MULTIPLICATION OF WATER APPLE (*Syzygium samarangense*) CULTIVARS THROUGH STEM CUTTING USING DIFFERENT PLANT GROWTH REGULATORS

HASIBUL HASAN

DEPARTMENT OF HORTICULTURE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

JUNE, 2020

MULTIPLICATION OF WATER APPLE (*Syzygium samarangense*) CULTIVARS THROUGH STEM CUTTING USING DIFFERENT PLANT GROWTH REGULATORS

BY

HASIBUL HASAN

REGISTRATION NO. 18-09190

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka-1207
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
HORTICULTURE

SEMESTER: JANUARY- JUNE, 2020
Approved by

Dr. Mohammad Humayun Kabir	**Dr. Jasim Uddain**
Professor	**Professor**
Supervisor	**Co-Supervisor**

Prof. Dr. Md. Jahedur Rahman
Chairman
Examination Committee

Department of Horticulture
Sher-e-Bangla Agricultural University
Sher-e -Bangla Nagar, Dhaka-1207

Memo No.: Date:

CERTIFICATE

This is to certify that the thesis entitled ***"MULTIPLICATION OF WATER APPLE (Syzygium samarangense) CULTIVARS THROUGH STEM CUTTING USING DIFFERENT PLANT GROWTH REGULATORS"*** *submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in HORTICULTURE****, embodies the result of a piece of bona fide research work carried out by* ***HASIBUL HASAN,*** *Registration No.* ***18-09190*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: June , 2020
Dhaka, Bangladesh

Dr. Mohammad Humayun Kabir
Professor
Supervisor

The greatest gift from Allah I ever had

‘’I had come to the world through my Parents’’

ACKNOWLEDGEMENTS

*All praises and thanks are due to the supreme ruler of the universe, the "**Almighty Allah**" who grace bestowed upon me for accomplishment of this research study.*

*I express the deepest sense of respect and heartiest gratitude to my respectable supervisor **Dr. Mohammad Humayun Kabir**, Professor, Department of Horticulture, Sher-e-Bangla Agricultural University for his efficient and scholastic guidance, constructive criticism, valuable suggestions and immense help to carry out the research work toward successful completion and preparation of the thesis by necessary corrections and modification through reviewing the text.*

*I wish to express my sincere appreciation and heartfelt gratitude to my Co-supervisor **Prof. Dr. Jasim Uddain** Department of Horticulture, SAU, Dhaka, for his valuable suggestions, constant cooperation, inspiration and sincere advice to improve the quality of the thesis.*

*I am grateful to all those people who contributed to this research work specially to my dear **respected teachers** Department of Horticulture, Sher-e-Bangla Agricultural University for their precious guidance, constructive criticism, valuable suggestions and constant cooperation toward successful completion and preparation of the thesis.*

*I express my gratitude to **Ministry of Science and Technology,** Government of People's Republic of Bangladesh for National Science and Technology Fellowship which helps me economically to carry out my field works and preparation of thesis paper.*

I express my immense indebtedness and the deepest senses of gratitude to my beloved parents and brothers who sacrificed all their happiness during the whole study period. I am grateful to all the respondents in the study area for their cooperation and help in accomplishing the objectives of this research work.

I wish to extend my heartfelt thanks and gratitude to all of my relatives, friends and younger brother in hall for their kind help, inspiration, blessing and encouragement that opened the gate of my higher study.

Finally I express my sincere appreciation to Md. Mrufur Rahman, Md. Mayen Uddin, Md. Matiul Alom, Md. Aman Ullah and other friends for their inspiration, help and encouragement throughout the study.

The author

MULTIPLICATION OF WATER APPLE (*Syzygium samarangense*) CULTIVARS THROUGH STEM CUTTING USING DIFFERENT PLANT GROWTH REGULATORS

ABSTRACT

An experiment was conducted at the Horticulture Germplasm Center, Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from September 2019 to December 2019 to find out the multiplication of water apple (*Syzygium samarangense*) cultivars through stem cutting using different plant growth regulators. The experiment was laid out in Randomized Complete Block Design having twelve treatment combinations, comprising with two factors (A) Cultivars (C_1: Red water apple, C_2: White water apple and C_3: Green water apple) and (B) Growth regulators (H_0: Control, H_1:Aloe vera gel, H_2: NAA-15mg/L, H_3: Mixed rooting hormone (IAA, IBA and NAA) - 3gm/L. The treatments were repeated thrice. The effect of this treatments on shooting, rooting, shoot and root growth parameters, and survival percentage were studied. The results revealed that the different cultivars, growth regulators and their interactions exerted significant influence on different parameters studied. White water apple (C_2) showed better multiplication efficiency than Red and Green water apple. Whereas among the growth regulators H_3 found superior in terms of significantly less days taken for shooting and rooting of cuttings with maximum shooting and rooting percentage. Similar trend were observed on the growth parameters of shoot and root such as number of leaves, shoots and roots, percentage of shoot and root, length of shoot and root, fresh and dry weight of plant, sprouting and survival percentage. The interaction of cultivars and different growth regulators concentrations revealed that C_2H_3 recorded the maximum shooting, better growth rate of roots and shoots at different intervals with higher sprouting and survival percentage. On the basis of the results obtained, it was concluded that the C_2 cultivar treated with H_3 recorded the highest shoot growth and survival of cutting and was found most useful, healthy and vigorous planting materials of water apple.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATION

SR. NO.	ABBREVIATION	MEANING
1	C.V	Coefficient of Variance
2	Cm	Centimeter
3	cv.	Cultivar
4	DAP	Days After Planting
5	*et al.*	and others (at elli)
6	Fig.	Figure
7	i.e.	That is
8	L	Liter
9	Mg	Milligram
10	Ml	Milliliter
11	No.	Number
12	Temp.	Temperature
13	R.H.	Relative Humidity
14	RCBD	Randomized Complete Block Design
15	Vit.	Vitamine
16	^{0}C	Degree Celsius or Centigrade
17	%	Percent

CHAPTER I
INTRODUCTION

The water apple is a non-climacteric tropical fruit and is botanically identified as the *Syzygium samarangense*. The genus of water apple is Syzygium and its belongs to the family Myrtaceae. The genus comprises about 1100 species. The pink, red, and green cultivars of wax apple are popular in Malaysia and other southeast Asian countries. It is also called Rose apple, Java apple, small cashew, Love apple, Bellfruit (In Taiwan), Jambu air (In Indonesian), Water apple, Mountain apple, Wax jambu, Maricopa, and Tambis (Philippines), Jamrul (In Bangladesh). This species presumably originated in Malaysia. It is also under cultivation in different parts of Bangladesh for their edible fruits (Peter *et al*., 2011).

Water Apple (*Syzygium samarangense*) is a medium tree, 8 -12m height, has a short 25- 30cm thick pinkish-gray trunk, flaking bark, and open, the wide-spreading crown (Bose *et al*,. 2002). The leaves are opposite nearly sessile, elliptic-oblong, rounded or slightly cordate at the base; yellowish to dark bluish-green;10- 25cm long and 5 - 12cm wide; very aromatic when crushed. Flowers are fragrant, yellowish-white,2- 4cm broad,4 – petalled with numerous stamens of 1.5 - 2.5 cm long. The waxy fruit, usually light- red, sometimes greenish-white or cream-colored and it is pear-shaped. The skin is very thin, flesh white, spongy, dry to juicy, sub acid, and very bland in flavor. It needs an extra-tropical climate growing at the lower altitudes up to 4,000 ft. in Bangladesh.

The flowers and resulting fruit are not limited to the axils of the leaves and can appear on nearly any point on the surface of the trunk and branches. When mature, the tree is considered a heavy bearer, and the crop yield up to 700 fruits. Water apple fruits are crispy, juicy, and tasty with apple aroma. Fruit flesh contains spongy tissue and 92.87 percent water content and therefore, water apple is more popular in torrid summer.

The ripe fruit is sweet and is mainly eaten fresh. In Indonesia, water jambu is used in fruit salads ('rojak') and they are also preserved by pickling ('asinan')

(Panggabean, 1992). Eighty percent or more of the fruit is edible. The composition of the species per 100 g edible portion: water more than 90%, protein 0.3 g, fat none, carbohydrates 3.9 g, fiber 1 g, vitamin A 253 IU, vitamin B1 and B2 traces, vitamin C 0.1 mg, energy value 80 kJ/100 g (analysis for water jambu in Thailand).

The pink fruits are juicier and tastier and suitable for eating out-of-hand. In Malaysia, the greenish fruits are eaten raw with salt or may be cooked as a sauce. They are also stewed with true apples. (Morton, 1987).

Various parts of the tree are used in traditional medicine, and some have been shown to possess antibiotic activity. The flowers are astringent and used in Taiwan to treat fever and halt diarrhea. Investigators have found the flowers principal constituent to be tannin. In scientific research, the flowers have shown weak antibiotic action against *Staphylococcus aureus*, *Mycobacterium smegmatis*, and *Candida albicans*.

Leaves and barks of water apple are used for various ailments like cough, cold, and menorrhea. Fruits are used as stomatitis aphtosa, diuretic, emmenagogue, abortifacient, and febrifuge (Peter *et al*., 2011).

Leaves of *S malaccense* have been used to treat a wide variety of inflammatory conditions in Western Samoa (Andersson *et al*., 1997). Previous phytochemical studies of the leaves of *S. samarangense* have shown the presence of ellagitannins (Nonaka *et al*., 1992), flavanones (Kuo *et al*., 2004), flavonol glycosides (Kuo *et al*., 2004; Nair *et al*., 1999), proanthocyanidins (Nonaka *et al*., 1992), anthocyanidins (Kuo *et al*., 2004; Nonaka *et al*., 1992), triterpenoids (Srivastava *et al*., 1995), chalcones (Resurreccion- Magno *et al*., 2005; Srivastava *et al*., 1995), and volatile terpenoids (Wong & Lai, 1996).

Several flavonoids, ellagitannins, and phenolic acids have been identified from the fruits of *S. samarangense* (Nair *et al*., 1999; Nonaka *et al*., 1992; Okuda *et al*., 1982; Srivastava *et al*., 1995).

The Wax apple is propagated sexually and asexually. The sexual method is time-consuming and late bearing and recalcitrant seed nature loss their viability within a short time and multiplication through seed create wide genetic

variability in fruit, shape, size, and color. But for obtaining uniform planting and maintaining genetic purity, asexual methods of propagation are necessary. In India, air layering is the most commonly used method to multiply water apple, but air layering can be done only in the rainy season and a limited number of plants can be produced from the mother plants. The process of air layering is tedious, time-consuming and costly.

The success rate is lower in air layering if a long dry spell will be there during Monsoon. On the other hand, multiplication through cutting can be done throughout the year. Moreover, it is easy to do, rapid, simple, and cheaper than other asexual methods and a large number of plants can be obtained within a short time. Demand may be increased in the future for good quality planting material. Therefore, it is necessary to find out the easy method of propagation for water apple.

Plant growth regulators are now widely used for plant propagation, particularly in the induction of rooting in cuttings and air layering. The most commonly used plant growth regulators for better rooting of cuttings are IAA,IBA and NAA.

Among those auxins, IBA and NAA have proved to be the best for proper root growth and are widely used for successful rooting of cuttings. Therefore, keeping the above viewpoints, the present research was undertaken as "Multiplication of water apple (*Syzygium samarangense*) cultivars through stem cutting using different plant growth regulators" at the Horticulture Germplasm Center, Horticulture Farm, Sher-e-Bangla Agricultural University, with the following objectives.

1. To find out the multiplication efficiency of water apple cultivar through stem cutting
2. To determine the suitable growth regulator on stem cutting of water apple
3. To find out the interaction effect of cultivar and growth regulators to obtain water apple sapling through stem cutting

CHAPTER II
REVIEW OF LITERATURE

Some of the important and informative works relevant to present work have been furnished in this chapter.

2.1 Review of cultivaral performance on water apple

Moneruzzaman *et al. (*2011)were carried out an experiment to evaluate the photosynthetic yield, color development and quality characteristics of three cultivars of *Syzygium samarangense* at commercial farm of Banting, Selangor and functional food laboratories, University of Malaya, Kuala Lumpur. Various physiological and biochemical parameters were studied during two seasons of fruit growth from October, 2009 to August, 2010 with the 'Giant Green', 'Masam manis Pink' and 'Jambu madu Red' cultivars of *S. samarangense*. Results showed that the highest chlorophyll content, maximal and variable fluorescence (Fm and Fv) in mature leaves and photosynthetic yield (Fv/Fm) were found in 'Jambu madu Red' cultivar. Furthermore, this cultivar that had the medium time for fruit development also produced the highest amount of Juice content (ml/100 g). The highest, lower fluorescence (F_0) in mature leaves, maximal fluorescence (Fm) and variable fluorescence (Fv) in new flush, the earliest peel color and the fruit maturity were observed in 'Masammanis pink' cultivar. The highest, lower fluorescence F0 in new flush and chlorophyll a, chlorophyll b and total chlorophyll were recorded in fruit of 'Giant Green' cultivar. Also, some other quality parameter like peel, pulp, biomass and juice color, aromatic flavor, texture and taste were taken into account to compare the quality in the cultivars of *S. samarangense*. This study also showed that the photosynthetic yield had a strong correlation with the fruit biomass among the three cultivars. In conclusion, Jambu madu Red' and 'Masam manis pink' 'cultivars are comparatively better than 'Giant Green' cultivar if cultivated under South Asian conditions.

Moneruzzaman *et al*.(2011) were carried out an experiment to selected physiological and biochemical characteristics of *Syzygium samarangense* for their physiological and biochemical characteristics at Functional Food Laboratory, University of Malaya, Kuala Lumpur. Various physiological and biochemical parameters were monitored during two seasons of fruit growth between October, 2009 to August, 2010 with the 'Giant green', 'Masam manis pink' and 'Jambu madu red' cultivars of *S. samarangense*. Ripened fruits of the different cultivars were collected from the experimental field of Banting, Selangor and analyzed for selected physiological parameters namely chlorophyll fluorescence, quantum yield, fruit weight, total yield, number of seed per fruit, seed weight and dry matter content and some biochemical parameters that is, juice content, pH, total soluble solids (TSS), glucose, fructose, inverted sugar, ethanol, total flavonoids, phenols and anthocyanins content. It was observed that highest chlorophyll fluorescence, maximum quantum yield (0.79), fruit weight, seed number (4) and seed weight per fruit (4.56 g) were in the 'Giant Green' cultivar while total yield, glucose (9.83%), fructose (9.9%), inverted sugar (9.57%), ethanol (20.5%), flavonoids (914.1 mg/100g) and phenols (326.67 mg GAE/100g) were in the 'Masam manis pink' cultivar, and the highest juice content (76.33 ml), highest total soluble solids (8.76ºBrix) and anthocyanins (2.78 mg/L) were in the 'Jambu madu Red' cultivar. From this study, it can be concluded that 'Masam manis pink' and 'Jambu madu red' cultivar are comparatively better than 'Giant green' cultivar under South Asian conditions.

Thantirige and Karunaratna *et al*. (2005) worked on propagation of seedless wax apple (*Syzygium samarangense*),and observed that the hardwood cuttings of seedless wax apple treated with 2500 ppm IBA gave highest survival percentage.

Miami *et al*. (1987) reported that It is a tropical tree growing to 5-20 m tall, with straight trunk, 20-45 cm diameter, often branched near the base and with broadly ovoid canopy. Leaves opposite, ellipticoblong, 15-38 cm x 7-20 cm,

thick-coriaceous, petiole 0.5-1.5 cm long, thick, red when young. Inflorescences exclusively on defoliate twig-parts, short and dense, 1-12-flowered; flowers 5-7 cm in diameter, red; calyx-tube ventricose towards apex, 1.5-2 cm long, with broad lobes 4-8 mm long; petals 4, oblong-ovate or orbicular-ovate, up to 2 cm long, dark red; stamens numerous, up to 3.5 cm long, with red filaments; style 3- 4.5 cm long, red. Fruit is a bell-shaped edible berry, ellipsoid, 5-8 cm in diameter, crowned by the incurved non-fleshy calyx segments, dark red or purplish-yellow or yellow-white; flesh 0.5-2.5 cm thick, juicy, white, fragrant. Seed per fruit is one, globose, 2.5-3.5cm in diameter. When mature, the tree is considered a heavy bearer and can yield a crop of up to 700 fruits.

