ; Aminah *et al.*, 1995 ; Karimi and Yadollahi, 2012 ; Eliasson and Areblad, 1984). The highest root fresh weight (1.46 g at 40 DAP ; 1.79 g at 60 DAP) was achieved in the T_{22} whereas lowest root fresh weight (0.72 g at 40 DAP ; 1.05 g at 60 DAP) was recorded in the T_4. This is in agreement with the findings of Malswamkimi *et al.* (2019) and Minz (2020).

The root dry weight varied significantly due to various treatments. The highest root dry weight (0.40 g at 40 DAP ; 0.62 g at 60 DAP) was obtained in the cuttings of April month. In April month, there may be higher cambial activity due to higher levels of endogenous auxins which may increase the number of roots thus increasing the root dry weight (Wodzicki, 1978). Higher absorption of water and minerals due to increased number of roots in the April month cuttings may also increase the metabolic activity which in turn may increase the root dry weight. The root dry weight was highest (0.42 g at 40 DAP ; 0.63 g at 60 DAP) in the cuttings of 20 cm size whereas lowest root dry weight (0.32 g at 40 DAP ; 0.53 g at 60 DAP) was found in the cuttings of 10 cm size. The 20 cm size of cuttings may have more carbohydrate reserves as compared to the smaller size of cuttings. Moreover, due to the larger surface area in 20 cm size of cuttings as compared to the smaller sizes, the 20 cm sized cuttings may have more chlorophyll concentration as a result of which more photosynthates may be produced in the 20 cm size of cuttings. The IBA concentration of 250 ppm recorded the highest root dry weight (0.41 g at 40 DAP ; 0.63 g at 60 DAP) whereas the control treatment recorded the lowest root dry weight (0.29 g at 40 DAP ; 0.51 g at 60 DAP). Rapid hydrolysis of stored carbohydrates into physiologically active forms of sugars by the higher concentration of IBA may be responsible for the higher root dry weight in the 250 ppm IBA treated cuttings (Chandramouli, 2001). Relatively lower dry weight (0.40 g at 40 DAP ; 0.62 g at 60 DAP) of the roots were recorded in 500 ppm treated cutting which may be due to the toxicity produced by auxins at higher concentrations (Tien *et al.*, 2020 ; Aminah *et al.*, 1995 ; Karimi and Yadollahi, 2012 ; Eliasson and Areblad, 1984). Among the interaction effects the T_{22} (0.50 g at 40 DAP ; 0.71 g at 60 DAP) recorded highest root dry weight whereas the T_4 recorded lowest root dry weight (0.24 g at 40 DAP ; 0.45 g at 60 DAP). This may be due to the combined effect of the levels of the three factors in the experiment that led to the increased root dry weight. Similar results were also reported by Malswamkimi *et al*. (2019) and Minz (2020).

The treatments revealed significant variation with respect to the rooting percentage. The higher rooting percentage (82.15 and 97.15 % at 40 DAP and 60 DAP respectively) obtained in the cuttings of April month may have higher levels of carbohydrates, shoot RNA, proteins and endogenous auxins (Davies, 1984). Relatively higher levels of carbohydrate reserves and more photosynthates production might have contributed in higher rooting percentage (83.75 and 98.75 % at 40 DAP and 60 DAP respectively) in the 20 cm sized cuttings.

The IBA concentration of 250 ppm led to the highest rooting percentage (85.23 and 99.19 % at 40 DAP and 60 DAP respectively) whereas the control treatment recorded the lowest rooting percentage (77.78 and 92.78 % at 40 DAP and 60 DAP respectively). Rapid hydrolysis of stored carbohydrates in the cuttings by the higher concentration of IBA may be responsible for higher rooting percentage in the 250 ppm IBA treated cuttings. Auxins induce stimulus for regeneration of roots by promotion of hydrolysis, mobilization and utilization of nutritional reserves in the region of root and shoot formation (Nanda, 1975).

Relatively lower rooting percentage (84.17 % at 40 DAP ; 99.17 % at 60 DAP) was recorded in 500 ppm IBA treated cutting which may be attributed to the toxicity produced by auxins at higher concentrations (Tien *et al*., 2020 ; Aminah *et al*., 1995 ; Karimi and Yadollahi, 2012 ; Eliasson and Areblad, 1984). The highest rooting percentage (85 and 100 % at 40 DAP and 60 DAP respectively) was in the T_{23} followed by T_{22}. Similar results were reported by Malswamkimi *et al*. (2019) and Siddiqua and Thippesha (2018).

5.2 Changes in shoot growth parameters

A significant variation in the days required for shoot initiation was noticed among the different treatments. Minimum days (33.44 days) for shoot initiation was recorded in the cuttings of April month. The higher levels of endogenous auxins and reserved carbohydrates in the April month cuttings may increase the rate of cell division in the meristematic tissues of vegetative buds present in the cuttings thus leading to early shoot initiation (Davies, 1984; Molnar and Croix, 1972; Wodzicki, 1978). Moreover, the early roots with increased length and number may also be responsible for the early shoot initiation in the April month cuttings. The 20 cm size of cuttings recorded early shoot initiation (29.58 days). The larger size cuttings may have more carbohydrate reserves as compared to the smaller size of cuttings. Moreover, due to the larger surface area as compared to the smaller sizes, the 20 cm sized cuttings may have more chlorophyll concentration as a result of which the cuttings may get proper nourishment for shoot initiation through increased photosynthates production. The early root initiation may also be responsible for the early shoot initiation in the larger sized cuttings. The IBA concentration of 250 ppm recorded early shoot initiation (29.44 days). This may be attributed to the rapid hydrolysis of stored carbohydrates into physiologically active forms of sugars which may favour the shoot initiation. Combined effect of appropriate size and time of cuttings and IBA concentration resulted in early shoot initiation (22.33 days). The results were in agreement with the previous works by Minz (2020), Siddiqua and Thippesha (2018) and Malswamkimi *et al.* (2019).

The shoot numbers varied significantly due to treatments. The cuttings taken in the month of April may have higher levels of carbohydrates and endogenous auxins which may increase the cell division in the vegetative buds of the cuttings thus leading to more number of shoots (3.32 and 4.66 at 40 DAP and 60 DAP respectively) Similar results were also repoted by Davies, 1984; Molnar and Croix, 1972; Wodzicki, 1978. Better root growth during that period might have enhanced absorption of water and minerals leading to better nourishment to the cuttings which in turn may have increased the number off shoots. Larger sized cuttings (20 cm) had relatively higher levels of carbohydrate reserves and more photosynthates production leading to higher number of shoots (3.1 and 4.43 at 40 DAP and 60 DAP respectively). Rapid hydrolysis of stored carbohydrates into physiologically active forms of sugars by the higher concentration of IBA may be responsible for higher shoot number (3.18 and 5.01 at 40 DAP and 60 DAP respectively) in the 250 ppm IBA treated cuttings. Similar results were reported by Malswamkimi *et al*. (2019), Minz (2020) and Siddiqua and Thippesha (2018).