2.2 Effect of plant growth regulators on Water Apple and others

Chaudhary,*et al.* (2018) conducted an experiment during 2015-16 at Agriculture Experimental Station (AES), Navsari Agricultural University, Paria, Dist- Valsad. An experiment comprised with two factors (1) Types of cutting [Hardwood cutting (P_1) and Semi-hardwood cutting (P_2)] and (2) Growth regulators [IBA 5000 mg/litre(G_1), IBA 7500 mg/litre (G_2), NAA 5000 mg/litre (G_3), NAA 7500 mg/litre (G_4), IBA 5000 + NAA 5000 mg/litre (G_5), IBA 5000 + NAA 7500 mg/litre (G_6), IBA 7500 + NAA 5000 mg/litre (G_7), IBA 7500 + NAA 7500 mg/litre (G_8) and Control (G_9)] in Completely Randomized Design with Factorial Concept and repeated thrice under Net house conditions. Results showed that among the different cutting types and growth regulators, hardwood cutting and IBA 5000 mg/litre + NAA 5000 mg/litre were recorded significantly the highest growth parameter in terms of number of roots per cutting, length of root (cm), fresh and dry weight of root (g) and survival percentage of wax apple cutting.

Khandaker *et al*. (2017) conducted to investigate the effects of napthalene acetic acid (NAA) and gibeberellic acid (GA_3) on plant physiological characteristics of *Syzygium samarangense* (wax apple) var. jambu madu. Different concentration was used in NAA and GA_3 treatments where NAA at

10, 20 and 40 mg/L and GA_3 at 20, 40 and 80 mg/L. In GA_3 treatment, the result shown that application of 40 mg/L concentration gives the best result while, 10 mg/L and 20 mg/L treatments were the best concentration for NAA application to improve the plant physiological characteristics of *Syzygium samarangense* leaves. In addition, GA_3 treatment had shown significant effect on new leaf length, petiole length, chlorophyll b, carotenoid content and stomatal conductance. NAA treatments had shown significant effects on petiole length, chlorophyll content (SPAD), chlorophyll b, carotenoid content and photosynthetic rate of leaf. It can be concluded that 40 mg/L GA_3 and 10 and 20 mg/L NAA treatments significantly improved the physiological characteristics wax apple plants under field conditions.

Chaudhary *et al*. (2015) conducted an experiment during 2015-16 at Agriculture Experimental Station (AES), Navsari Agricultural University, Paria, Dist- Valsad. An experiment comprised with two factors (1) Types of cutting [Hardwood cutting (P_1) and Semi-hardwood cutting (P_2)] and (2) Growth regulators [IBA 5000 mg/lit.(G_1), IBA 7500 mg/lit. (G_2), NAA 5000 mg/lit. (G_3), NAA 7500 mg/lit. (G_4), IBA 5000 + NAA 5000 mg/lit. (G_5), IBA 5000 + NAA 7500 mg/lit. (G_6), IBA 7500 + NAA 5000 mg/lit. (G_7), IBA 7500 + NAA 7500 mg/lit. (G_8) and Control (G_9)] in Completely Randomized Design with Factorial Concept and repeated thrice under Net house conditions. Results showed that among the different cutting types and growth regulators, hardwood cutting and IBA 5000 mg/lit. + NAA 5000 mg/lit. were individually as well as in their combination found to be the most beneficial for early sprouting. Similar trend was observed on the growth parameters such as number of shoots, leaves and leaf area, length and diameter of longest shoot, fresh and dry weight of plant and survival percentage

Khandaker *et al* .(2012) found that the effects of growth regulators on the physiochemical and phytochemical properties of the wax apple fruit, a widely cultivated fruit tree in southeast Asia. Net photosynthesis, sucrose phosphate synthase (SPS) activity, peel color, fruit firmness, juice content, pH value, total

soluble solids (TSSs), and the sugar acid ratio were all significantly increased in growth regulators (PGRs) treated fruits. The application of gibberellin (GA_3), naphthalene acetic acid (NAA), and 2,4-dichlorophenoxy acetic acid (2,4-D) significantly reduced titratable acidity and increased total sugar and carbohydrate content compared to the control. The 50mg/L GA_3, 10mg/L NAA, and 5 mg/L 2,4-D treatments produced the greatest increases in phenol and flavonoid content; vitamin C content was also higher for these treatments. PGR treatment significantly affected chlorophyll, anthocyanin, and carotene content and produced higher phenylalanine ammonialyase (PAL) and antioxidant activity levels. There was a positive correlation between peel color and TSS and antioxidant activity and both phenol and flavonoid content and PAL activity and anthocyanin formation. A taste panel assessment was also performed, and the highest scores were given to fruits that had been treated with GA_3 or auxin. The study showed that application of 50mg/L GA_3, 10mg/L NAA, and 5mg/L 2,4-D once a week from bud development to fruit maturation increased the physiochemical and phytochemical properties of wax apple fruits.

Al-saif *et al*.(2011) conducted to investigate the effects of Gibberellic Acid (GA_3), Naphthalene Acetic Acid (NAA) and N-2-chloro-4-pyridyl-N-phenylurea (CPPU) on the growth and quality development of water apple/ wax apple (*Syzygium samarangense*). GA_3 at the concentrations of 0 (water control) 30, 60 and 90 ppm was used in experiment 1. NAA at the concentrations of 0 (water control), 6, 12 and 18 ppm was used in experiment 2. CPPU at the concentrations of 0 (water control) 10, 15 and 20 ppm was used in experiment 3. The swabbing technique of hormone application was used for all plant growth regulator applications in the three experiments. The growth regulators at different concentration levels (GA_3, NAA and CPPU) were applied once a week starting from bud formation stage to flower opening stage (blooming), of twelve year old trees.

In the GA_3 experiments, it was observed that application of GA_3 (30, 60 and 90 ppm) increased fruit length and diameter. Fruit length and diameter proved to

be highest in GA_3 at 60 ppm (60 mg/l). Furthermore, it increased the rate of fruit growth and maturity (represented by color) development in addition to increasing fruit number, weight and yield. Premature fruit drop was observed to have declined. With regard to fruit quality, the application of GA_3 at 60 ppm increased the TSS , inverted sugar, fructose and total flavonoid content in wax apple. In addition, anthocyanin, potassium (K+) and total phenol content were higher in GA_3 treated fruit than control fruit. From these experiments it can be concluded that swabbing 60 ppm (60 mg/l) of GA_3 produced better performance in terms of size, yield and quality of wax apple fruit.

In the NAA treated experiments, bud number was highest in 12 ppm NAA treated branch compared to other NAA treated and control branches. Bud drop decreased with decreasing NAA concentrations. Lowest fruit drop occurred in fruits treated with 12 ppm NAA. Fruit length and diameter were greatly enhanced at the different concentrations of NAA used. Yield and fruit weight had also significantly increased when 12 ppm NAA was used per branch. The chlorophyll content was also higher in 12 ppm NAA treated leaves than in control leaves. Dan similarity potassium and total flavonoid content, TSS, sucrose and fructose were also highest in 12 ppm NAA treated fruits. It was also observed that the anthocyanin content and pH value were highest in 12 ppm NAA. From this experiment it can be concluded that the swabbing application of 12 ppm (12 mg/l) NAA showed the best effects on fruit length, set, size and biochemical quality in wax apple fruits.

In the CPPU treated experiments, higher bud drop was observed in 15 ppm CPPU than in the control fruit. Fruit length, diameter, per fruit weight and yield were observed to be higher in 15 ppm CPPU compared with the control. The highest increment in TSS content was recorded in 15 ppm CPPU treated-fruit. Similarity, the highest pH value was observed in 15 ppm CPPU treated fruits. Chlorophyll content was highest in 15 ppm CPPU treated-leaves. The results showed that the pH value, and the potassium content were higher in 15 ppm CPPU treated compared to those of the control fruit. The highest flavonoid,

total phenolic and fructose content were recorded in 15 ppm CPPU concentration. Sucrose was also higher in 15 ppm CPPU than in other treatments. From this experiment it can be concluded that the swabbing application of 15 ppm (15 mg/l) CPPU showed the best effects on the fruit size and biochemical quality of the wax apple.

Overall this study has shown that the plant growth regulators at different concentrations (60 ppm GA3, 12 ppm NAA and 15 ppm CPPU) applied using the swabbing technique greatly improved fruit growth and quality, when applied a week during bud initiation.

Mohammad Moneruzzaman Khandaker *et al*. (2016) investigated the study about the fruit growth, development and quality of wax apple (*Syzygium samarangense*), a widely cultivated fruit tree in South East Asia. The growth and development of this fruit is sometimes very low due to low photosynthates supply at early growth stages. Growth regulators, hydrogen peroxide and phloemic stress are important tools to improve the growth, development and quality of horticultural products. The extracts of wax fruits, flower and bark have potent free radical scavenging, antioxidation, antimutation and anticancer activities. The leaves of wax apple used as tea and is proposed as a possible supplement for type II diabetes patients. Wax apple studied for its numerous pharmacological properties such as antioxidant and antidiabetic properties, anti-inflammation and antinociceptive activity, wound healing activity, antiulcerogenic effect, antibacterial, anticancer and also it's potential as an uterotonic agent. From this review, it can be concluded that GA_3, NAA, 2, 4-D, H_2O_2 and girdling have significant effect on fruit growth, development and yield improvement. Fruit pigmentations and anthocyanin content also significantly by using these growth promoting chemicals and girdling technique. This review paper provide detail information about wax apple fruit growth and development, origin, ecology, fruit morphology and variety, commercial usage, quality improvement and its medicinal benefits.

Moneruzzaman *et al* (2011) were carried out to investigate the effects of gibberellic acid (GA_3) on the growth and development of the red jambu air madu fruits (*Syzygium samarangense*). Various horticultural parameters were monitored during two seasons of fruit growth between December, 2008 to December, 2009 with the application of three concentrations of GA_3 at 20, 50 and 100 mg/L. It was observed that the application of GA_3 at 50 mg/L increased fruit length and diameter. Furthermore, it enhanced faster fruit growth and color development in addition to increasing fruit number, weight and yield. It also decreased premature fruit dropping. However, spraying with 20 mg/L GA_3 increased the number of buds and fruit setting and reduced bud dropping before anthesis. With regard to fruit quality, the application of GA_3 at 50 mg/L increased total soluble solids (TSS), total sugar, total biomass and total flavonoids content in the fruits by 112, 97, 45 and 92% compared with the control treatment. In addition, anthocyanin content, total phenol and antioxidant activity was higher in GA_3 treated fruits. From this study, it can be concluded that spraying with 50 mg/L GA3 once a week results in better yield and quality of jambu madu fruits under field conditions.

Paul and Aditi (2009) reported that IBA and NAA 1000 ppm induce more improved rooting characters in water apple (Syzygium javanica L.), and found that the application of IBA and NAA at 1000 ppm improve the rooting characters like root length, diameter, branching, hardness and the relation of rooting with sprouting.

Sharma *et al*. (1989) revealed that the highest root lengths were recorded in semi -hardwood cuttings of rose - apple (*Syzygium jambos* Alston.) with IBA 5000 mg/l treatment. While, percentage of rooting success was more reduce with NAA, but root length increased with IBA.

Faghihi *et al*. (2013) studied the effect of different concentrations of hormones, IBA, IAA and NAA on rooting of the woody cuttings of MM106, M9 and MM111 apple rootstocks. After preparing woody cuttings of MM111, MM106 and M9, rootstocks were disinfects with fungicide

Benomel. These cuttings were treated with Indole Butyric Acid (IBA), Indole Acetic Acid (IAA) and Naphthalene Acetic Acid (NAA) at three levels (0, 3500 and 5500 ppm) and planted in bed of perlite and sand (50:50 ratio), and found that all the studied traits such root length, shoot length, root dry weight and percentage of rooting were maximum under IBA and NAA 3500 ppm treatment.

Pirlak (2000) investigated the effects of IBA doses and cutting timings on rooting of hardwood cuttings of some Cornelian cherry (Cornusmas L.) . Hardwood cuttings were collected and treated with IBA at 2000, 4000 and 6000 ppm. The rooting rate, viability rate, callused cutting rate, root number, root length, root dia meter and root quality were determined. Results of the study revealed that IBA 6000 ppm application gave the best result for rooting of the hardwood cuttings of Cornelian cherry.

Esitken *et al*. (2003) evaluated the effects of a range of Indole -3- butyric acid (IBA) concentrations (250, 500 and 750 ppm) alone and in combination with three strains of Agrobacterium rubi (A1, A16 and A18) on the rooting capacity of wild sour cherry (*Prunus cerasus* L.) of softwood and semi - hardwood cuttings. The bacterial strains used in the present study were isolated from the foliage of pome fruits (from apple and pear orchards) growing in the eastern Anatolia region of Turkey. No rooting was observed on the cuttings of wild sour cherry with control treatment (no IBA or bacterial treatment) in both types of cuttings, whereas different rooting were observed on the cuttings treated with IBA and bacteria. The highest rooting percentage of 65% for softwood and 70% for semi - hardwood cuttings were observed when they were treated with IBA 250 ppm + A16 treatments. Among the different level of hormone applied, the best rooting percentage was found at the treatment o f IB A 250 ppm (39.4%). In semi - hardwood cuttings, the highest rooting percentage among the bacterial strains and hormone doses

was obtained with the treatments of A16 (49.4%) and IBA 750 ppm (46.9%).

Arora *et al* . (1985) studied that effect of growth regulators on rooting of lemon cuttings with and without leaves. They found that the application of NAA at 2000 ppm to the cultivars Baramasi and Kagzi - Kalan and 3000 ppm to the cv. Eureka gave the best rooting and survival in lemon cuttings with leaves .In cuttings without leaves, NAA at 4000, 3000 and 2000 ppm for Baramasi, Kagzi- Kalan and Eureka, respectively ,was the best rooting treatment.

Debnath *et al*. (1986) observed that the auxin synergists in the rooting of stem cuttings of lemon (Citrus limon Burm .) Two hundred semi - hardwood shoots on 8 – year -old trees were ringed and 200 were left intact. The maximum rooting (95%) was observed in cuttings pre - treated with ferulic acid at 200 ppm and then treated with NAA 5000 ppm.

Ozcan *et al*.(1990)studied the effects of plant growth regulators and different propagation times on the percentage rooting of semi - hardwood cuttings of some citrus rootstocks cuttings 20 cm long with 1 to 2 leaves, cuttings were taken in May, July and October from sour orange cv. Common, Poncirus trifoliate cultivars Rubidoux, Common and Flying Dragon, and rough lemon cv. Florida. They were treated cuttings with IBA or NAA each at 2000, 4000 or 6000 ppm and rooted in a volcanic soil medium in mist propagation benches. The highest rooting percentage was obtained with cuttings taken in July and the lowest with October propagation. The best results of growth regulator treatment were obtained with IBA 4000 ppm for Common sour orange (57.77% rooting), IBA 2000 ppm for Flying Dragon trifoliate orange (100%), NAA 4000 ppm for Common trifoliate orange (55.55%) and NAA 6000 ppm for Rubidoux trifoliate orange (44.44%).

Singh *et al*. (2013) studied the effect of IBA concentrations on growth and rooting of cutting of citrus lemon cv. Pant Lemon. The maximum average

diameter of root per cutting was observed under 2000 ppm concentration of IBA followed by 1000 ppm concentration of IBA. Among all the treatments ,the number of sprouted cuttings (6.29), length and diameter of sprout (23.77 c m and 1.52 c m, respectively),number of sprouts, number of leaves and number of roots/cutting (17.77 and 23.00 and 52.42, respectively) in hardwood cutting.

Bhatt and Tomar *et al*.(2010) studied the effects of IBA on rooting performance of Citrus auriantifolia Swingle (Kagzi -lime)in different growing conditions. Investigation clearly revealed that the IBA 500 ppm is most effective in the stimulation of rootsystem arising from cutting and development of roots of Citrus auriantifolia cutting and can be used for massscale multiplication.