The treatments showed significant difference with respect to the length of primary shoots. Early root and shoot initiation may be responsible for longer primary shoots (13.29 and 14.63 cm at 40 DAP and 60 DAP respectively) in the April month cuttings. This may also be attributed to the higher levels of carbohydrates and endogenous auxins in the April cuttings which may increase the rate of cell division in the meristematic tissues of the shoot tip thus helping in the shoot elongation (Davies, 1984; Molnar and Croix, 1972; Wodzicki, 1978). Larger size cuttings (20 cm) gave longest primary shoot due to more carbohydrate reserves. The 250 ppm IBA solution may cause rapid hydrolysis of the reserved carbohydrates thus providing more energy through respiratory activity resulting in longest primary shoot (14.97 and 16.3 cm at 40 DAP and 60 DAP respectively). Reddy *et al.* (2005) reported that auxin cause increased linear growth of stem due to cell elongation and maximum shoot length was recorded with the application of auxin (IBA, NAA). T_{22} recorded highest length (21.37 and 22.7 cm at 40 DAP and 60 DAP respectively) of primary shoots. Similar results were reported by Malswamkimi *et al*. (2019). There was also significant variation in length of secondary shoots among the treatments as that of primary shoots.

The shoot fresh and dry weight varied significantly due to various treatments (Table 4.25 and 4.27). The higher number of roots with better lengths in the April cuttings may have led to better absorption of water and minerals which may increase the shoot fresh and dry weight. A relatively higher number of shoots with better lengths may also supplement to the fresh and dry weight of shoots in the April month cuttings. The 20 cm size of cuttings may have more carbohydrate reserves as compared to the smaller size of cuttings. Moreover, due to the larger surface area in 20 cm size of cuttings as compared to the smaller sizes, more photosynthates may be produced due to higher chlorophyll concentration which may increase the shoot fresh and dry weight. The 250 ppm IBA solution may have caused rapid hydrolysis of the reserved carbohydrates into physiologically active forms of sugars which may boost the plant metabolism to increase the shoot fresh and dry weight. The increase in shoot weight might be due to IBA treatment, which results in early sprouting, increase in number of leaves and leaf area and well developed shoot system. The results are in agreement with the findings of Stancato *et al*., (2003).

Combined effect of 20 cm size cuttings treated with 250 ppm IBA taken in the month of April (T_{22}) recorded the highest shoot fresh and dry weight. Similar results were reported by Minz (2020) and Siddiqua and Thippesha (2018).

There was significant variation in the root to shoot ratio among the different treatments. The higher root to shoot ratio in the cuttings of April might be be attributed to the higher levels of carbohydrates, shoot RNA, proteins and endogenous auxins (Davies, 1984; Molnar and Croix, 1972; Wodzicki, 1978). The 20 cm size of cuttings recorded highest (0.09 and 0.10 at 40 DAP and 60 DAP respectively) root to shoot ratio. This may be attributed to the increased root and shoot numbers in the 20 cm sized cuttings. The IBA concentration of 250 ppm recorded highest (0.11 and 0.12 at 40 DAP and 60 DAP respectively) root to shoot ratio. The 250 ppm IBA solution may have caused rapid hydrolysis of the reserved carbohydrates thus providing more energy through respiratory activity for cell division and metabolic reactions. The T_{23}, T_{22}, T_{18} and T_{19} treatment combinations recorded highest (0.09 and 0.1 at 40 DAP and 60 DAP respectively) root to shoot ratio. The combination of the specific levels of the three factors that led to higher root to shoot ratio may be responsible for the higher root to shoot ratio in the T_{23}, T_{22}, T_{18} and T_{19} treatment combinations. Concurrent results were reported by Malswamkimi *et al*. (2019) and Siddiqua and Thippesha (2018).

5.3 Biochemical changes in shoot

The treatments had significant influence on nitrogen content in shoots. The higher nitrogen content (2.5 and 2.53 % at 40 DAP and 60 DAP respectively) of shoot was recorded in the cuttings of April month. The early shoot initiation and development of higher number of long shoots may be responsible for the higher nitrogen accumulation (2.59 and 2.63 % at 40 DAP and 60 DAP, respectively) in the 20 cm sized cuttings. The IBA concentration of 250 ppm recorded highest nitrogen content (2.56 and 2.6 % at 40 DAP and 60 DAP respectively) of shoot. IBA at optimum concentration is reported to increase the activity of the hydrolytic enzymes due to which there may be higher production of the plant metabolites thus increasing the nitrogen content in the cuttings. Among the interaction effects, T_{22} recorded highest nitrogen content (2.71 and 2.75 % at 40 DAP and 60 DAP respectively) of shoot. Similar results were reported by Malswamkimi *et al*. (2019) and Siddiqua and Thippesha (2018).

The treatments showed profound difference with respect to the protein content in shoots. The higher nitrogen absorption due to more number of roots may be responsible for higher protein production (15.6 and 15.84 % at 40 DAP and 60 DAP respectively) in the April month cuttings. The 20 cm size of cuttings recorded highest protein content (16.18 and 16.42 % at 40 DAP and 60 DAP respectively) of shoot. The higher numbers of shoots may be responsible for higher protein content in the shoots of 20 cm sized cuttings. The IBA concentration of 250 ppm recorded highest protein content (15.99 and 16.23 % at 40 DAP and 60 DAP respectively) of shoot which might be attributed to the higher production of plant metabolites due to the increased activity of the hydrolytic enzymes by the 250 ppm IBA concentration. T_{22} recorded highest protein content (16.94 and 17.18 % at 40 DAP and 60 DAP respectively) of shoot. Concurrent results were reported by Malswamkimi *et al*. (2019) and Siddiqua and Thippesha (2018).

A significant variation in the chlorophyll content of shoots was noticed among the different treatments. The highest chlorophyll content of shoot (0.38 and 0.44 mg/g at 40 DAP and 60 DAP respectively) was recorded in the cuttings of April month which might be attributed to the higher shoot number and shoot length in the cuttings of April month. The 20 cm size of cuttings recorded highest chlorophyll content of shoot (0.39 and 0.45 mg/g at 40 DAP and 60 DAP respectively). Higher shoot number and longer shoots may be responsible for higher chlorophyll content in the 20 cm sized cuttings. The IBA concentration of 250 ppm recorded highest chlorophyll content (0.39 and 0.45 mg/g at 40 DAP and 60 DAP respectively) of shoot. This might be attributed to the fact that auxins like IBA and NAA is reported to increase the chlorophyll content in cuttings (Deb *et al.* ,2009; Kaur *et al.*, 2002). Combined effect of appropriate size and time of cuttings and IBA concentration attributed to the highest total chlorophyll content of shoot. Similar results were reported by Siddiqua and Thippesha (2018).

5.4 Changes in thickness of vascular cambium

Vascular cambium activity has a significant role in plant growth and development. The vascular cambium activity is regulated by endogenous factors like hormones and reserved food materials and environmental factors like temperature and precipitation. In the present study, the treatments were found to have significant effect on thickness of vascular cambium. The higher thickness (0.07 and 0.08 mm at 40 DAP and 60 DAP respectively) of the vascular cambium of shoot was recorded in the cuttings of April month. This may be attributed to the higher levels of endogenous auxins leading to higher cambial activity in the April month cuttings (Wodzicki, 1978). The 20 cm size of cuttings recorded highest vascular cambium thickness (0.1 and 0.11 mm at 40 DAP and 60 DAP respectively) of shoot. This may be attributed to the higher levels of reserve carbohydrates boosting the rate of cell division. The IBA concentration of 250 ppm recorded highest vascular cambium thickness of shoot (0.08 and 0.1 mm at 40 DAP and 60 DAP respectively). This may be due to the fact that auxins at higher concentrations increase the cambial activity (Davies, 1984;

Molnar and Croix, 1972; Wodzicki, 1978). T_{22} recorded highest vascular cambium thickness (0.12 and 0.15 mm at 40 DAP and 60 DAP respectively) of shoot. The results were in agreement with the previous works by Moghadam *et al*. (2012).

5.5 Survival of saplings

The survival of saplings varied significantly among the treatments (Table4.39). The higher survival (98.13 %) was recorded in the cuttings of April month which might be attributed to the early initiation of roots and shoots. The 20 cm size of cuttings recorded highest survival (99.17 %) whereas the 10 cm size of cutting recorded lowest survival (95.42 %). This may be attributed to the higher number of roots with better length and diameter thus enabling better absorption of water and minerals. The IBA concentration of 250 ppm recorded highest survival (99.17 %) whereas the control treatment recorded lowest survival (95.83 %). Early root and shoot initiation, a greater number of roots and shoots might be the probable reasons for higher survival percentage of the 250 ppm IBA treated cuttings. The treatment combinations T_{23}, T_{22}, T_{19}, T_{18}, T_{11} and T_{10} treatment combinations recorded highest survival (100 %) of the saplings whereas T_4 recorded lowest survival (92.5%) of the saplings. The results were in conformity with the works done by Siddiqua and Thippesha (2018) and Nandi *et al.* (2019).

Computation of treatment combinations (Table 4.41) showed that the cost was highest (Rs 26.12) in 20 cm size cuttings treated with 500 ppm IBA(L_3I_3) followed by 15cm size cuttings treated with 250 ppm L_3I_2 (Rs 25.97) whereas lowest cost (Rs 15.82) in 10 cm cuttings without IBA (L_1I_4). The increased cost in these treatments was due to increase in length of cuttings and IBA concentrations. Although, the cost involvement was high in L_3I_3 and L_3I_2 the early readiness of the dragon fruit saplings would give an indirect economic benefit to the growers by sustaining marketing activity.

CHAPTER VI

SUMMARY AND CONCLUSION

The present study entitled "Standardisation of stem cutting technique of Dragon Fruit (*Hylocereus costaricensis* Britton & Rose)" was carried out at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat during 2020 and 2021. The objective of the experiment was to standardize the size of cuttings, time of cuttings and to find out optimum concentration of IBA for rooting and growth of stem cuttings in dragon fruit. The experiment was laid out in a factorial completely randomised design with three replications. The treatments were: two time of cuttings – January (M_1) and April(M_2); three sizes of cuttings – 10 cm(L_1), 15 cm(L_2), 20 cm(L_3); four IBA concentrations –100 ppm(I_1), 250 ppm(I_2), 500 pm(I_3) and 0 ppm(I_4). There were twenty-four treatment combinations in the trial. The cuttings were raised in polybags (20 cm x 22 cm) under shade net house. The salient results of the experiment were summarised below.

1. There was significant variation in root growth parameters of dragon fruit between the cuttings taken in January and April. April month cuttings took minimum days (18.09 days) for root formation and registered significantly highest root number (10.79 at 40 DAP ; 12.79 at 60 DAP), root length (10.79 cm at 40 DAP ; 12.79 cm at 60 DAP), root fresh weight (1.09 g at 40 DAP ; 1.42 g at 60 DAP), root dry weight (0.40 g at 40 DAP ; 0.62 g at 60 DAP), rooting percentage ((82.15 and 97.15 % at 40 DAP and 60 DAP respectively).

2. Shoot growth parameters also varied significantly between cuttings taken in the month of January and April. Cuttings of April month recorded minimum days (33.44 days) required for shoot initiation. The highest shoot numbers (3.32 and 4.66 at 40 DAP and 60 DAP respectively), length of primary shoots (13.29 and 14.63 cm at 40 DAP and 60 DAP respectively), shoot fresh weight (61.44 and 64.27 g at 40 DAP and 60 DAP respectively), shoot dry weight (9.38 and 10.88 g at 40 and 60 DAP respectively), root to shoot ratio (0.09 and 0.10 at 40 DAP and 60 DAP respectively).

3. Superior shoot quality parameters like nitrogen content (2.5 and 2.53 % at 40 DAP and 60 DAP respectively), protein content (15.6 and 15.84 % at 40 DAP and 60 DAP respectively), chlorophyll content (0.38 and 0.44 mg/g at 40 DAP and 60 DAP respectively) were obtained in the cuttings taken in the month of April.
4. Cuttings of April month recorded the highest vascular cambium thickness (0.07 and 0.08 mm at 40 DAP and 60 DAP respectively).
5. Survival of dragon fruit saplings were better in April month cuttings (98.13 %).
6. The size of cuttings had significant effect on the root growth parameters. The 20 cm size of cutting recorded minimum days for root formation (18.46 days) and registered significantly highest root number (12.81 at 40 DAP ; 14.81 at 60 DAP), root length (12.81 cm at 40 DAP ; 14.81 cm at 60 DAP), root fresh weight (1.26 g at 40 DAP ; 1.58 g at 60 DAP), root dry weight (0.42 g at 40 DAP ; 0.63 g at 60 DAP) and rooting percentage (83.75 and 98.75 % at 40 DAP and 60 DAP respectively).
7. Shoot parameters registered significant variations among the sizes of cuttings. The 20 cm size of cuttings required minimum days for shoot initiation (29.58 days) and recorded significantly highest shoot numbers (3.1 and 4.43 at 40 and 60 DAP, respectively), length of primary shoots (16.73 cm at 40 DAP and 18.06 cm at 60 DAP), shoot fresh weight (71.68 g at 40 DAP and 74.52 g at 60 DAP), shoot dry weight (10.02 g at 40 DAP and 11.52 g at 60 DAP) and root to shoot ratio (0.09 and 0.10 at 40 and 60 DAP, respectively).
8. The cuttings of 20 cm size recorded superior shoot quality parameters like nitrogen content (2.59 and 2.63 % at 40 DAP and 60 DAP respectively), protein content (16.18 and 16.42 % at 40 DAP and 60 DAP respectively) and chlorophyll content (0.39 and 0.45 mg/g at 40 DAP and 60 DAP respectively).
9. The 20 cm size of cuttings recorded thickest vascular cambium (0.1 and 0.11 mm at 40 DAP and 60 DAP respectively).
10. Dragon fruit saplings prepared from 20 cm sized cuttings recorded better survival (99.17%).
11. Root parameters showed significant variation with respect to the IBA concentrations. The 250 ppm IBA treated cuttings recorded significantly highest

root number (13.97 at 40 DAP ; 15.97 at 60 DAP), root length (13.97 cm at 40 DAP ; 15.97 cm at 60 DAP), root fresh weight (1.23 g at 40 DAP ; 1.56 g at 60 DAP), root dry weight (0.41 g at 40 DAP ; 0.63 g at 60 DAP) and rooting percentage (85.23 and 99.19 % at 40 DAP and 60 DAP respectively). Whereas, the 500 ppm IBA treated cuttings recorded minimum days for root formation (15.06 days) and the longest root (14 cm at 40 DAP ; 17 cm at 60 DAP).