Khapare *et al* . (2012) propagational studies in fig as affected by plant growth regulator. A propagation of fig cv.'Dinker' involving of two type of cuttings (Hardwood cuttings and semi hardwood cuttings), plant growth regulators IBA (1000 and 2500 ppm) , NAA (1000 + 2500 ppm) their combination (IBA 2500 ppm + NAA 2500 ppm and IBA 1000 ppm + NAA 1000 ppm), and recorded the maximum number of sprout per cutting, leaf area , number of leaves, root and shoot dry matter in hard wood cuttings treated with IBA 2500 ppm + NAA 100 ppm.

Moreno *et al*. (2009) evaluated the effect of five concentrations of Indole Butyric Acid (IBA) (0, 200, 400, 600 and 800 mg 1-1) and two substrates (peat moss, and 1:1 v/v mixture of black soil and rice husks) on the rooting and growth of terminal cuttings from Cape Gooseberry plants. The best results were observed when applying IBA 800 mg l – 1 to cuttings planted in peat moss. This treatment combination determined the highest rooting percentage and the highest root length, fresh and dry mass of roots, leaf number and leaf area scores.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from September 2019 to December 2019 to study the "Multiplication of water apple (*Syzygium samarangense*) cultivars through stem cutting using different plant growth regulators". This chapter includes a brief description of the methods and materials that were used for conducting the experiment.

3.1 Experimental site

The experiment was conducted at the Horticulture Germplasm Center, Horticulture Farm of Sher-e-Bangla Agricultural University , Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experiment was carried out during rabi season. The location of the study was situated in 23^0 $74^/$ N latitude and 90^0 $35^/$ E longitude (Anon., 1989). The altitude of the location was 8 m from the sea level (The Meteorological Department of Bangladesh, Agargaon , Dhaka).

3.2 Climate

The experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix I.

3.3 Soil

The soil of the experimental area belongs to the Modhupur Tract. The analytical data of the soil sample collected from the experimental area were determined in Soil Resources Development Institute, Farmgate Dhaka Appendix II.

The experimental site was a medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plots are given below –

AEZ No. : 28

Soil series : Tejgaon **General soil** : Non-calcarious dark grey

3.4 Preparation of land

The land for the experiment was spaded several times and big and small clods were broken to obtain a good tilth. The weeds and stubbles were removed from the land. The land was divided into 24 plots. The plots were raised to about 6 cm high from the soil surface. No chemical fertilizers were used in the soil.

3.5 Cutting bed

Cutting beds having the size of 3m (length) X lm (breadth) X 15cm (height) were prepared between three adjacent beds, a distance of 30cm width and 15cm depth were kept for ease of movement and proper drainage of rain water.

3.6 Experiment details

Crop: Water apple

Cultivars : Local

Design of experiment : RCBD

Treatment combinations : 12

Replications : 3

No. of cutting per treatment : 20

Total no. of cuttings : 720

3.7 Treatment details

There were 12 treatment combinations comprising of three cultivars and 4 growth regulators treatments. The treatment details are given below:

Factor A: Cultivars:

C_1: Red water apple

C_2: White water apple

C_3: Green water apple

Factor B: Growth regulators:

H_0: No hormone (Control)

H_1: Aloe vera gel

H_2: NAA (Napthalene Acetic Acid) -15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA) -3gm/L

Treatment combinations

There were 12 (6 x 2) treatment combinations as follows:

C_1H_0,C_1H_1,C_1H_2,C_1H_3,C_2H_0,C_2H_1,C_2H_2,C_2H_3,C_3H_0,C_3H_1,C_3H_2,C_3H_3

3.8 Design of the experiment:

The experiment was laid out in Randomized Complete Block design (RCBD) with three replications.

3.9 Preparation of plant growth regulators

3.9.1 Preparation of NAA solution:

To prepare 15 mg/L of NAA, 15mg of NAA and 10 ml of ethanol was taken in a volumetric flask and then the volume was raised to one liter by adding distilled water with frequent stirring to prepare 15 mg/L of NAA solutions.

3.9.2 Preparation of mixed rooting hormone:

To prepare 3gm/L of mixed rooting hormone solution 3gm of mixed hormone was taken, 10 ml of ethanol was taken in a volumetric flask and then the volume was raised to one liter by adding distilled water with frequent stirring to prepare 3gm/L of mixed hormone solutions.

3.9.3 Preparation of aloe vera gel:

At first the aloe vera leaves were cut from the plants. Then extracted the gel from the leaves by peeling and cut off small pieces with a sharp knife.

3.9.4 Control solution

Distilled water was used for this purpose.

3.10 Preparation of stem cutting

Cuttings were taken from old healthy tree of water apple situated at the Horticulture Germplasm Center at Horticulture Farm in Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh. This cuttings are generally made mature branches from one year old branches about 15 cm long having 2-3 nodes depending on the species. All the leaves were cut off and 20 cuttings were used in each treatment combination. The lower cuts of the stems were made slanting below the nodes and the upper cuts were horizontal above the nodes.

The prepared cuttings were then dipped in the plastic bowl for 24 hours, immerging 2.5 to 5 cm of their basal portion before planting in the field. On the contrary, the stems were dipped in distilled water only in case of control treatments.

3.11 Planting of cuttings :

Cuttings of three variets of water apple(*Syzygium samarangense*) were planted in the beds on 1st september, 2019 at a spacing of 10cm X 10cm. One thirds of the length of the cuttings was inserted into the soil at an angle of 45°. Immediately after inserting watering was done uniformly by water can.

Shading was provided by bamboo made overhead chatai at a height of 2 m to protect the cuttings from excessive rainfall and sunlight. The shading was kept for 2 weeks.

3.12 Media Preparation:

For the experiment, the cuttings were raised in polythene bags, containing media of 40% well drained soil + 20% cocopeat + 40% cowdung (2:1:2).

3.13 Cuttings Management:

Weeding and earthing up was done as and when needed for proper growth and development of the cuttings. There was no incidence of insect and disease in the experimental cuttings. The plots were kept free from weeds by weeding six times.

3.13.1 Irrigation:

Irrigation was given by observing the soil moisture condition. Irrigation was provided to cuttings in polythene bags using water can and maintained the proper moisture level. The bags were watered as and when required.

3.14 Data collection procedures

Data were recorded on the following parameters from the sample plants during the course of experiment. The crop response to the treatment application under the present investigation was evaluated on the basis of growth of cuttings during 15 , 30 , 45 , 60, 75, and 90 DAP. The cuttings were kept under observation for 90 days. After that 5 cuttings were collected randomly from each of the 24 plots for data collection. Cutting were uprooted from each plot by digging soils without tearing the roots. Base of cach cutting was washed carefully in a bucket of dear water without damaging the roots. Then data were collected for the following parameters-

i. Days to shoot initiation
ii. Days to root initiation
iii. Number of shoots per cuttings
iv. percentage of shooting
v. Length of shoot (cm) per cutting
vi. Number of leaves per cutting
vii. Number of roots per cutting
viii. Percentage of Rooting
ix. Length of root (cm) per cutting
x. Sprouting Percentage
xi. Survival Percentage
xii. Fresh weight of plant(g)
xiii. Dry weight of plant(g)

3.14.1 Days to shoot initiation:

Days taken by cuttings to new sprout after planting in each treatment were counted and mean number of days taken for sprouting were worked out.

3.14.2 Days to root initiation:

Days taken by cuttings to new root after planting in each treatment were counted and mean number of days taken for rooting were worked out.

3.14.3 Number of shoots per cuttings

The number of shoots was recorded 15, 30, 45, 60,75, and 90 days after planting and mean number of shoots per cutting was worked out.

3.14.4 percentage of shooting

The percentage of shooting was calculated 15, 30, 45, 60,75, and 90 days after planting . It was calculated by given formula:

$$\text{Shooting \%} = \frac{\text{Number of shoots per cuttings}}{\text{Number of cuttings}} \times 100$$

3.14.5 Length of shoot (cm) per cutting

The shoot lengths of selected cuttings were measured with the help of a scale and the total length was recorded. Then the shoot length (cm) per cutting was calculated by dividing the total length of shoots by 5.

3.14.6 Number of leaves per cutting

The number of leaves per cutting were counted at 15,30,45,60,75 and 90 DAT from 5 randomly selected plants and the average number of leaves produced per cutting was recorded.

3.14.7 Number of roots per cutting

The number of roots per cutting were recorded with the help of measuring scale after 30,60 , and 90 days of planting and average was calculated.

3.14.8 Percentage of Rooting

The percentage of rooting was calculated 30, 60 and 90 days after planting . It was calculated by given formula:

$$\text{Rooting \%} = \frac{\text{Number of roots per cuttings}}{\text{Number of cuttings}} \times 100$$

3.14.9 Length of roots (cm)

Length of largest root was recorded at 30, 60 and 90 days after planting. Five tagged plants from each repetition were uprooted and length of longest root was measured with the help of scale in cm and average was calculated.

3.14.10 Sprouting Percentage

The sprouting percentage was calculated after 30 DAP. It was calculated by given formula:

$$\text{Sprouting \%} = \frac{\text{Number of cuttings sprouted}}{\text{Number of cuttings per treatment}} \times 100$$

3.14.11 Survival Percentage:

The survival percentage was calculated after 90 DAP. It was calculated by given formula:

$$\text{Survival \%} = \frac{\text{Number of cuttings survived}}{\text{Number of cuttings sprouted}} \times 100$$

3.14.12 Fresh weight of plant (g) of water apple

Fresh plant were removed from poly bag and fresh weight of plant was obtained with the help of electronic balance.

3.14.13 Dry weight of plant(g) of water apple

Dry plants were oven dried at 60^0 C for 48 hours and dry weight was taken with the help of electronic balance.

3.15 Statistical analysis

The recorded data on different parameters were statistically analyzed using MSTAT software to find out the significance of variation resulting from the experimental treatments. The mean for the treatments was calculated and analysis of variance for each of the characters was performed by F (variance ratio) test. The differences between the treatment means were evaluated by LSD test at 1% or 5% probability whenever applicable.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Number of days to shoot Initiation

The data regarding the number of days taken to the first shooting of cuttings as influenced by cultivars and growth regulators are presented in Table: 1 & 2

The data presented in Table 1 regarding cultivars showed that the number of days taken for the first shooting was significantly influenced by water apple cultivars (Appendix III). The minimum days (11.88days) taken for the first shooting was noted in C_2. Whereas maximum days (15.75days) were noted in C_3. Similar results are in close agreement with Manan *et al.*, (2002) in guava and Chauhan and Reddy (1974) in plum.

The perusal of data presented in Table 1 clearly indicated that the number of days taken for the first shooting was significantly different due to different growth regulators (Appendix III). Among the different growth regulators of aloe vera gel, NAA, and Mixed rooting hormone, significantly the minimum days (8.17days) taken for the shooting were recorded in H_3 followed by H_1. While maximum days (21days) taken for the first shooting was noted in H_0. Increased level of auxins resulted in earlier completion of physiological processes in rooting and sprouting of cuttings. The above results are in accordance with the findings of Kurd *et al*.(2010) in olive stem cutting

The data presented in Table 2 clearly indicated that interaction between cultivars and different growth regulators for the number of days taken for sprouting were found significantly. The minimum days (6.50 days) taken for the first shooting was noted in C_2H_3 followed by C_1H_3. However, significantly the maximum (23days) days taken for the first shooting was recorded in control (C_1H_0). Similar results were obtained by Singh *et al*. (2013

) in citrus, Canli, and Bozkurt (2009) in plum and Purohit and Shekharappa (1985) in pomegranate.

4.2 Number of days to root Initiation

The data regarding the number of days took to first rooting of water apple cuttings as influenced by different cultivars and growth regulators are presented in Table 1 & 2.

The data of Table 1 indicated that cultivars had significant influence on number of days are taken for first rooting (Appendix III) . The minimum days (17.25days) taken for first rooting was noted in C_2. whereas maximum days (22days) were noted in C_1.

The perusal of data presented in Table 1 clearly indicated that the number of days taken for first rooting was significantly different due to different growth regulators (Appendix III). Among the different growth regulators of aloe vera gel, NAA, and mixed rooting hormone, significantly the minimum days (12.50days) taken for rooting was recorded in mixed rooting hormone (H_3) followed by Aloe vera gel (H_1). While maximum days (27.17days) taken for first rooting was noted in control (H_0).

The data presented in Table 2 clearly indicated that interaction between cultivars and different growth regulators for the number of days taken for rooting was found significantly. The minimum days (11.50 days) taken for first rooting were noted in C_2H_3 followed by C_3H_3. However, significantly the maximum (28.50days) days taken for first rooting was recorded in control (C_1H_0)

Table 1. Effect of cultivars and growth regulators on number of days to shoot Initiation and number of days to root initiation per cutting

Treatment	Days to shoot initiation	Days to root initiation
Cultivars		
C_1	13.63b	22.00a
C_2	11.88c	17.25c
C_3	15.75a	20.50b
$LSD_{(0.05)}$	1.067	1.196
Growth regulators		
H_0	21.00a	27.17a
H_1	11.83c	18.00c
H_2	14.00b	22.00b
H_3	8.17d	12.50d
$LSD_{(0.05)}$	1.232	1.382
CV%	7.05	5.46

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1:Red water apple

C_2:White water apple

C_3:Green water apple

Growth regulators

H_0:Control

H_1:Aloe vera gel

H_2:NAA (Napthalene Acetic Acid)-15mg/L

H_3:Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Table 2. Interaction effect of cultivars and growth regulators on number of days to shoot initiation and number of days to root initiation per cutting

Interaction (C x H)		Days to shoot initiation	Days to root initiation
C_1	H_0	20.00b	28.50a
	H_1	12.00de	20.00d
	H_2	14.00d	25.00c
	H_3	8.50gh	14.50f
C_2	H_0	20.00b	25.50bc
	H_1	9.50fg	14.50f
	H_2	11.50ef	17.50e
	H_3	6.50h	11.50g
C_3	H_0	23.00a	27.50e
	H_1	14.00d	19.50de
	H_2	16.50c	23.50c
	H_3	9.50fg	11.50g
$LSD_{(0.05)}$		2.133	2.393
CV%		7.05	5.46

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1:Red water apple

C_2:White water apple

C_3:Green water apple

Growth regulators

H_0:Control

H_1:Aloe vera gel

H_2: NAA (Napthalene Acetic Acid)-15mg/L

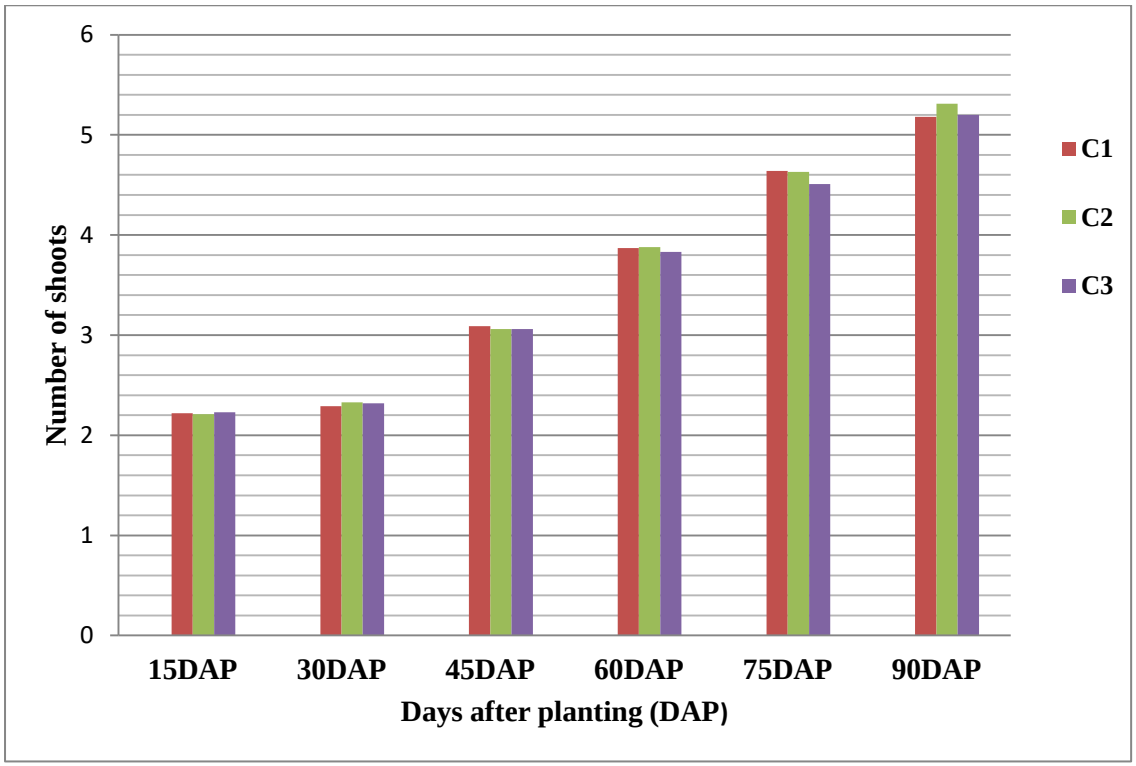
H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

4.3 Number of shoots per cutting

The data regarding the number of shoots of water apple cuttings as influenced by different cultivars and growth regulators are presented in (Table 3) and graphically depicted in (Fig. 1 and 2)

The effect of the cultivar was found to be non-significant in respect to the number of shoots per cutting (Appendix IV). The data regarding number of shoots per cutting at 15, 30,45, 60, 75 and 90 DAP as presented in (Figure 1).