12. The IBA concentrations had significant effect on the shoot parameters. The 250 ppm IBA treated cuttings recorded early shoot initiation (29.44 days) and significantly highest shoot numbers (3.18 and 5.01 at 40 DAP and 60 DAP respectively), length of primary shoots (14.97 and 16.3 cm at 40 DAP and 60 DAP respectively), shoot fresh weight (70.02 and 72.86 g at 40 DAP and 60 DAP respectively), shoot dry weight (9.71 and 11.21 g at 40 DAP and 60 DAP respectively) and root to shoot ratio (0.11 and 0.12 at 40 DAP and 60 DAP respectively).
13. Shoot quality parameters like nitrogen content (2.56 and 2.6 % at 40 DAP and 60 DAP respectively), protein content (15.99 and 16.23 % at 40 DAP and 60 DAP respectively) and chlorophyll content (0.39 and 0.45 mg/g at 40 DAP and 60 DAP respectively) were superior in the cuttings treated with 250 ppm IBA.
14. The thickest vascular cambium (0.08 and 0.1 mm at 40 DAP and 60 DAP respectively) was recorded in the 250 ppm IBA treated cuttings.
15. The 250 ppm IBA treated cuttings led to highest survival (99.17 %) of the dragon fruit saplings.
16. The $T_{22}(M_2L_3I_2)$ treatment combination recorded significantly highest root number (18.84 at 40 DAP; 20.83 at 60 DAP), root length (18.83 cm at 40 DAP; 20.83 cm at 60 DAP), root fresh weight (1.46 g at 40 DAP; 1.79 g at 60 DAP) and root dry weight (0.50 g at 40 DAP; 0.71 g at 60 DAP). Whereas, T_{23} recorded early root initiation (14 days) and the treatment combinations *viz.*,T_{23}, T_{22}, T_{18}, T_{19}, T_{10} and T_{11} recorded highest rooting percentage (85 and 100 % at 40 DAP and 60 DAP respectively).
17. Shoot parameters like days required for shoot initiation (22.33 days), shoot numbers (4.4 and 5.73 at 40 DAP and 60 DAP respectively), length of primary shoots (21.37 and 22.7 cm at 40 DAP and 60 DAP respectively), shoot fresh

weight (84.07 and 86.9 g at 40 DAP and 60 DAP respectively) and shoot dry weight (11.93 and 13.43 g at 40 DAP and 60 DAP respectively) were superior in the $T_{22}(M_2L_3I_2)$ treatment combination. The root to shoot ratio was best (0.09 and 0.1 at 40 DAP and 60 DAP respectively) in the treatment combinations *viz*., T_{23}, T_{22}, T_{18} and T_{19}.

18. The $T_{22}(M_2L_3I_2)$ treatment combination recorded significantly highest nitrogen content (2.71 and 2.75 % at 40 DAP and 60 DAP respectively), protein content (16.94 and 17.18 % at 40 DAP and 60 DAP respectively), chlorophyll content (0.45 and 0.51 mg/g at 40 DAP and 60 DAP respectively).
19. The vascular cambium thickness was highest (0.12 and 0.15 mm at 40 DAP and 60 DAP respectively) in the $T_{22}(M_2L_3I_2)$ treatment combination.
20. The treatment combinations *viz*., T_{23}, T_{22}, T_{19}, T_{18}, T_{11} and T_{10} led to highest survival (100 %) of the dragon fruit saplings.

Conclusion

Thus, it may be concluded that 20 cm size cuttings of dragon fruit taken in the month of April treated with 250 ppm IBA appeared to be the best treatment combination which registered minimum days required for root formation and shoot initiation, highest root and shoot growth parameters, shoot nitrogen, protein, chlorophyll and thickest vascular cambium layer with 100% survival of saplings.

BIBLIOGRAPHY

Abbas, M.M. ; Raza, M.K. ; Javed, M.A. ; Saeed, A.S. ; Riaz, S. and Iqbal, J. (2013). Production of true-to-type guava nursery plants via application of IBA on soft wood cuttings. *J. Agric. Res.*, **51** (3) : 289-296.

Abdullah, G.R. and Al-Khateeb, A.A. (2004). Rooting response of lime (*Citrus aurantifolia Christm* Swingle) cultivar Loomi to Indole Butyric Acid (IBA), rooting media and planting date. *Sci. J. King Faisal Univ*., **5** (2) : 53-71.

Ahmad, H. ; Mirana, A. S. ; Mahbuba, S. ; Tareq, S. M. and Jamaluddin, A. F. M. (2016). Performance of IBA concentrations for rooting of dragon fruit (*Hylocereus undatus*) stem cuttings. *Int. J. Business, Social and Scientific Research*, **4** (4): 231-234.

Ahmed, A. E. (2006). Mass propagation of pitaya (dragon fruit). *Fruits*, **61** (5) : 313 - 319.

Almeida, M. R. D.; Aumond, M.; Costa, C. T. D.; Schwambach, J.; Ruedell, C. M.; Correa, L. R.; Fett, A. G. (2017). Environmental control of adventitious rooting in Eucalyptus and Populus cuttings. *Trees*, **31** (5), 1377-1390. DOI : https://doi.org/10.1007/s00468-017-1550-6

Aminah, H.; Dick, J. M. P.; Leakey, R. R. B.; Grace, J. and Smith, R. I. (1995). Effect of indole butyric acid (IBA) on stem cuttings of *Shorea leprosula*. *Forest Ecology and Management*, **72** : 199-206.

Britton, N. L. and Rose, J. N. (1963). The Cactaceae : description and illustrations of plants of the cactus family, Volumes 1 and 2, Courier Corporation , Dover, New York (U.S.A.).

Cabahug, R. A. M. ; Nam, S. Y. ; Lim, K. B. ; Jeon, J.K. and Hwang, Y. J. (2018) .Propagation techniques for Ornamental Succulents; *Flower Res. J.* **26** (3) : 90 - 101.

Cavalcante, I. H. L. and Martins, A. B. G. (2008). Effect of juvenility on cutting propagation of red pitaya. *Fruits*, **63** : 277 – 283.

Chandramouli, H. (2001). Influence of growth regulators on the rooting of different types of cuttings in *Bursera penicilliatai* (DC) Engl. M.Sc. Thesis, Univ. Agric. Sci., Bangalore, Karnataka (India).

Curir, P. ; Sulis, S. ; Bianchini, P. ; Marchesini, A. ; Guglieri, L. and Dolci, M. (1992). Rooting herbaceous cuttings of *Genista monosperma* Lam.: Seasonal fluctuations in phenols affecting rooting ability. *J. Hort. Sci*., **67** (3) : 301 - 306.

Das, P. ; Bask, U. C. and Das, A. B. (1997). Metabolic changes during rooting in pregirdled stem cuttings and air layers of Heritiera. *Bot. Bull. Acad. Sin.*, **38** : 91 – 95.

Davies, F. T. (1984). Shoot RNA, cambial activity and indolebutyric acid effectivity in seasonal rooting of juvenile and mature *Ficus pumila* cuttings. *Physiol. Plant*, **62**: 571 - 575.

Deb, P. B. N. ; Ghosh, S. K. and Suresh, C. P. (2009). Effect of different concentrations of IBA and NAA on success and groeth of semi hardwood cuttings of lemon (Citrus limon). *Environ. Ecol.* , **27** (3) : 1130 – 1131.

Dhruve, L. (2017). Studies on methods of propagation of dragon fruit (*Hylocereus undatus*) cultivars. M.Sc.(Horti) thesis. College of Horticulture, Dr. Y.S.R. Hoticultural University, Venkataramannagudem, West Godavari District, Andhra Pradesh. http://krishikosh.egranth.ac.in/handle/1/5810036444

Druege, U. ; Zerche, S. and Kandner, R. (2004). Nitrogen and storage-affected carbohydrate partitioning in high-light-adapted pelargonium cuttings in relation to survival and adventitious root formation under low light. *Ann Bot*., **94**: 831-832

Eliasson, L. and Areblad, K. (1984). Auxin effects on rooting in pea cuttings. *Physiol. Plant*, **61** : 293-297.

Fathi, G. and Ismailpor, B. (2000). Plant growth regulators. Jihad-e-Daneshgahi Publication, Mashhad, Iran.

Fumuro, M. (2011). Effects of the Character of Cuttings and the Type of Auxin on Rooting Ability in Dragon Fruit. Combined *Proceedings Int. Plant Prop. Society*, **61**: 270 - 274.

Fumuro, M. (2015). Effects of light intensity, soil acidity and nitrogen concentration on the vegetative growth of pitaya seedlings. Proceedings of the 2015 Annual Meeting of the International Plant Propagators Society. *ISHS Acta Hort*., **1140** : 105 – 112. DOI: https://doi.org/ 10.17660/ActaHortic.2016.1140.21

Ghosh, J. K. and Basu, R. N. (1973). Effect of nutrition of stock plant on rooting of cuttings. *Indian Agriculturist,* **17** : 7 – 16.

Gomez, R. L. ; Perez, J. C. D. and Martinez, G. F. (2000). Vegetative propagation of three species of cacti : Pitaya (*Stenocereus griseus*), Tunillo (*Stenocereus stellatus*) and Jiotilla (*Escontria chiotilla*). *Agrociencia*, **34** : 363 – 367.

Gunasena, H. P. M. ; Pushpakumara, D. K. N. G. and Kariyawasam, M. (2007). Dragon Fruit *Hylocereus undatus* (Haw.) Britton and Rose. *Underutilized fruit trees in Sri Lanka*, **1** : 110 – 141.

Haissig, B.E. (1986). Metabolic processes in adventitious rooting of cuttings. In: Jackson M.B. (eds) New Root Formation in Plants and Cuttings. Developments in Plant and Soil Sciences , Vol. 20. Springer , Dordrecht. DOI : https://doi.org/10.1007/978-94-009-4358-2_5

Hartmann, H. T. ; Kester, D. E. ; Davies, F.T. and Geneve, R.L. (2002). Plant propagation, principles and practices, 6 th edition, Prentice hall of India Pvt. Ltd., New Delhi, pp :329 – 385.

Hartmann, H. T. ; Kester, D.E. ; Davies, F.T. and Geneve, R.L. (2011) .Hartmann and Kester's plant propagation: Principles and Practices .8th ed., Pearson Education Ltd., Pearson Prentice Hall, USA.

Hua, Q. ; Chen, P. ; Liu, W. ; Ma, Y. ; Liang, R. ; Wang, L. ; Wang, Z. and Hu, G. (2015). *A protocol for rapid in vitro propagation of genetically diverse pitaya. Plant Cell, Tissue and Organ Culture (PCTOC)* .**120** (2) : 741 - 745.

Jackson, M.L. (1973). Soil chemical analysis, Prentice Hall of India Pvt. Ltd., New Delhi, pp.498

Jalgaonkar, K. ; Mahawar, M. K. ; Bibwe, B. and Kannaujia, P. (2020). Postharvest profile, processing and waste utilization of dragon fruit (*Hylocereus* spp.) : A Review. *Food Reviews International*, pp- 1525 – 6103. https://doi.org/10.1080/87559129.2020.1742152

Jeronimo, M. C ; Orsine, J. V. C. ; Borges, K. K. and Novaes, M. R. C. G. (2015). Chemical and physico- chemical properties, antioxidant activity and fatty acids profile of red pitaya (*Hylocereus undatus* (Haw.) Britton and Rose) grown in Brazil. *J. Drug Metabolism and Toxicology*, **6** : 1 - 6.

Johanson, D. A. (1940). Plant micro technique, 5th ed., Mc-Graw-Hill book company, INC, New York, pp- 523.

Kakade, V. ; Dinesh, D. ; Singh, D. ; Bhatnagar, P.R. and Kadam, D. (2019). Influence of length of cutting on root and shoot growth in dragon fruit (*Hylocereus undatus*); *Indian J. Agril. Sc.,* **89** (11) : 1895 - 1899.

Kari, R. ; Lukman, A.L. ; Zainuddin, R. and Ja'afar, H. (2010). Basal media for in-vitro Germination of Red-Purple Dragon Fruit *Hylocereus polyrhizus*. *J. Agrobiotech*, **1**: 87 - 93.

Karimi, S. and Yadollahi, A. (2012). Using putrescine to increase the rooting ability of hardwood cuttings of the peach x almond hybrid GF677. *J. of Agrobiology*, **29** (2) : 63-69. DOI : https://doi.org/10.2478/v10146-012-0010-6

Karunakaran , G. ; Arivalagan, M. and Sriram, S. (2019). Dragon fruit country report from India. Dragon Fruit Network: Marketing and the whole value chain and steering committee meeting.

Kasim, H. and Basri, Z. (2015). The strength of MS media and sterilization technique on red dragon fruit (*Hylocereus polyrhizus*) seed germination. *Agroland: The Agri. Sc. J.*, **2** (1) : 33 - 40.

Kaur, S. ; Cheema, S. S. ; Chhabra, B. R. and Talwar, K. K. (2002). Chemical induction of physiological changes during adventitious root formation and bud break in grapevine cuttings. *Plant Growth Regul*., **37** : 63 – 68.

Lazcano, C. A.; Davies, F. T.; Estrada, A. A.; Duray, S. A. and Olalde, V. (1999). Effect of Auxin and Wounding on Adventitious root formation of Prickly-pear cactus cladodes. *Hort. Tech*., **9** (1) : 99-102.

Lone, A. B.; Colombo, R. C.; Silva, C. M. D.; Takahashi, L. S. A.; Inagati, A. T. and Roberto, S. R. (2018). Shading levels in the development of dragon fruit (pitaya) nurseries. *Agron.-Sc. Biotechnol.*,**4** (1) : 8 - 13.

Malsawmkimi ; Ringphawan, H. and Alila, P. (2019). Effect of various levels of IBA and stem cutting sizes on propagation of dragon fruit (*Hylocereus polyrhizus*). *Current Hort.*, **7** (1) : 64 - 68.

Minz, V. (2020). Effect of growing media and plant growth regulators on root and shoot growth of dragon fruit cuttings. M.Sc. (Horti) thesis. Indira Gandhi Krishi Viswavidyalaya, Raipur, Chattisgarh (India). https://krishikosh.egranth.ac.in/handle/1/5810163143

Minz, V., Panigrahi, H. K. and Sangeeta (2021). Effect of different plant growth regulators and media on shooting of stem cuttings in dragon fruit. *The Pharma Innovation J*., **10** (8) : 330 – 332.

Mizrahi, Y. ; Nerd, A. and Nobel, P. S. (1997). Cacti as a crop. *Hort. Review*, **18** : 291 – 320.

Moghadam, A.R.L.; Ardebili, Z.O. and Rezaie, L. (2012). Effect of indole butyric acid on micrografting of cactus. *African J. of Biotechnol.* **11**(24): 6484-6493. DOI: https://doi.org/10.5897/AJB11.2672

Molnar, J. M. and Croix, L. J. L. (1972). Studies of the rooting of cuttings of Hydrangea macrophylla: enzyme changes. *Canadian J. Botany*, **50** (2): 315 - 322.

Mordor Intelligence (2020). Dragon fruit market- Growth, trends, Covid- 19 impact and forecasts (2021-2026). https://www.mordorintelligence.com/industry-reports/dragon-fruit-market

Nanda, K. K., (1975). Physiology of adventitious root formation. *Indian J. Pl. physiol*., **18**: 80-89.