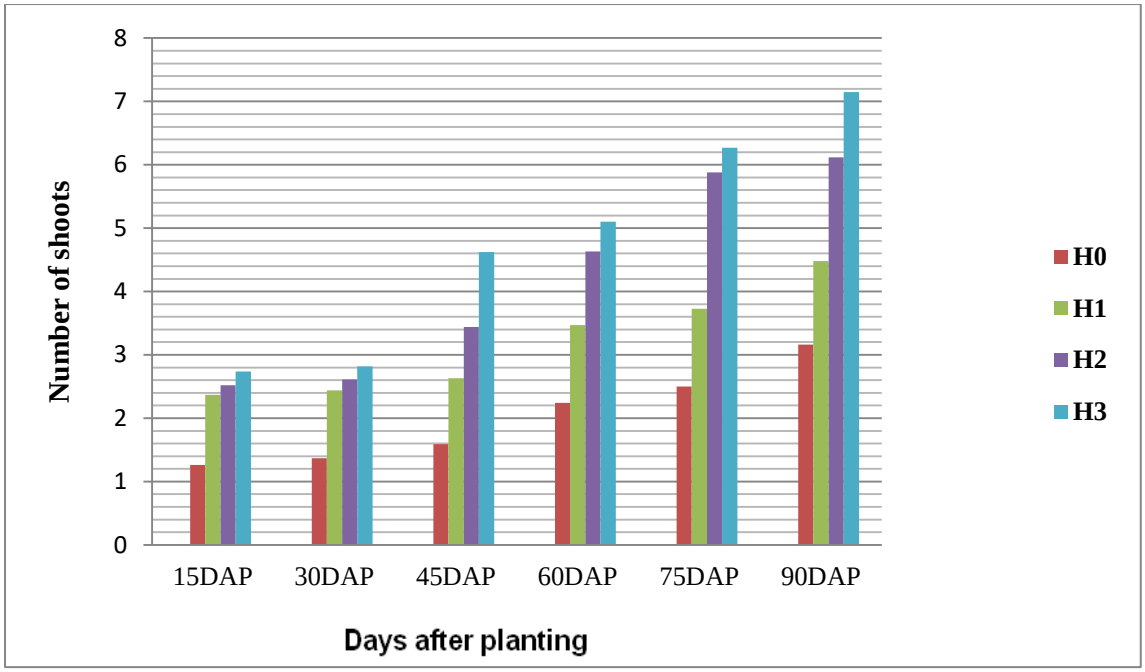
The maximum number of shoots per cutting of water apple at 15, 30, 45, 60, 75, and 90 DAP (2.23, 2.33, 3.09,3.88,4.64 and 5.31 respectively) were observed in C_2. Similar results were noted by Singh *et al.* (2013) in citrus.



C_1: Red water apple C_2:White water apple C_3:Green water apple

Fig.1. Effect of cultivars on number of shoots per cutting

The effect of different growth hormones was found to be highly significant with respect to the number of shoots per cutting (Figure 2 & Appendix IV). Among the different growth regulators, significantly the maximum number of shoots per cutting of water apple at 15, 30, 45, 60, 75, and 90 DAP (2.74, 2.82, 4.62, 5.10, 6.27 and 7.15 respectively) were recorded in H_3 followed by H_2. While significantly the minimum number of shoots per cutting at 15, 30, 45, 60, 75, and 90 DAP (1.26, 1.37, 1.59, 2.24, 2.50 and 3.16 respectively) were noted in control (H_0). Mobilization and utilization of the stored carbohydrates due to the influence of the auxin were increased the number of shoots (Severino *et al.*, 2011).



H_0:Control, H_1: Aloe vera gel , H_2: NAA (Napthalene Acetic Acid)15mg/L, H_3 : Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Fig.2.Effect of growth regulators on number of shoots per cutting

The data given in Table 3 clearly showed that the interaction between cultivars and different growth regulators had a significant effect on the number of shoots per cutting. The highest number of shoots per cutting at 15, 30, 45, 60, 75, and 90 DAP (2.76, 2.86, 4.67, 5.17, 6.45 and 7.25 respectively) were found in C_2H_3 followed by C_1H_3. The minimum number of shoots per cutting were in C_2H_0 at 15, 30, 45, 60, 75, and 90 DAP (1.22, 1.33, 1.56, 2.22, 2.44 and 275, respectively) . The results are conformity with Singh *et al. (*2014) in mulberry, Singh *et al*. (2013) in citrus, and Alam *et al*. (2007) in kiwifruit.

Table 3. Interaction effect of cultivars and growth regulators on number of shoots per cutting

Interaction (C x H)		Number of shoot					
		15DAP	30DAP	45DAP	60DAP	75DAP	90DAP
C_1	H_0	1.23e	1.36h	1.62g	2.27e	2.50i	3.31d
	H_1	2.39c	2.43f	2.65e	3.46d	3.77f	4.50c
	H_2	2.52b	2.61d	3.42d	4.64c	5.91d	6.25b
	H_3	2.75a	2.82b	4.64a	5.15a	6.39b	7.23a
C_2	H_0	1.22e	1.33h	1.56h	2.22e	2.44j	2.75e
	H_1	2.35c	2.44ef	2.61f	3.47d	3.75f	4.54c
	H_2	2.53b	2.64c	3.44cd	4.64c	5.91d	6.15b
	H_3	2.76a	2.86a	4.67a	5.17a	6.45a	7.25a
C_3	H_0	1.33d	1.42g	1.61g	2.25e	2.56h	3.42d
	H_1	2.37c	2.47e	2.63ef	3.49d	3.69g	4.42c
	H_2	2.50b	2.58d	3.46c	4.62c	5.82e	5.96b
	H_3	2.73a	2.80b	4.55b	4.98b	5.96c	6.99a
$LSD_{(0.05)}$		0.040	0.019	0.032	0.060	0.055	0.490
CV%		0.83	0.66	0.47	0.70	0.54	4.25

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1:Red water apple

C_2:White water apple

C_3:Green water apple

Growth hormone

H_0:Control

H_1:Alovera gel

H_2: NAA (Napthalene Acetic Acid)-15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

4.4 Percentage of shooting

The data regarding the percentage of shoots of water apple cuttings as influenced by different cultivars and growth regulators are presented in (Table 4) and graphically depicted in (Fig. 3 and 4)

The effect of the cultivars was found to be non-significant in respect of the percentage of shoots per cutting (Appendix V). The data regarding the

percentage of shoots per cutting at 15, 30,45, 60, 75 and 90 DAP is presented in (Figure 3). The maximum percentage of shoots per cutting of water apple cultivars at 15, 30, 45, 60, 75, and 90 DAP (11.14, 11.62, 15.29, 19.40, 23.21 and 26.55 respectively) were observed in C_2.

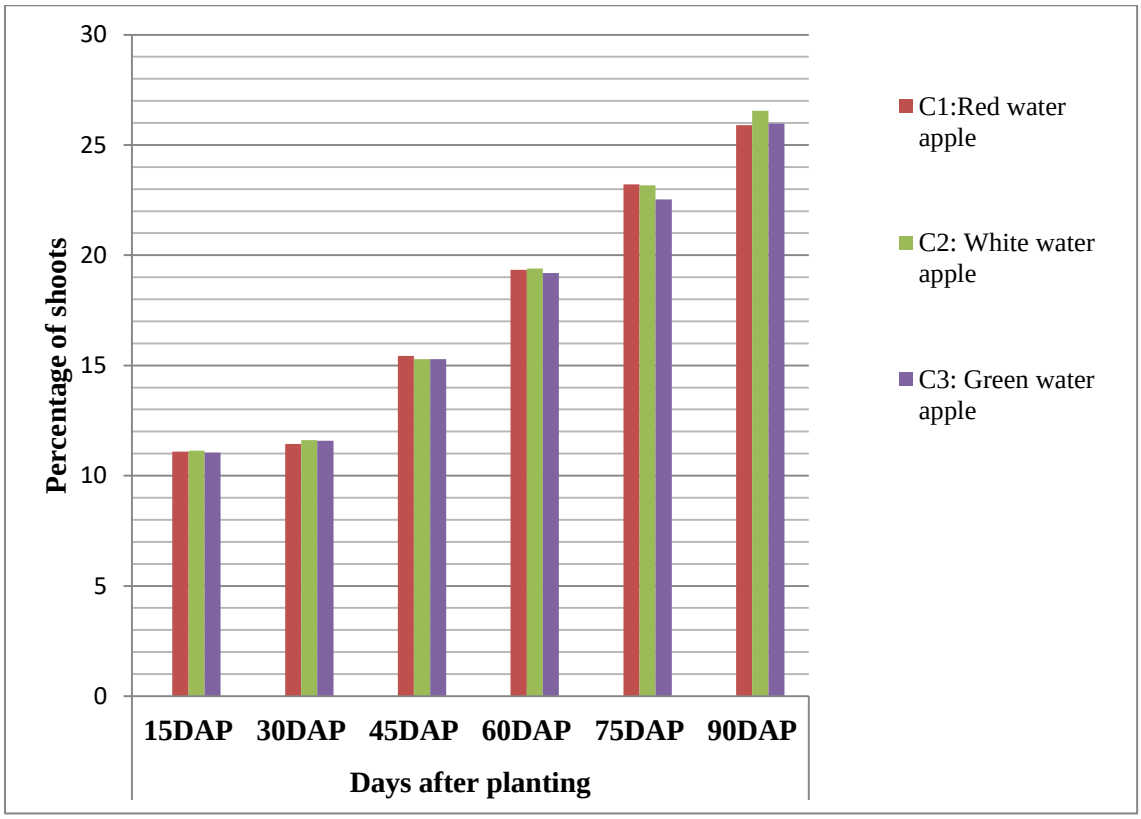
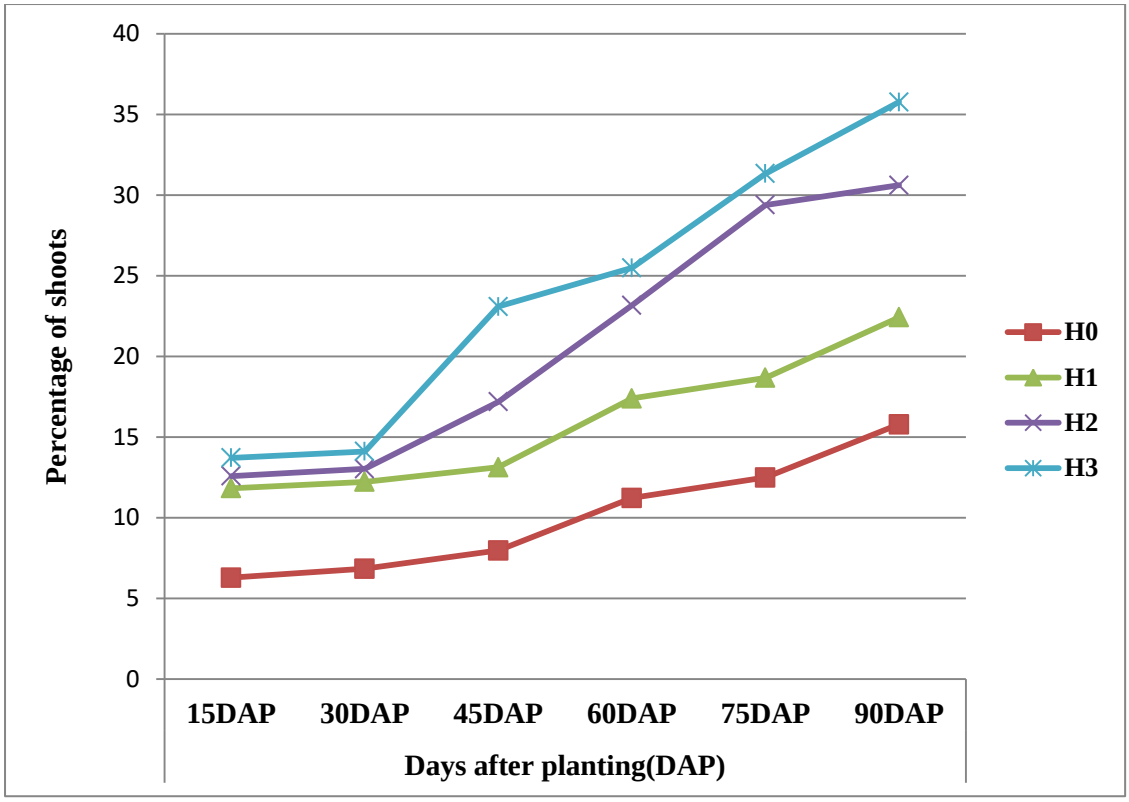


Fig.3. Effect of cultivars on percentage of shoots per cutting

The effect of different growth regulators was found to be highly significant in respect of the percentage of shoots per cutting (Figure 4 & Appendix V). Among the different growth regulators, significantly the maximum percentage of shoots per cutting at 15, 30, 45, 60, 75, and 90 DAP(13.71, 14.11, 23.08, 25.48, 31.33 and 35.76 respectively) were in H_3 followed by H_2. The minimum percentage of shoots per cutting at 15, 30, 45, 60, 75, and 90 DAP (6.28, 6.84, 7.97, 11.22, 12.49 and 15.78 respectively) were noted in H_0.



H_0:Control H_1: Aloe vera gel H_2: NAA (Napthalene Acetic Acid)-15mg/L H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Fig: 4. Effect of growth regulators on percentage of shoots per cutting

The data are given in (Table 4) clearly showed that the interaction between cultivars and different growth regulators had a significant effect on the percentage of shoots per cutting. The the highest percentage of shoots per cutting at 15, 30, 45, 60, 75, and 90 DAP (13.78, 14.28, 23.33, 25.83, 32.25 and 36.23 respectively) were found in C_2H_3 followed by C_1H_3. The minimum percentage of shoots per cutting were recorded in C_2H_0 at 15, 30, 45, 60, 75, and 90 DAP (6.08, 6.65, 7.78, 11.10, 12.18 and 13.73, respectively).