Nandi, P. ; Tarai, R. K. and Ghosh, S. N. (2019). Study on rooting behaviour of different types of cutting of Dragon fruit at different period of year. *Int. J. Minor Fruits, Medicinal and Aromatic Plants*, **5** (2) : 45 - 49.

Panse, V.C. and Sukhatme, P.V. (1985). Statistical methods for agricultural workers, ICAR, New Delhi.

Pedda, K. D. ; Sai, K. N. ; Suneetha, P. ; Rao, K. B. ; Naresh, K. M. and Krishna, M. S. R. (2019). Multiple Shoot Regeneration in Seed-derived Immature Leaflet Explants of Red Dragon Fruit (*Hylocereus costaricensis*). *Research J. Pharm. Tech.* **12**: 1491 - 1494.

Piper, C.S. (1966). Soil and plant analysis. Hans Publishers, Bombay, India.

Poethig, R.S. (2013). Vegetative phase change and shoot maturation in plants. *Current topics in developmental biology*, **105**: 125-152.

Rahad, M. A. B. ; Islam, M. A. ; Rahim, M. A. and Monira, S. (2016). Effects of rooting media and varieties on rooting performance of dragon fruit cuttings (*Hylocereus undatus* Haw.). *Res. Agric. Livest. Fish*., **3** (1) : 67 – 77.

Rana, H. S. (1996). Mist propagation of plum clonal rootstocks by stem cuttings and their relationship with some biochemical constituents. *Adv. in Hort. Forestry*, **5** : 61 – 68.

Raveh, E. ; Nerd, A. and Mizrahi, Y. (1998). Response of two hemiepiphytic fruit crop cacti to different degrees of shade. *Scientia Hort*., **73** (2-3) : 151 – 164.

Reddy, C.H., Chandra sekhar, R., Reddy, Y.N. and Rajkumar, M. (2005). Effect of growth regulators on rooting of Scented geranium (*Pelargonium graveolens* (L.) cuttings. *Journal of Research ANGARU*, **33** (4) : 114-116.

Seran, T. H. and Thiresh, A. (2015). Root and shoot growth of dragon fruit (Hylocereus undatus) stem cutting as influenced by Indole Butyric Acid. *Agril.-Biolog. Sci. J.*, **1** (2) : 27 - 30.

Sheng, W. K. W. ; Sundarasekar, J. ; Sathasivam, K. and Subramaniam, S. (2016) . Effects of plant growth regulators on seed germination and callus induction of *Hylocereus costaricensis*. *Pak. J. Bot*., **48** (3) : 977 - 982.

Shivaji, T. ; Madhavi, K. and Sudhavani, V. (2014). Effect of type of cuttings and IBA concentrations on the propagation of Fig (Ficus carica) Cv. Poona Fig under open conditions. *Trends of Biosciences*, **7** (11) : 1087-1090.

Siddiqua, A. and Thippesha, D. (2018). Influence of plant growth regulators on rooting of stem cuttings in dragon fruit [*Hylocereus undatus* (Haworth) Britton and Rose]. *Int. J. of Chemical Studies,* **6** (5) : 1834 - 1839.

Sousa, G. G. ; Sousa, S. B. ; Pereira, A. C. S.; Marques, V. B. ; Silva, M. L. G. and Lopes, J. S. (2021). Effect of saline water and shading on dragon fruit (pitaya) seedling growth. *Rev. bras. Eng. Agric. Ambient*., **25** (8) : 547

– 552. DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v25n8p547-552

Stancato, G. C. ; Aguiar, F. F. A. ; Kanashiro, S. ; Tavares, A. R. ; Catharino, E. L. M. and Silveira, R. B. (2003). *Rhipsalis grandiflora* Haw. (Cactaceae) propagation by stem cuttings. *Scientia Agricola*, **60** (40) : 651 - 656.

Sudarjat ; Isnaniawardhani, V. ; Mubarok, S. (2018). Different growing media effect on the cutting quality of two dragon fruit species (*Hylocereus* sp.). *J. Agron.* , **17** (3) : 174 – 179.

Suman, K. ; Rani, R. and Reddy, P. V. (2017). Response of dragon fruit (*Hylocereus undatus*) explants on MS media with growth regulators under in-vitro for mass multiplication. *Agric. Update*, **12** : 1 – 8.

Sugunakrishnan, S. (2015). Effect of time, etiolation and IBA concentration on rooting of semi hardwood cuttings of tamarind (*Tamarindus indica* L.). M.Sc. Thesis. Dr. Y.S.R. Hortic. Univ., Venkataramannagudem, Andhra Pradesh (India).

Thiha, S. (2019). Effects of explants and growth regulators on in-vitro regeneration of dragon fruit (*Hylocereus undatus* Haworth). Thesis. Yezin Agril. University, Nay PyiTaw, Myanmar.

Thimmaiah, S. K. (1999). Standard methods of biochemical analysis. Kalyani Publishers, New Delhi, India, pp-78 – 79 & 307 – 308.

Tien, L. H.; Chac, L. D.; Oanh, L. T. L.; Sau, P.T.L.H.T.; Huang, N.; Thanh, V.Q.; Doudkin, R.V. and Thinh, B. B. (2020). Effect of auxins (IAA, IBA and NAA) on clonal propagation of *Solanum procumbens* stem cuttings. *Plant Cell Biotechnol. Molecular Biol.*, **21** (55 & 56) : 113-120.

Tripathi, P. C. ; Karumakaran, G. ; Sankar, V. and Senthikumar, R. (2014). Dragon Fruit: Nutritive and ruminative fruit. Central Hort. Exp. Station, IIHR, Chettalli - 571248, Kodagu, Karnataka.

Trivellini, A. ; Lucchesini, M. ; Ferrante, A. ; Massa, D. ; Orlando, M. ; Incrocci, L. and Sodi, A. M. (2020). Pitaya, an attractive alternative crop for Mediterranean Region. *Agronomy*, **10** : 10 – 65. DOI : https://doi.org/10.3390/agronomy10081065

Upadhyay, S.D. and Badyal, J. (2007). Effect of growth regulators on rooting of pomegranate (*Punica granatum* L.) cutting. *Haryana J. Hort. Sci*., **36** (2) :58-59.

Vinas, M. and Brenes, M. F. (2012). In vitro propagation of purple pitahaya (*Hylocereus costaricensis* [F.A.C. Weber] Britton and Rose) cv. Cebra. *In Vitro Cell. Dev. Biol. Plant*, **48**: 469-477.

Wakchaure, G, C. ; Kumar, S. ; Meena , K. K ; Rane, J. and Pathak, H. (2020). Dragon fruit marketing in India: Scope, Marketing, Constraints and

Policy Issues. NIASM Technical Bulletin- 46, ICAR- NIASM, Malegaon, Baramati, Pune- 413115, Maharashtra, India.

Wang, B.; Wei, Q. ; Zheng, W. ; Li, X. ; Cai, Y. and Peng, Y. (2011). Dragon fruit grafting method. *Chinese patent No. CN1021134498A.* Guizhou Fruit Institute , China.

Weismann, Z. and Lavee, S. (2011). Relationship of carbohydrate sources and Indole-3-Butyric Acid in olive cuttings. *Australian J. Plant Physiol*., **22** (5) : 811 – 816

Weixi, K. ; Shuying, L. ; Yucang, S. ; Wenxue, W. ; Lichun, Y. and Yonghui, Z. (2015). Pitaya grafting method .*Chinese patent No. CN105103966A.* Res. Inst. of Tropical Eco. Agril. Sc. , Yunan Academy of Agril. Sc. , Yunnan Changrun Ecological Agril. Tech. Dev. Co. Ltd., China.

Wodzicki, T. J. (1978). Seasonal variation of auxin in stem cambial region of *Pinussihestris* L.; *Acta Societatis Botanicorum Poloniae,* 47(3): 225-231.

Xiankun, L. ; Shuhua, L. and Yangfang, T. (2013). Single- thorn grafting method for pitaya .*Chinese patent No. CN102845240A.* Guangxi Institute of Botany, The Chinese Academy of Science , China

Ziyou, H. (2015) . Dragon fruit grafting method. *Chinese patent No. CN104770226A.* Guangxi Agril. Voc. College, China.

Plate 1: Dragon fruit plant at bearing stage in KVK, Jorhat

Plate 2: Dragon fruit mother block at KVK, Jorhat

Plate 3: Collection of segments

Sizing of cuttings

Curing of cuttings in shade

IBA solution treatment

FYM, Sand and Soil @ 1:2:1

Plate 4: Preparation and planting of cuttings

Plate 5: A general view of the experimental plot

Plate 6: Root formation

Plate 7: Shoot initiation

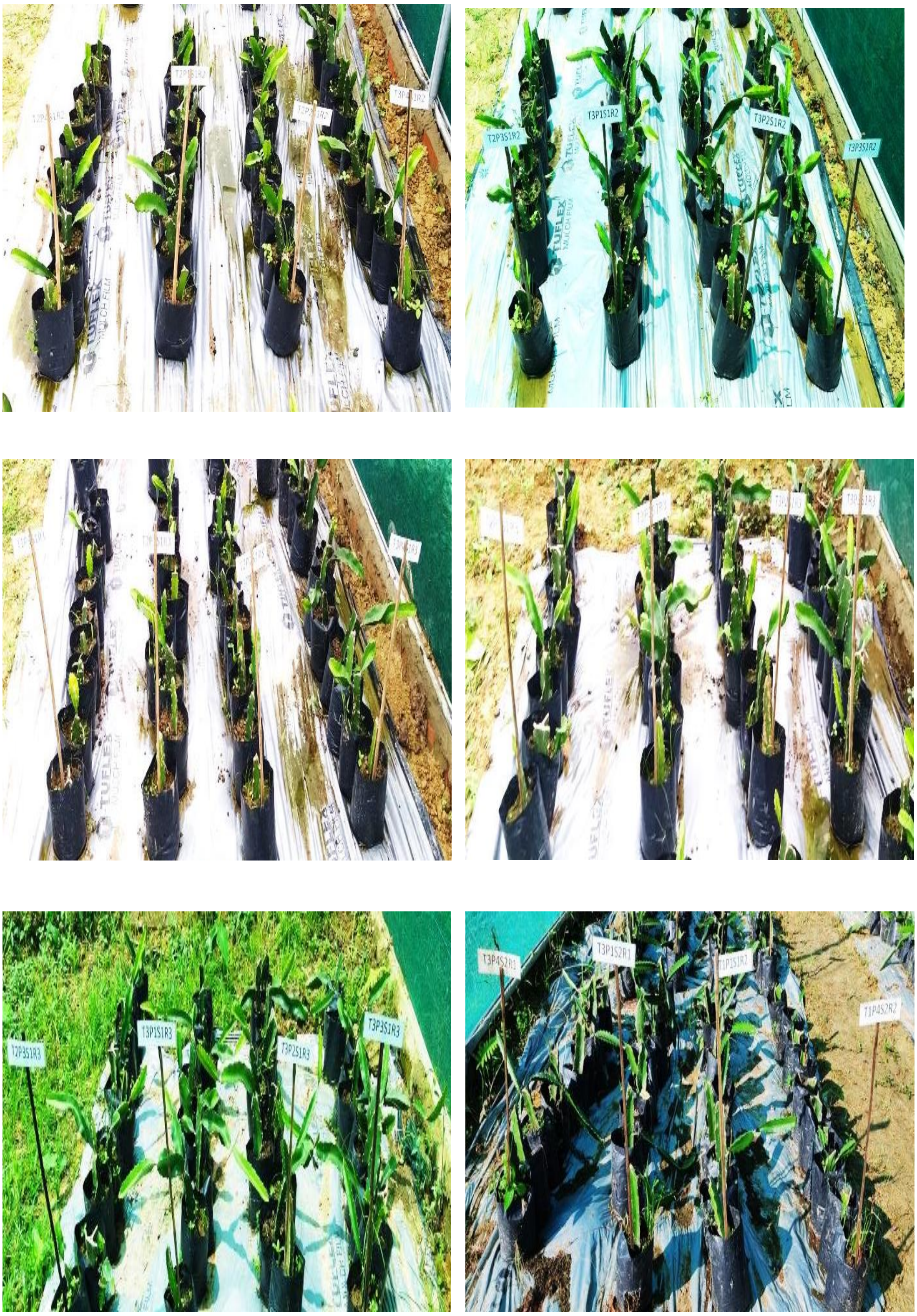


Plate 8: Sapling growth at 40 days after planting

Plate 9: Root and shoot growth at 40 days after planting

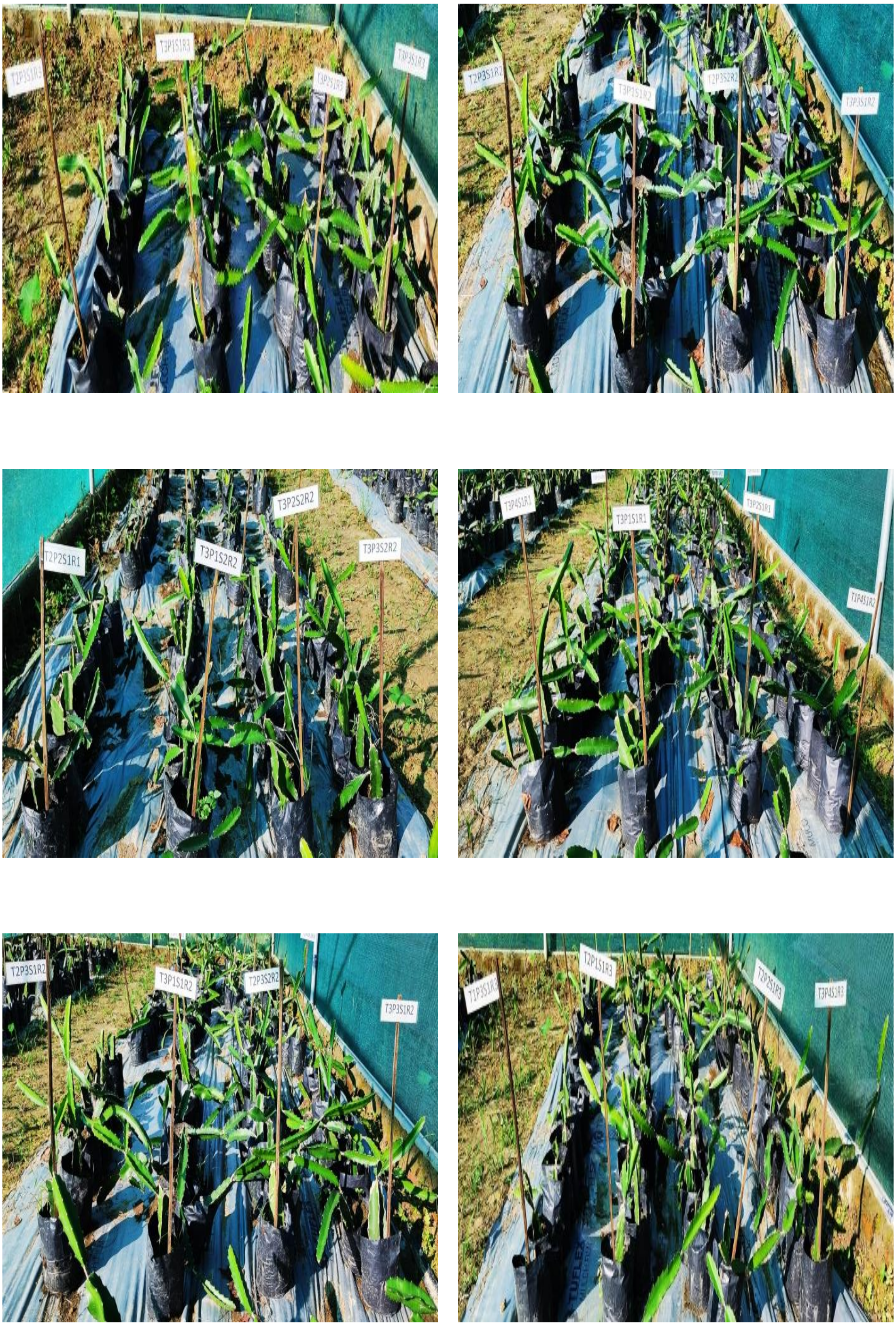