Table 4. Interaction effect of cultivars and growth regulators on percentage of shoots per cutting

Interaction (C x H)		Percentage of shoots					
		15DAP	30DAP	45DAP	60DAP	75DAP	90DAP
C_1	H_0	6.13e	6.80h	8.10g	11.33e	12.50i	16.55d
	H_1	11.93c	12.13f	13.23e	17.28d	18.85f	22.50c
	H_2	12.60b	13.03d	17.08d	23.18c	29.53d	31.25b
	H_3	13.73a	14.08b	23.18a	25.75a	31.95b	36.13a
C_2	H_0	6.08e	6.65h	7.78h	11.10e	12.18j	13.73e
	H_1	11.73c	12.20ef	13.05f	17.33d	18.73f	22.68c
	H_2	12.63b	13.20c	17.18cd	23.20c	29.53d	30.75b
	H_3	13.78a	14.28a	23.33a	25.83a	32.25a	36.23a
C_3	H_0	6.63d	7.08g	8.03g	11.23e	12.80h	17.08d
	H_1	11.83c	12.33e	13.13ef	17.58d	18.43g	22.08c
	H_2	12.50b	12.88d	17.30c	23.10c	29.10e	29.80b
	H_3	13.63a	13.98b	22.73b	24.88b	29.80c	34.93a
$LSD_{(0.05)}$		0.202	0.167	0.160	0.345	0.275	2.448
CV%		0.83	0.66	0.47	0.81	0.54	4.25

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1: Red water apple

C_2: White water apple

C_3: Green water apple

Growth regulators

H_0: Control

H_1:Aloe vera gel

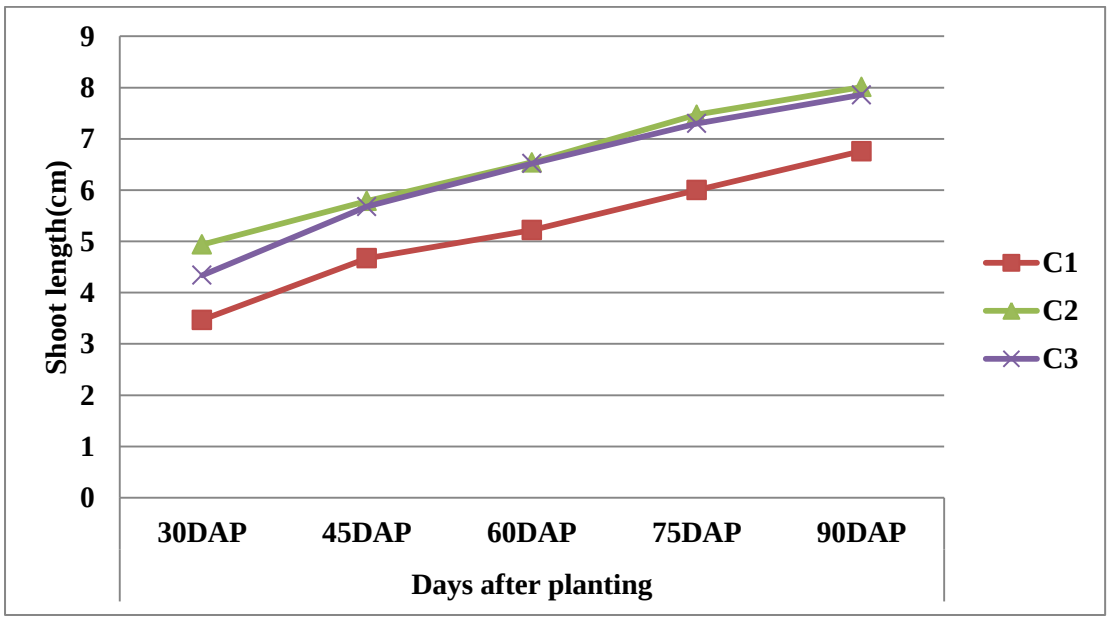
H_2: NAA (Napthalene Acetic Acid)-15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

4.5 Length of the shoot (cm) per cutting

The data regarding the length of shoots of cuttings as influenced by different cultivars and growth regulators are presented in (Table 5) and graphically depicted in (Fig. 5 and 6)

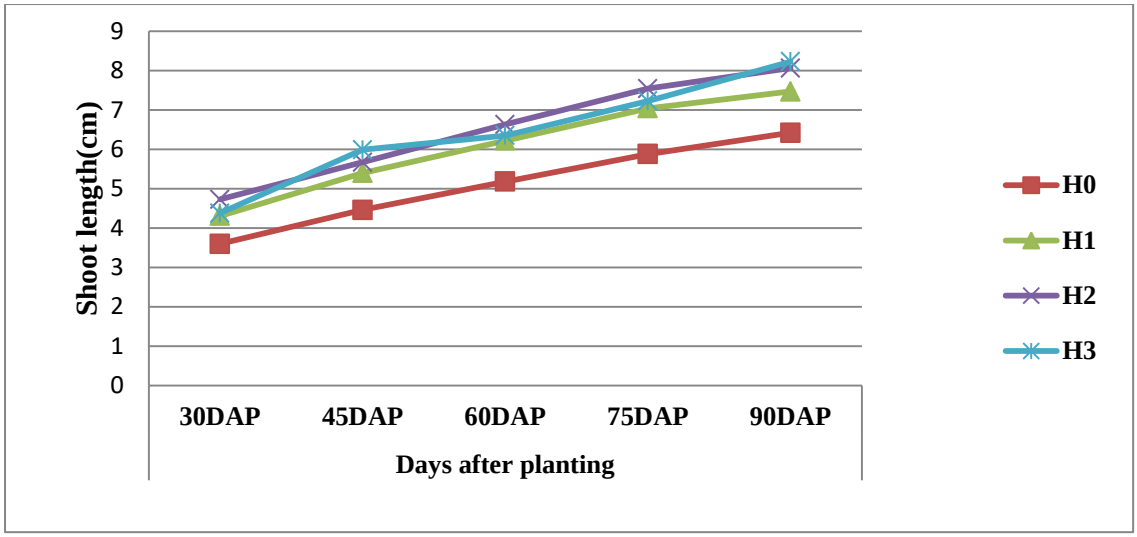
The effect of the cultivars was found to be significant in respect of the length of shoots per cutting at 30 and 90 DAP but such variation was not significant at 45, 60, and 75 DAP (Figure 5 & Appendix VI). The length of shoots per cutting was 4.34 and 8.01 at 30 and 90 DAP, respectively for C_2, which was statistically significant over C_1 and C_3.



C_1: Red water apple C_2:White water apple C_3:Green water apple

Fig. 5. Effect of cultivars on shoot length per cutting

The effect of different growth regulators was found to be highly significant in respect of the length of shoots per cutting at 45 and 90 DAP but such variation was not significant at 30, 60, and 75 DAP (Figure 6 & Appendix VI). The length of shoots per cutting was 5.99 and 8.23 at 45 and 90 DAP respectively for H_3, which was statistically significant over H_0, H_1, and H_2. More or less similar results were also reported by Sandhu and Singh (1986) and Singh *et al*. (2013) and Bhatt and Tomar (2011) in citrus.



H_0:Control H_1: Aloe vera gel H_2: NAA (Napthalene Acetic Acid)-15mg/L H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Fig.6. Effect of growth regulators on shoot length per cutting

The data are given in (Table 5) clearly showed that the interaction between cultivars and growth regulators had a significant effect on the length of shoots per cutting. The highest length of shoots per cutting at 15, 30, 45, 60, 75, and 90 DAP (5.27, 6.33, 7.10, 7.76, and 8.84, respectively) were found in C_2H_3 followed by C_3H_3. The minimum length of shoots per cutting were found in C_2H_0 at 15, 30, 45, 60, 75, and 90 DAP (3.12, 4.05, 4.70, 5.31 and 5.89, respectively) .However, the length of shoots varied from 3.12 to 8.84 but such variation was mostly due to the effect of different growth hormones not for the interaction, which reveals that both the factors acted independently. The results are conformity with, Sandhu and Singh (1986) in citrus and Faghihi *et al*. (2013) in apple, Paul and Aditi (2009) in water apple, Alam *et al*. (2007)in kiwifruit and Singh *et al*. (2009) in citrus.

Table 5. Interaction effect of cultivars and growth regulators on shoot length per cutting

Interaction (C x H)		Shoot length(cm)				
		30DAP	45DAP	60DAP	75DAP	90DAP
C_1	H_0	3.12e	4.05f	5.17f	5.31d	5.89g
	H_1	3.54de	4.79e	5.17f	6.02c	6.76e
	H_2	3.71cd	5.10d	5.64de	6.33c	7.17d
	H_3	3.53de	4.77e	5.39ef	6.35c	7.24d
C_2	H_0	4.01bcd	4.71e	4.70g	5.96c	6.29f
	H_1	5.22a	5.81bc	6.89b	7.61b	7.80c
	H_2	5.28a	6.31a	7.02ab	7.87b	8.51b
	H_3	5.27a	6.33a	7.10ab	7.76b	8.84a
C_3	H_0	3.66cd	4.63e	5.68d	6.35c	7.09d
	H_1	4.17bc	5.60c	6.61c	7.51b	7.84c
	H_2	5.21a	6.58a	7.22a	8.43a	8.50b
	H_3	4.33b	5.90b	6.58c	7.59b	8.61ab
$LSD_{(0.05)}$		0.508	0.294	0.265	0.438	0.248
CV%		5.43	2.48	1.98	2.88	1.49

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1:Red water apple

C_2:White water apple

C_3:Green water apple

Growth regulators

H_0:Control

H_1:Aloe vera gel

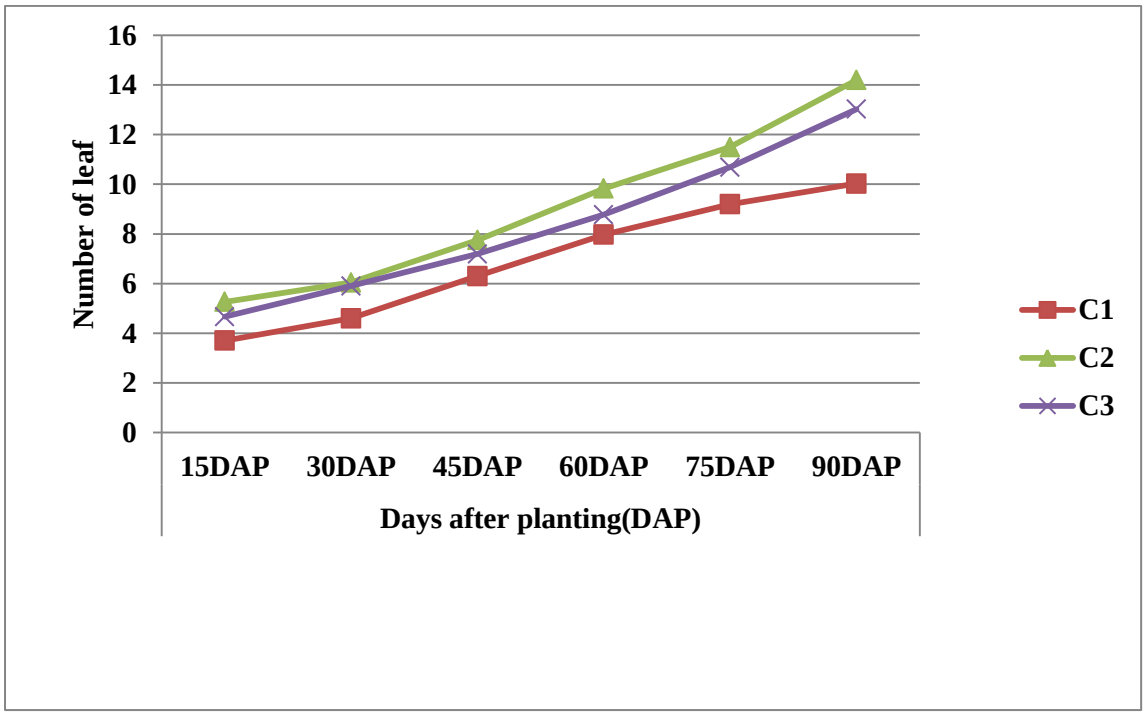
H_2:NAA (Napthalene Acetic Acid)-15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

4.6 Number of leaves per cutting

The data regarding the number of leaves per cutting at 15, 30,45, 60, 75, and 90 DAP of water apple cuttings as influenced by different cultivars and growth regulators are presented in (Table 6) and graphically depicted in (Fig 7 and 8)

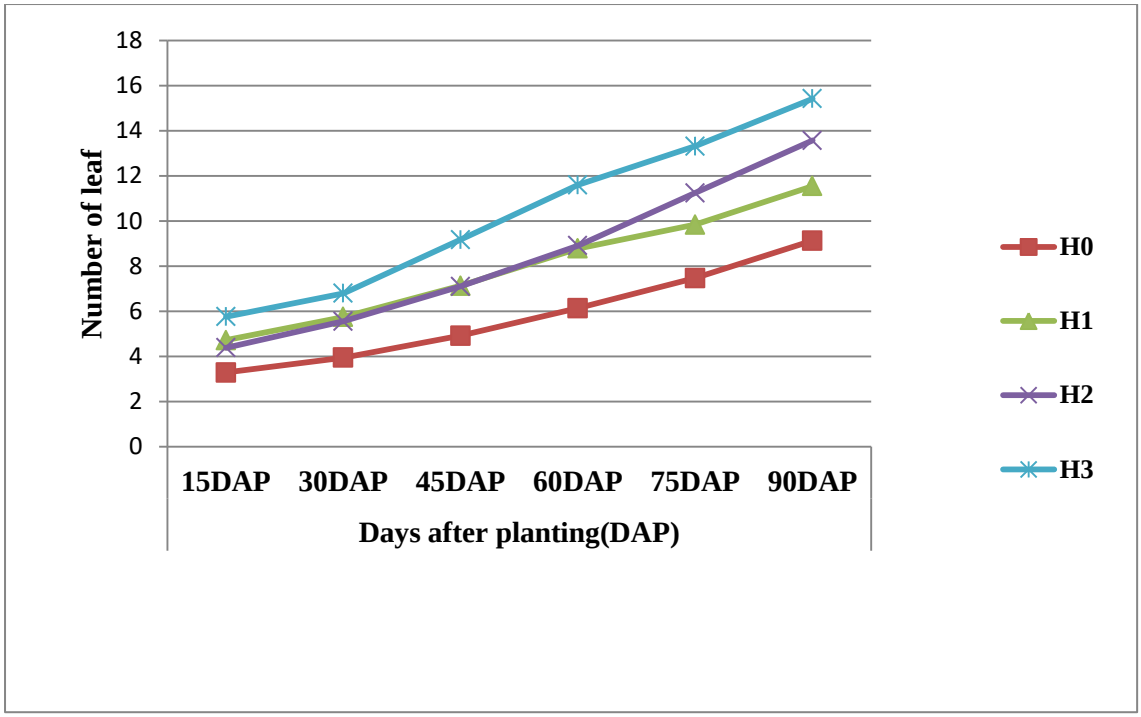
The effect of the cultivars was found to be significant in respect of the number of leaves per cutting at 45, 60, 75, and 90 DAP but such variation was not significant at 15and 30 DAP (Figure 7 & Appendix VII). The number of leaves per cutting was 7.75, 9.83,11.50, and 14.20 at 45, 60, 75, and 90 DAP, respectively for C_2, which was statistically significant over C_1 and C_3.



C_1: Red water apple C_2:White water apple C_3:Green water apple

Fig: 7.Effect of cultivars on number of leaf per cutting

The effect of different growth regulators was found to be highly significant in respect of the number of leaves per cutting at 75 and 90 DAP but such variation was not significant at 15, 30,45, and 60 DAP (Figure 8 & Appendix VII). The number of leaves per cutting was 13.31 and15.42 at 75 and 90 DAP, respectively for H_3, which was statistically significant over H_0, H_1, and H_2. These results are in agreement with the finding of Khapare *et al.* (2012) in fig, Singh *et al. (*2013) in citrus.



H_0:Control H_1: Aloe vera gel H_2: NAA (Napthalene Acetic Acid)-15mg/L H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Fig: 8. Effect of growth regulators on number of leaf per cutting

The data are given in (Table 6) clearly showed that the interaction between cultivars and different growth regulators had a significant effect on the number of leaves per cutting. The highest number of leaves per cutting at 15, 30, 45, 60, 75, and 90 DAP (6.68,7.97,10.72,13.88, 15.79 and 19.03 respectively) were found in C_2H_3 followed by C_3H_3. The minimum number of leaves per cutting were recorded in C_1H_0 at 15, 30, 45, 60, 75, and 90 DAP (2.83,3.21, 4.22, 6.10, 7.38 and 8.59, respectively) . This result is in conformity with the findings of Thakur *et al*. (2014)in olive, Singh *et al*. (2013) in *Citrus lemon.*

Table 6. Interaction effect of cultivars and growth regulators on number of leaf per cutting

Interaction (C x H)		Number of Leaf					
		15DAP	30DAP	45DAP	60DAP	75DAP	90DAP
C_1	H_0	2.83f	3.21g	4.22g	6.10g	7.38f	8.59h
	H_1	4.34cde	5.20def	7.29cd	8.56def	9.49e	10.29fg
	H_2	3.07ef	4.51ef	6.30e	7.90f	9.51e	10.30fg
	H_3	4.56bcd	5.50cde	7.41cd	9.31cd	10.42d	10.94ef
C_2	H_0	3.71def	4.44ef	5.08f	7.90g	7.62f	9.49gh
	H_1	5.42abc	6.22bcd	7.43c	9.44c	10.72d	12.44d
	H_2	5.89ab	6.60bc	7.78c	9.79c	11.88c	15.83b
	H_3	6.68a	7.97ab	10.72a	13.88a	15.79a	19.03a
C_3	H_0	3.35def	4.20fg	5.47f	6.11g	7.40f	9.32gh
	H_1	4.41cde	5.84bcd	6.69de	8.35ef	9.32e	11.93de
	H_2	4.23cde	5.58cde	7.22cd	9.04cde	12.32c	14.59c
	H_3	6.06a	6.92ab	9.39b	11.61b	13.72b	16.31b
$LSD_{(0.05)}$		1.380	1.158	0.728	0.787	0.836	1.172
CV%		13.81	9.54	4.67	4.04	3.63	4.29

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1:Red water apple

C_2:White water apple

C_3:Green water apple

Growth regulators

H_0:Control

H_1:Aloe vera gel

H_2: NAA (Napthalene Acetic Acid)-15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

4.7 Number of roots (cm) per cuttings

The data regarding the number of roots of water apple cuttings as influenced by different cultivars and growth regulators are presented in (Table 7) and graphically depicted in (Fig. 9 and 10)

The effect of the cultivars was found to be significant in respect of the number of roots per cutting at 60 DAP but such variation was not significant at 30 and 90 DAP (Figure 9 & Appendix VIII). The number of roots per cutting was 12.67 at 60 DAP respectively for C_2 which was statistically significant over C_1 and C_3.

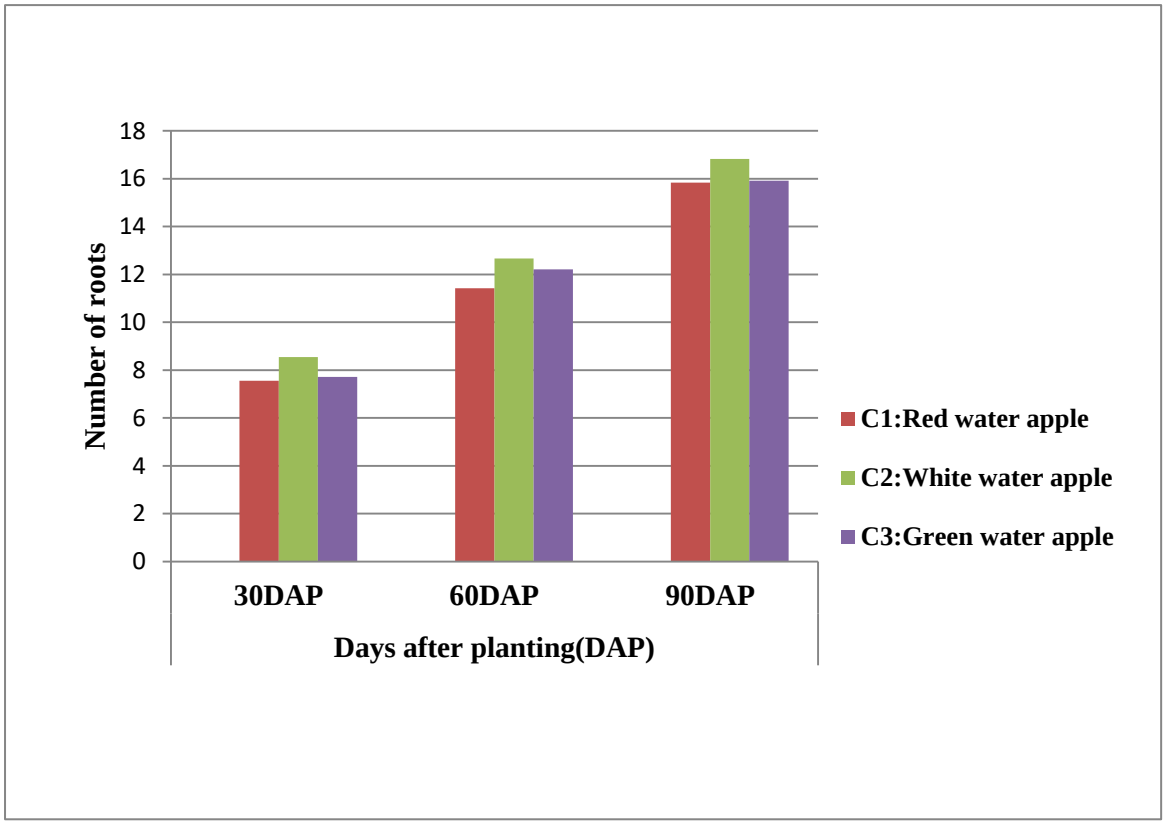
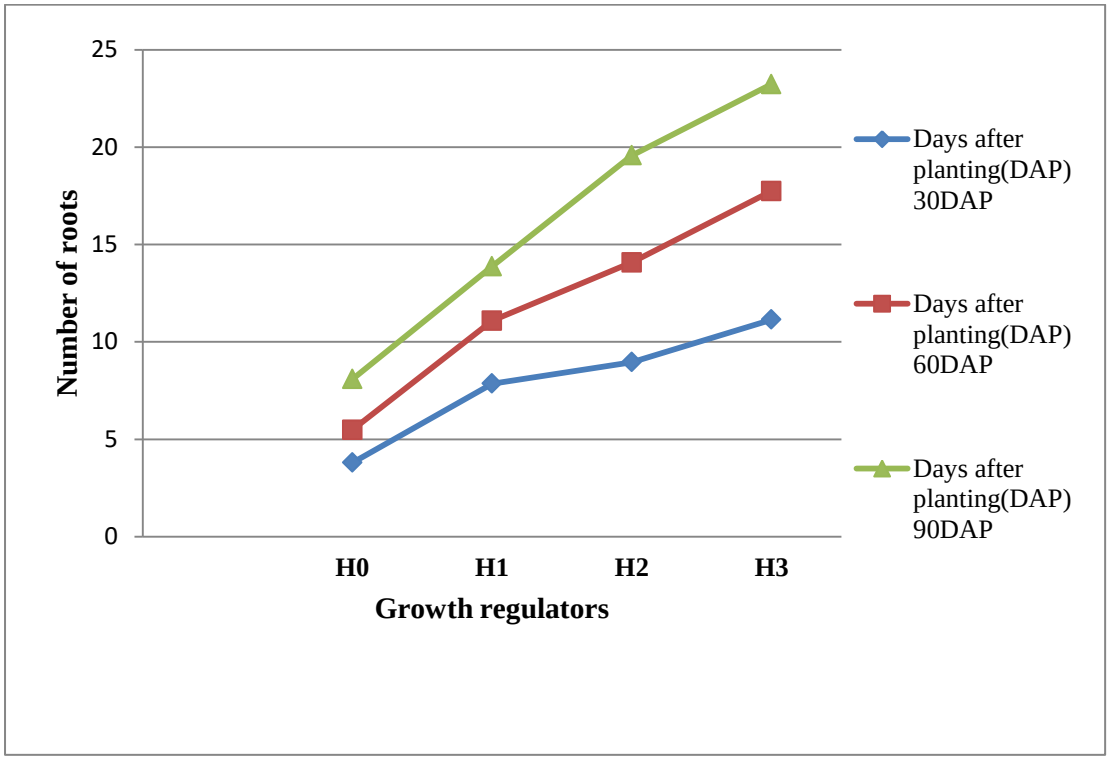


Fig.9. Effect of cultivars on number of roots per cutting

The effect of different growth regulators was found to be highly significant with respect to the number of roots per cutting (Figure 10 & Appendix VIII). Among the different growth regulators, significantly the maximum number of roots per cutting at 30,60 and 90 DAP(11.15, 17.75, and 23.24 respectively) were recorded in H_3 followed by H_2. While significantly the minimum number of shoots per cutting at 30, 60 and 90 DAP (3.80,5.48 and 8.09 respectively) were noted in control (H_0). Similar results were observed by Lal *et al*. (2007) in guava and Khapare *et al*. (2012) in fig, Alam *et al*. (2007)

in kiwifruit, Singh *et al*. (2013) in citrus, Thakur *et al*. (2014) and Porghorban *et al*. (2014) in olive.



H_0:Control H_1: Aloe vera gel H_2: NAA (Napthalene Acetic Acid)-15mg/L H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Fig.10. Effect of growth regulators on percentage of shoots per cutting

The data given in Table 7 noted that the interaction between cultivars and different growth regulators had a significant effect on the number of roots per cutting. The maximum number of roots per cutting at 30, 60 and 90 DAP (11.80, 19.05, and 24.07 respectively) were found in C_2H_3 followed by C_3H_3. The minimum number of roots per cutting at 30, 60, and 90 DAP (3.20, 5.14, and 7.46 respectively) were recorded in C_1H_0. Similar results are conformed by Singh *et al*. (2014) in mulberry, Singh *et al*. (2013) in citrus, Alam *et al*. (2007) in kiwifruit, Bhatt, and Tomar (2010) in citrus.

Table 7.Interaction effect of cultivars and growth regulators on number of roots per cutting

Interaction (C x H)		Number of roots		
		30DAP	60DAP	90DAP
C_1	H_0	3.20h	5.14h	7.46f
	H_1	7.75ef	10.17g	13.70e
	H_2	8.56cde	13.44d	19.40d
	H_3	10.72b	16.92b	22.82b
C_2	H_0	4.73g	5.80h	8.59f
	H_1	8.30def	11.10f	13.87e
	H_2	9.39c	14.73c	20.77c
	H_3	11.80a	19.05a	24.07a
C_3	H_0	3.47h	5.49h	8.22f
	H_1	7.55f	11.99e	14.07e
	H_2	8.93cd	14.09cd	18.57d
	H_3	10.94b	17.27b	22.83b
$LSD_{(0.05)}$		0.853	0.876	1.198
CV%		4.88	3.29	3.36

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1: Red water apple

C_2: White water apple

C_3: Green water apple

Growth regulators

H_0: Control

H_1:Aloe vera gel

H_2: NAA (Napthalene Acetic Acid)-15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

4.8 Percentage of Rooting

The data regarding the percentage of roots of water apple cuttings as influenced by different cultivars and growth regulators are presented in Table 8 and graphically depicted in Fig. 11 and 12

The effect of the cultivars was found to be significant in respect of the percentage of roots per cutting at 60 DAP but such variation was not significant at 30 and 90 DAP (Figure 11 & IX). The percentage of roots per cutting was 63.35 at 60 DAP respectively for C_2, which was statistically significant over C_1 and C_3.

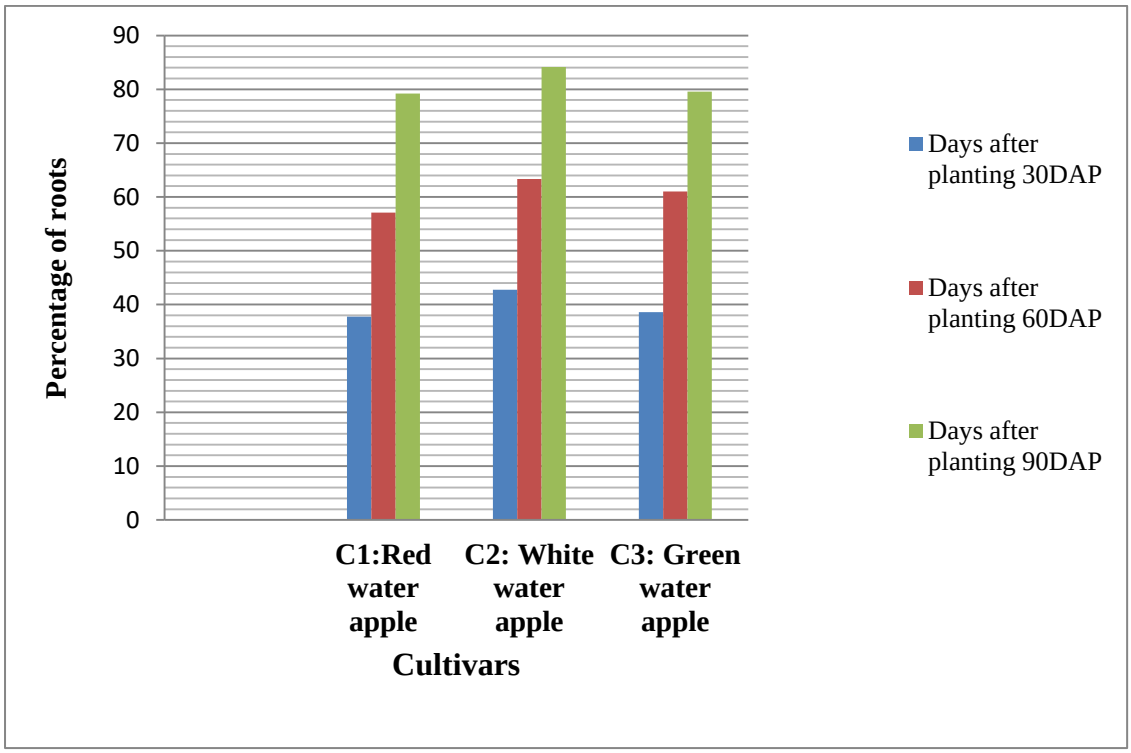
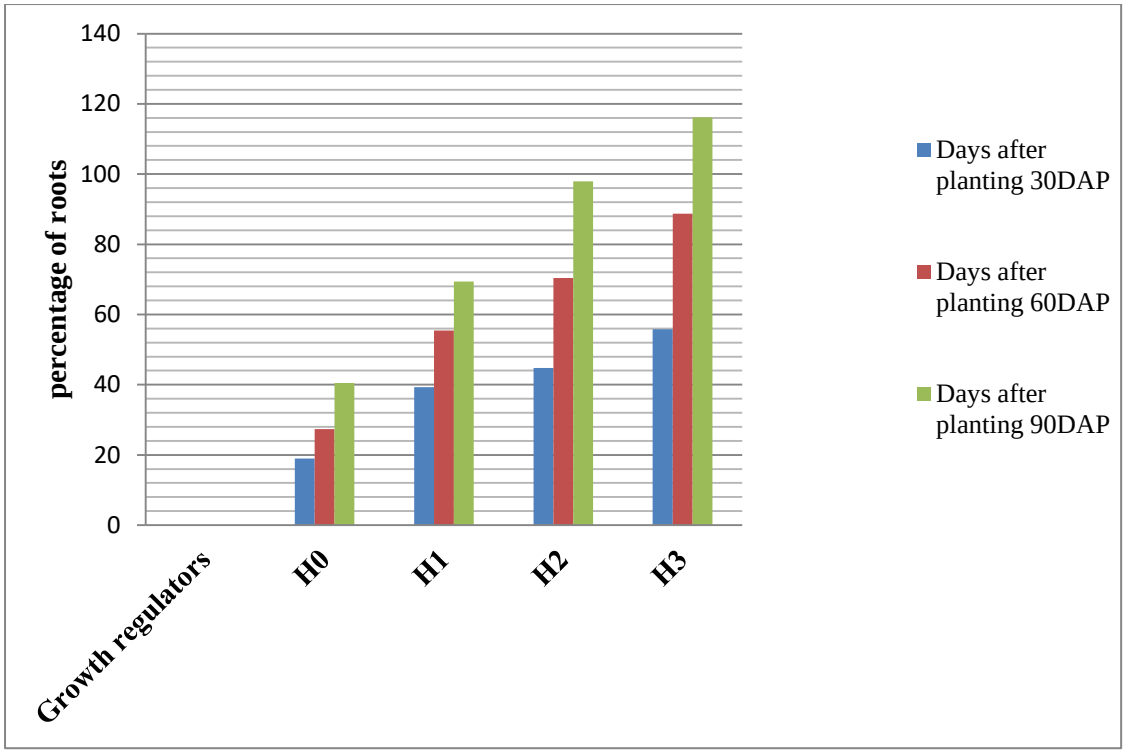


Fig.11. Effect of cultivars on percentage of roots per cutting

The effect of different growth regulators was found to be highly significant in respect of the percentage of roots per cutting (Figure 12 & Appendix IX). Among the different growth regulators, significantly the maximum percentage of roots per cutting at 30,60 and 90 DAP (55.76, 88.73 and 116.18 respectively) were recorded in H_3 followed by H_2. While significantly the minimum percentage of roots per cutting at 30, 60, and 90 DAP (18.99, 27.38 and 40.44 respectively) were noted in control (H_0).