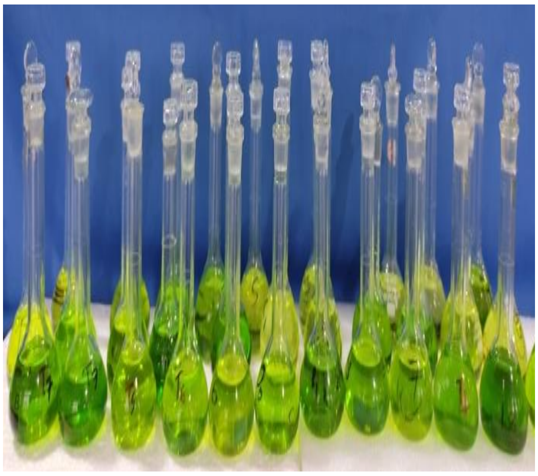


Plate 10: Sapling growth at 60 days after planting

Plate 11: Root and shoot growth at 60 days after planting



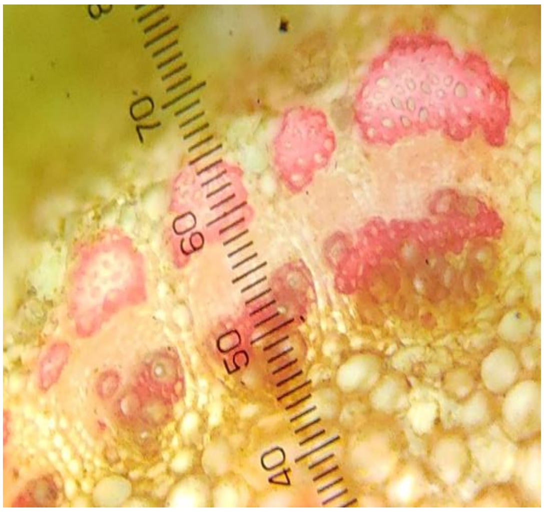
Extracted chlorophyll samples

Recording the absorbance of the extracted chlorophyll samples

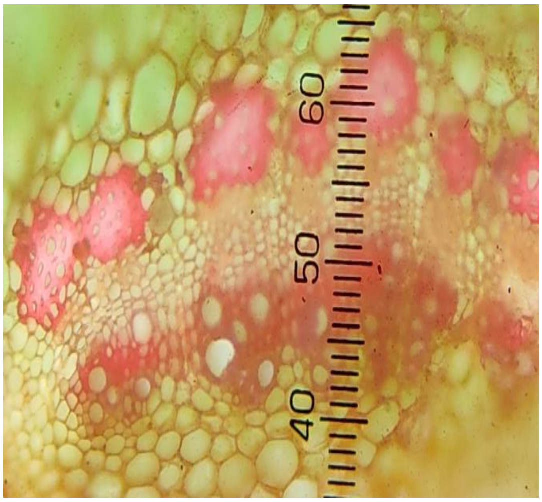
Digested samples for nitrogen estimation

Kjeldahl apparatus and Kelplus Distillation System

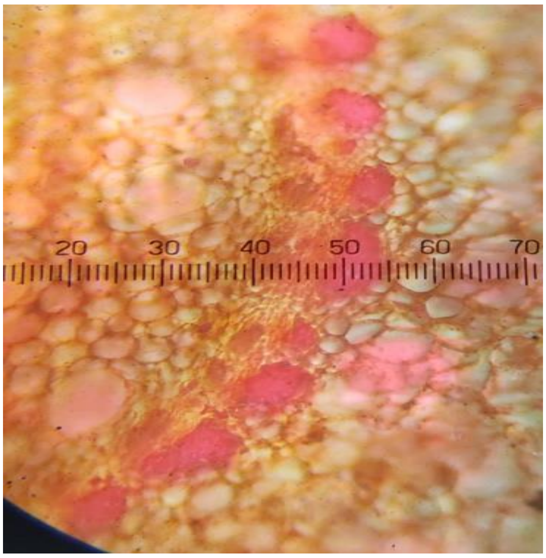
Plate 12: Chlorophyll and Nitrogen estimation in laboratory



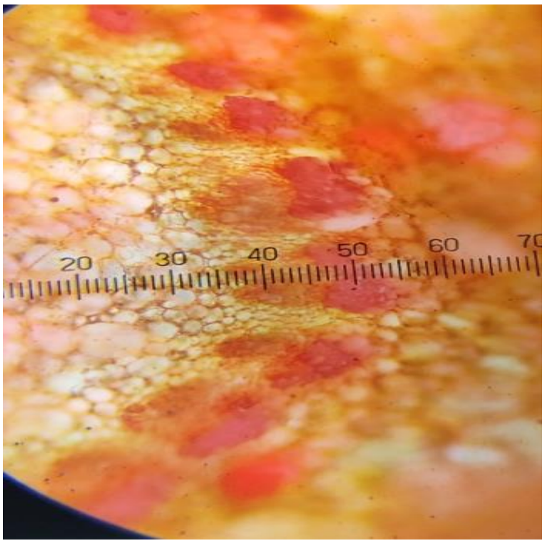
T_{22} ($M_2L_3I_2$)



T_{22} ($M_2L_3I_2$)



T_4 ($M_1L_1I_4$)



T_4 ($M_1L_1I_4$)

Plate 13: Microscopic view of vascular cambium thickness

APPENDIX I

RATES OF THE ARTICLES

ARTICLES	RATES
Polybag	Rs 1.23/bag
Cutting	Rs 1/cm
Sand	Rs 20/ cft
Soil	Rs 800/ 100 cft
FYM	Rs 800/ 100 cft
Labour	Rs 303.76/ manday
IBA	Rs 2725/ 25 g

***Labour rate as per Assam Agricultural University guidelines**

***Total mandays required for 720 saplings = 8**

Therefore, labour cost per sapling = Rs (303.76×8)/720

= Rs 3.38