H_0:Control H_1: Aloe vera gel H_2: NAA (Napthalene Acetic Acid)-15mg/L H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Fig.12. Effect of growth regulators on percentage of roots per cutting

The data presented in Table 8 exhibited that the interaction between cultivars and different growth regulators had a significant effect on the percentage of roots per cutting. The the maximum percentage of roots per cutting at 30, 60, and 90 DAP (58.98, 95.25, and 120.35 respectively) were found in C_2H_3 followed by C_3H_3. The minimum percentage of roots per cutting at 30, 60, and 90 DAP (15.98, 25.70, and 37.28, respectively) were recorded in C_1H_0.

Table 8. Interaction effect of cultivars and growth regulators on percentage of roots per cutting

Interaction (C x H)		Percentage of roots		
		30DAP	60DAP	90DAP
C_1	H_0	15.98h	25.70h	37.28f
	H_1	38.73ef	50.85g	68.50e
	H_2	42.78cde	67.20d	96.98d
	H_3	53.60b	84.58b	114.07b
C_2	H_0	23.65g	29.00h	42.95f
	H_1	41.48def	55.50f	69.32e
	H_2	46.93c	73.63c	103.85c
	H_3	58.98a	95.25a	120.35a
C_3	H_0	17.35h	27.45h	41.10f
	H_1	37.73f	59.93e	70.35e
	H_2	44.65cd	70.43cd	92.85d
	H_3	54.70b	86.35b	114.13b
$LSD_{(0.05)}$		4.263	4.380	5.991
CV%		4.88	3.29	3.36

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1: Red water apple

C_2: White water apple

C_3: Green water apple

Growth regulators

H_0: Control

H_1: Aloe vera gel

H_2:NAA (Napthalene Acetic Acid)-15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

4.9 Length of root (cm) per cutting

The data regarding the length of roots of water apple cuttings as influenced by different types of cultivar and growth regulators are presented in Table 9 and graphically depicted in Fig. 13 and 14

The examination of data regarding the length of roots of different cultivars were noted in (Figure13&AppendixX) clearly showed non-significant difference. The maximum length of root per cutting at 90 DAP (11.25) was recorded in C_2. It was also observed by Paul and Aditi(2009).

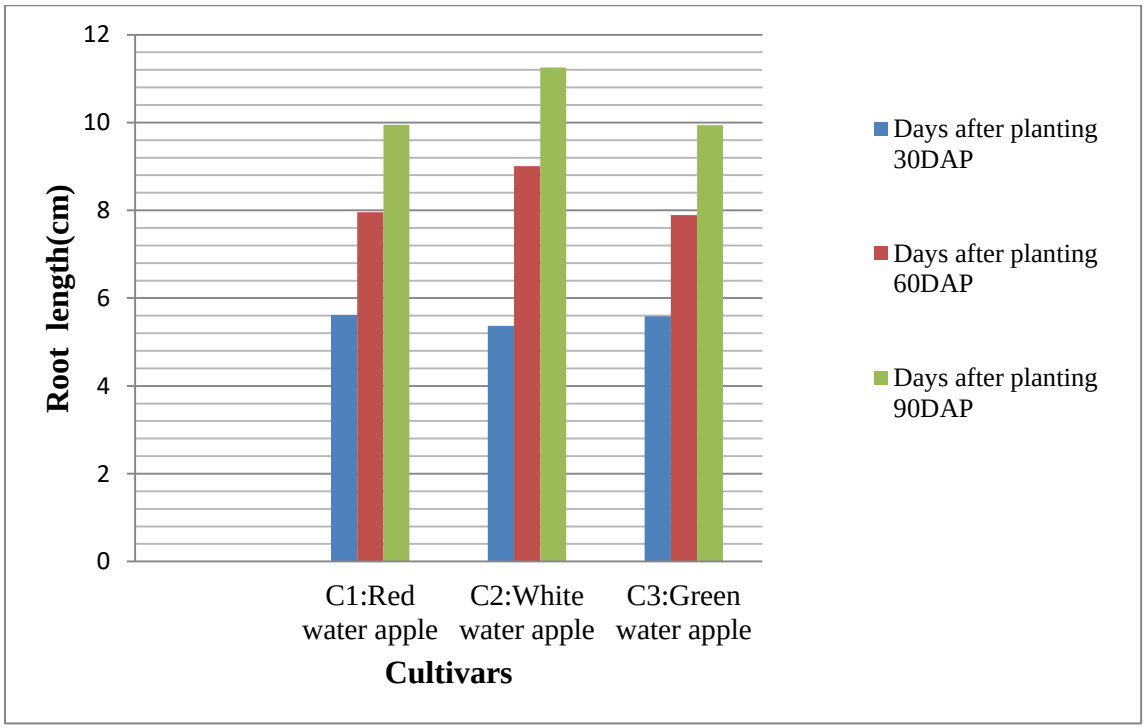
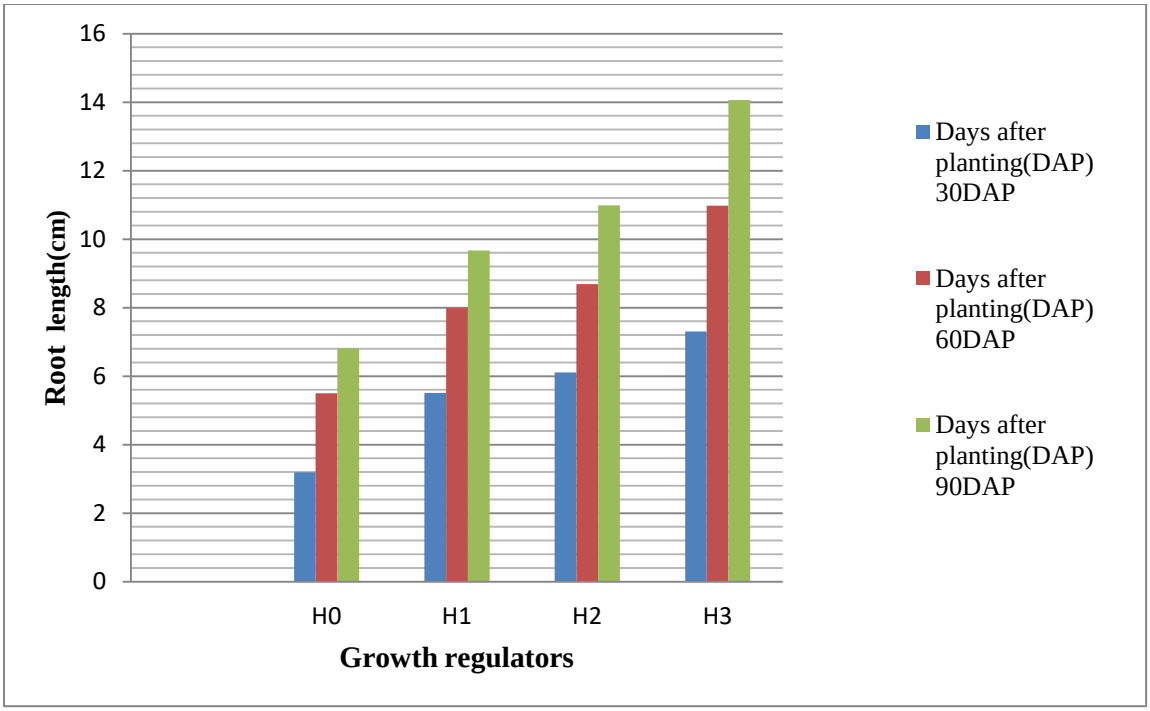


Fig.13. Effect of cultivars and growth regulators on root length per cutting

The effect of different growth regulators was found to be highly significant with respect to the length of roots per cutting (Figure 14 & X). Among the different growth regulators, significantly the maximum length of roots per cutting at 30,60 and 90 DAP(7.30, 10.98, and 14.06, respectively) were recorded in H_3 followed by H_2. The minimum length of roots per cutting at 30, 60, and 90 DAP (3.19, 5.50, and 6.81, respectively) were noted in control (H_0). Similar results are conformed by Lal *et al*. (2007) in guava, Tu *et al*. (1991), and Alam *et al*. (2007) in kiwifruit, Kumar *et al*. (2008) in passion fruit.



H_0:Control H_1: Aloe vera gel H_2: NAA (Napthalene Acetic Acid)-15mg/L H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Fig.14.Effect of growth regulators on root length per cutting

The data presented in Table 9 exhibited that the interaction between cultivars and different growth regulators had a significant effect on the length of roots per cutting. The maximum length of roots per cutting at 30, 60, and 90 DAP (7.69, 11.74, and 15.75, respectively) were found in C_2H_3 followed by C_3H_3. The minimum length of roots per cutting at 30, 60, and 90 DAP (3.03, 4.95, and 6.80, respectively) were recorded in C_1H_0. Similar results were noted by Bhatt and Tomar (2010) in citrus, Saroj *et al*. (2008) in pomegranate, Kurd *et al*. (2010) in olive, Moreno *et al*. (2009)in cape goose berry, Singh *et al*. (1993) in plum

Table 9.Interaction effect of cultivars and growth regulators on root length per cutting

Interaction (C x H)		Root length(cm)		
		30DAP	60DAP	90DAP
C_1	H_0	3.03f	4.95g	6.80gh
	H_1	5.70d	7.66e	9.29f
	H_2	6.27cd	8.46d	10.97de
	H_3	7.22ab	10.78b	12.75c
C_2	H_0	3.30f	6.49f	7.45g
	H_1	5.06e	8.69cd	10.40e
	H_2	5.72d	9.15c	11.39d
	H_3	7.69a	11.74a	15.75a
C_3	H_0	3.24f	5.07g	6.18h
	H_1	5.79cd	7.64e	9.31f
	H_2	6.34c	8.46d	10.61de
	H_3	6.98b	10.42b	13.67b
$LSD_{(0.05)}$		0.621	0.548	0.892
CV%		5.11	3.00	3.91

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars	Growth regulators
C_1: Red water apple	H_0: Control
C_2: White water apple	H_1: Aloe vera gel
C_3: Green water apple	H_2:NAA (Napthalene Acetic Acid)-15mg/L
	H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

4.10 Sprouting Percentage of water apple

The data pertaining to the sprouting percentage of water apple cuttings as influenced by cultivars and different growth regulators are presented in Table 10 and graphically depicted in Fig. 15 and 16.

The examine of data regarding sprouting percentage of different cultivars were noted in (Figure 15 & Appendix XI) clearly showed

significantly difference. The maximum sprouting percentage (89.38 %) was recorded in C_2.

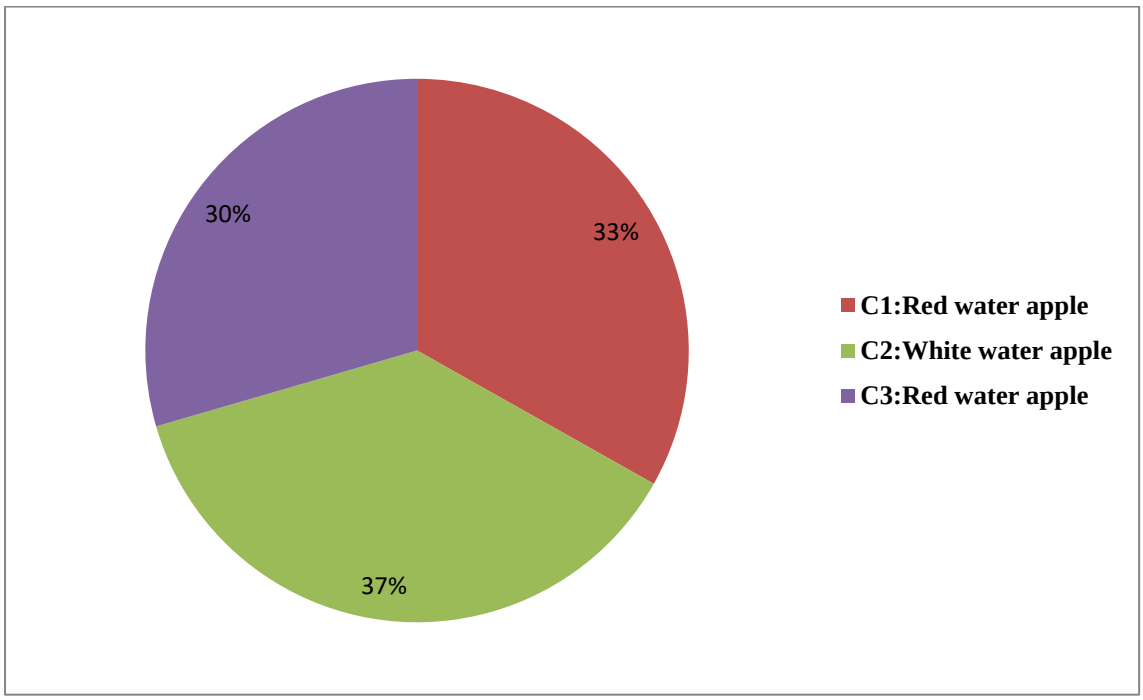
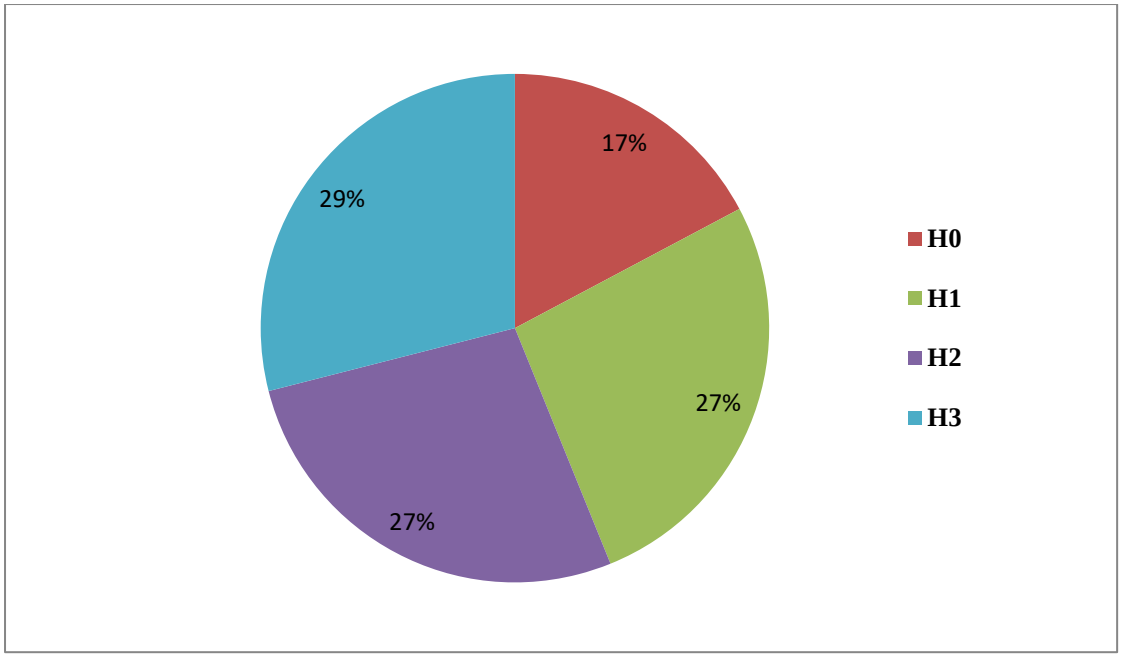


Fig.15. Effect of cultivars on sprouting percentage .

It can be intended from (Figure 16 & Appendix XI) that the sprouting percentage was non significantly differ by different growth regulators and the maximum (92.50 %) sprouting the percentage was recorded in H_3 followed by H_2. While the minimum survival sprouting (55.00%) was noted in control (H_0).



H_0:Control H_1: Aloe vera gel H_2: NAA (Napthalene Acetic Acid)-15mg/L H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Fig.16. Effect of growth regulators on sprouting percentage .

Data presented Table 10 clearly indicates that the interaction between cultivars and different growth regulators showed a significant effect on sprouting percentage. The maximum sprouting percentage (100 %) was recorded in C_2H_3 which was at par with treatment C_2H_2. However, the minimum sprouting percentage (52.50 %) was recorded in C_1H_0.

Table 10. Interaction effect of cultivars and growth regulators on sprouting percentage

Interaction (C x H)		Sprouting percentage
		30DAP
C_1	H_0	52.50h
	H_1	82.50def
	H_2	90bcd
	H_3	92.50abc
C_2	H_0	70g
	H_1	92.50abc
	H_2	95ab
	H_3	100a
C_3	H_0	42.50i
	H_1	80ef
	H_2	75fg
	H_3	85cde
$LSD_{(0.05)}$		9.062
CV%		5.16

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1: Red water apple

C_2: White water apple

C_3: Green water apple

Growth regulators

H_0: Control

H_1: Aloe vera gel

H_2:NAA (Napthalene Acetic Acid)-15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

4.11 Survival percentage

The data pertaining to the survival percentage of water apple cuttings as influenced by types of cultivars and different growth regulators are presented in (Table 11).

The examine of data regarding survival percentage of different type of cultivars were noted in (Table 11 & Appendix XI) clearly showed a significant difference. The maximum survival percentage (83.13%) was recorded in C_2.

It can be intended from (Table 11 & Appendix XI) that the survival percentage was significantly different by different growth regulators and the maximum (89.27 %) survival the percentage was recorded in H_3 followed by H_2. While the minimum survival percentage (45.79%) was noted in control (H_0).

Data presented Table 12 clearly indicates that the interaction between types of varieties and different growth regulators showed a significant effect on survival percentage. The maximum survival percentage (99.13 %) was recorded in C_2H_3 which was at par with treatment C_3H_3. However, the minimum survival percentage (36.39 %) was recorded in C_3H_0.

4.12 Fresh weight of plant (g)

The data regarding the fresh weight of a plant (g) at 90 DAP of cuttings as influenced by different cultivars and growth regulators are presented in Tables 11 and 12.

The data pertaining to the fresh weight of a plant (g) of water apple cutting was recorded in (Table 11 & Appendix XII) and clearly showed a significant effect. The maximum fresh weight of plant (30.93g) was noted in C_2. Similar results were observed by Khapare *et al*. (2012) in fig, Alam *et al.* (2007) in kiwifruit, and Kumar *et al*. (2008) in passion fruit

The perusal of data regarding different growth regulators were a significant influence on fresh weight of the plant (g) at 90 DAP (Table 11& Appendix XII). Among the different growth regulator of aloe vera gell, NAA, mixed rooting hormone, the maximum fresh weight of the plant (31.75 g) was recorded in H_3 treated cuttings followed by H_2 while the minimum fresh weight of plant (21.26 g) was noted in control (H_0). Similar results are conformity with Khapare *et al*. (2012)in fig and Thakur *et al*. (2014) in olive.

It is obvious from the data that interactions between types of water apple cultivar and different growth regulators on fresh weight of the plant was

significantly effect (Table 12). The maximum fresh weight of plant (21.45 g) was noted in C_2H_3 which was at par with C_3H_3 treatment. However, minimum fresh weight of plant (10 g) was recorded in treatment combination C_1H_0. Similar results were also reported by Thakur *et al*. (2014) in olive and Faghihi *et al*. (2013) in apple.

4.13 Dry weight of plant (g)

The data regarding the dry weight of the plant (g) at 90 DAP of water apple cuttings as influenced by different varieties and growth regulators are presented in Tables 11 and 12.

The data pertaining to the dry weight of a plant (g) of water apple cutting was recorded in (Table 11 & Appendix XII) and clearly showed a significant effect. The maximum dry weight of a plant (17.29 g) was noted in C_2. Similar results were observed by Khapare *et al*. (2012) in fig, Alam *et al*. (2007) in kiwifruit, and Kumar *et al*. (2008) in passion fruit.

The data regarding different growth regulators were significant influence on dry weight of plant (g) at 90 DAP (Table 11 & Appendix XII). Among the different growth hormone of aloe vera gell, NAA, and mixed rooting hormone, the maximum dry weight of plant (19.32 g) was recorded in H_3 treated cuttings followed by H_2, while the minimum dry weight of plant (10.67 g) was noted in control (H_0). Similar results are conformity with Khapare *et al*. (2012)in fig and Thakur *et al*. (2014) in olive.

The data indicated that interactions between cultivars and different growth regulators on the dry weight of plant was significantly effect (Table 12). The maximum dry weight of the plant (21.45 g) was noted in C_2H_3 which was at par with C_3H_3 treatment. However, minimum dry weight of plant (10 g) was recorded in treatment combination C_1H_0(red water apple variety+ control). Similar results were also reported by Thakur *et al*. (2014) in olive and Faghihi *et al.* (2013) in apple.

Table 11. Effect of cultivars and growth regulators on Survival percentage, Fresh weight of plant (g), Dry weight of plant (g) .

Treatment	Survival percentage	Fresh weight of plant(g)	Dry weight of plant(g)
	90DAT		
Cultivars			
C_1	65.88c	25.66a	15.22c
C_2	83.13a	30.93a	17.29a
C_3	72.19b	23.54c	16.24b
$LSD_{(0.05)}$	3.609	1.586	0.628
Growth regulators			
H_0	45.79d	21.26d	10.67d
H_1	77.11c	25.42c	16.70c
H_2	82.77b	28.40b	18.31b
H_3	89.27a	31.75a	19.32a
$LSD_{(0.05)}$	4.168	1.831	0.726
CV%	4.45	5.39	3.51

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1: Red water apple

C_2: White water apple

C_3: Green water apple

Growth regulators

H_0: Control

H_1: Aloe vera gel

H_2:NAA (Napthalene Acetic Acid)-15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

Table 12. Interaction effect of cultivars and growth regulators on Survival percentage, Fresh weight of plant (g), Dry weight of plant (g)

Interaction (C x H)		Survival percentage	Fresh weight of plant(g)	Dry weight of plant(g)
		90DAP		
C_1	H_0	42.16f	20.43fg	9.995f
	H_1	71.67d	23.30ef	15.95e
	H_2	73.86d	27.38cd	18.16c
	H_3	75.82cd	31.54b	16.77de
C_2	H_0	58.82e	25.35de	10.93f
	H_1	82.92c	30.19bc	17.85cd
	H_2	91.66b	32.46b	18.93bc
	H_3	99.13a	35.71a	21.45a
C_3	H_0	36.39f	18.01g	11.07f
	H_1	76.73cd	22.78ef	16.30e
	H_2	82.79c	25.35de	17.84cd
	H_3	92.88ab	28.01cd	19.74b
$LSD_{(0.05)}$		7.218	3.171	1.257
CV%		4.45	5.39	3.51

In a column, means followed by same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability

Cultivars

C_1: Red water apple

C_2: White water apple

C_3: Green water apple

Growth regulators

H_0: Control

H_1: Aloe vera gel

H_2:NAA (Napthalene Acetic Acid)- 15mg/L

H_3: Mixed rooting hormone (IAA, IBA and NAA)-3gm/L

CHAPTER V

SUMMARY AND CONCLUSION

An investigation entitled "Multiplication of water apple (*Syzygium samarangense*) cultivars through stem cutting using different plant growth regulators" was conducted at the Horticulture Germplasm Center, Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka during the period from September 2019 to December 2019. The experiment was laid out in Randomized Complete Block Design with Factorial concept having twelve treatment combinations, comprising with two factors (1) cultivars (red water apple, white water apple, and green water apple) and (2) growth regulators (aloe vera gel, NAA -15mg/L, mixed rooting hormone (IAA, IBA, and NAA) -3gm/L . The treatments were repeated thrice. The effect of these treatments on shooting, rooting, shoot, and root growth parameters and survival percentages were studied. The salient features of the experimental findings are summarized and concluded in this chapter.

The minimum number of days taken for shooting and rooting was significantly obtained in C_2.The maximum number of shoots per cutting of water apple at 15, 30, 45, 60, 75, and 90 DAP (2.23, 2.33, 3.09,3.88,4.64 and 5.31 respectively) were observed in C_2.The the maximum percentage of shoots per cutting of water apple cultivars at 15, 30, 45, 60, 75, and 90 DAP (11.14, 11.62, 15.29, 19.40, 23.21 and 26.55 respectively) were observed in C_2. The length of shoots per cutting at 30 and 90 DAP was found to be significant but such variation was not significant at 45, 60, and 75 DAP in C_2. The number of leaves per cutting at 45, 60, 75, and 90 DAP was found to be significant but such variation was not significant at 15and 30 DAP in C_2.The the number of roots per cutting at 60 DAP was found to be significant but such variation was not significant at 30 and 90 DAP in C_2. The effect of the cultivars was found to be significant in respect of the percentage of roots per cutting at 60 DAP but such variation was not significant at 30 and 90 DAP. The maximum length of root per cutting at 90 DAP (11.25) was recorded in C_2. The maximum

sprouting percentage (89.38 %) and survival percentage (83.13%) were recorded in C_2. Fresh and dry weight of plant at 90 DAP was recorded significantly the higher in C_2.

The minimum number of days taken for shooting and rooting was significantly recorded in H_3. The maximum number of shoots, leaves and length of shoots(cm) were significantly recorded in H_3 at 15, 30, 45, 60, and 90 DAP. The highest number of roots and length of roots per cutting at 30, 60, and 90 DAP were significantly recorded in H_3. The maximum shooting and rooting percentage (%) were significantly recorded in H_3. The highest fresh and dry weight of plant (g) at 90 DAP were significantly recorded in H_3. The highest sprouting and survival percentage of cuttings were significantly higher in H_3.

The interaction effect of types of cultivars and growth regulators showed significantly effect on shooting, rooting, number of leaves, shoots, and roots per cutting, length of shoot and root, percentage of shoot and root, fresh and dry weight of plant, sprouting, and survival percentage of water apple cuttings. The best results for all the parameters were recorded in C_2H_3.

Conclusion

On the basis of results of the present investigation, it can be concluded that the C_2 cultivar and H_3 growth regulator were significantly proved superior in all the studied. The interaction of cultivars and growth regulators revealed that the treatment combination C_2H_3(white water apple + mixed rooting hormone - 3gm/L) had recorded significantly the highest growth parameter in terms of shooting, rooting, number of leaves, shoots, and roots per cutting, length of shoot and root, percentage of shoot and root, fresh and dry weight of plant, sprouting, and survival percentage of cuttings. Therefore, the use of C_2 cultivar cuttings with a combination of mixed rooting hormone (IAA, IBA & NAA) - 3gm/L can be utilized for multiplication of healthy and vigorous planting materials of water apple.

CHAPTER VI

REFERENCES

Alam, R ., Rahman, K., Ilyas , M., Ibrahim, M. and Rauf, M. A. (2007). Effect of indole butyric acid concentrations on the rooting of kiwi cuttings. *Sarhad J. A*gri, **23**(2): 293-295.

Al-Saif, A. M. (2011). Effect of plant growth regulators on fruit growth and quality development of *syzygium samarangense* (water apple/wax apple). Faculty of science university of malaya kualalumpur.

Al-Saif1, A. M., Sharif Hossain,A. B. M., Taha, R. M . and Moneruzzaman, K. M. (2011). Photosynthetic yield, fruit ripening and quality characteristics of cultivars of *Syzygium samarangense*. *African J. Agric. Res.,* **6**(15): 3623-3630.

Andersson, D. C., Noreen, Y., Serrano, G., Cox, P. A., Perera, P. and Bohlin, L. (1997). Evaluation of some Samoan and Peruvian medicinal plants by prostaglandin biosynthesis and rat ear oedema assays. *J. Ethnopharmacology.,* **57**(1):35–56.

Akamine, E. K. and Goo, T. (1979). Respiration and ethylene production in fruits of species and cultivars of Psidium and species of Eugenia. *J. Am. Soc. Hortic. Sci*., 98: 381–383.

Arora, R . K. and Yamdagni, R. (1985). Effect of growth regulators on rooting of lemon cuttings with and without leaves. Haryana Agric. *Uni. J . Res* .,**15** (1):77 – 81

Bose T K, Mitra S K, Sanyal D. (2002). "Fruits: Tropical and Subtropical", Naya Udyog Publishers, Kolkata, India.,645.

Bhatt, B. B. and Toma r, V. K. (2010). Effects of IBA on rooting performance of Citrus auriantifolia Swingle (Kagzi - lime) in different growing conditions. *Nature and Sci*.,**8**(7): 8-11.

Chaudhary ,H. L., Tandel ,M., Patel, V. K., Panchal,S. B. and Patel, A. (2018). Effect of type of cuttings and growth regulators on rooting of wax apple (*Syzygium Samarangense* L.). *Int. J. Chem. Stud.,* **6**(2): 2475-2478

Chaudhary ,H.L., Tandel,B ,M.,Patoliya, R.M.and Rathwa, A.D.(2018). Effect of type of cuttings and growth regulators on sorouting of wax apple (*Syzygium Samarangense* L.). *Int. J. Chem. Stud.*, **6**(1): 73-76.

Chang, H., Jones, M.L., Banowetz, G. M. and Clark, D.G. (2003). Overproduction of cytokinins in Petunia flowers transformed with PSAG12-IPT delays corolla senescence and decreases sensitivity to ethylene. *Plant Physiol*., 132: 2174–2183

Debnath, S.;Hore , J. K.;Dhua, R. S. and Sen, S. K. (1986). Auxin synergists in the rooting of stem cuttings of lemon (Citrus limon Burm .). *South Ind. Hort* .,**34** (3):123- 128

Esitken, A., Ercisu, S., Sevik, I . and Sahin, F. (2003). Effect of Indole -3 - Butyric Acid and different strains of Agrobacterium rubi on adventives root for mation from softwood and semi - hardwood wild sour cherry cuttings. *Turk J. Agric*., 27 : 37 - 42.

Faghihi, K., Pyrayvatlo, S. P. and Imani, A. (2013). Effect of indole butyric acid (IBA) , indole acetic acid (IAA) and naphthalene acetic acid (NAA) on woody cuttings rooting of apple M9, MM106 and M111 rootstock. *J. Basic Appl. Res*.,**3** (1): 570 -576.

Galvis, J. A. and Hernandez, M. S. (1993). Comportamiento fisiologicodel arazabajo diferentes temperaturas dealmacenamiento (Araza´ physiological behavior under different storage temperatures). *Colombia Amazo´nica*, **6**: 123–134.

Khandaker, M. M., Awang, I. and Ismail,S. Z. (2017). Effects of naphthalene acetic acid and gibberellic acid on plant physiological characteristics of wax apple (var. *Jambu madu*). *Bulg. J. Agric. Sci.*, **23** (3): 396–404.

Khandaker, M. M., Boyce, A. N.,Osman, N. and Sharif Hossain, A. B. M. (2012). Physiochemical and Phytochemical Properties of Wax Apple (*Syzygium samarangense* [Blume]Merrill & L. M. Perry var. *JambuMadu*) as Affected by Growth Regulator Application. *The ScientificWorld Journal* Volume .Article ID 728613, 13 pages .

Khandaker, M. M. and Boyce, A. N. (2016). Growth, distribution and physiochemical properties of wax apple (*Syzygium samarangense*). *AJCS* **10**(12):1640-1648 .

Kader, A. A. (2000). Postharvest Technology of Horticultural Crops, 3rd ed. Publ. 3311. Division of Agriculture and Natural Resources, University of California, CA.

Khapare, L. S. Dahale, M . H. and Bhusari, R. B. (2012). Propagational studies in fig as affected by plant growth regulator. *Asian J . Hort*., **7**(1): 118-120.

Kuo, Y.-C., Yang, L.-M. and Lin, L.-C. 2004. Isolation and inmunomodulatory effects of flavonoids from *Syzygium samarangense*. Planta Medica, **70**(1): 1237–1239.

Kumar , S., Chithiraichelvan, R., Ka runakaran, G. and Sakthivel, T. (2008). Studies on propagation of passion fruit cv. 'Kaveri' by cuttings under Coorg conditions. *Ind. J. Hort*., **65**(1): 106-109.

Kurd, A. A., Amanullah, Khan, S, Shah, B. H. and Khetran, M. A. (2010). Effect of Indole butyric acid (IBA) on rooting of olive stem cuttings. Pak. *J. Agric. Res*., **23**(3-4): 193-195.

Khapare, L. S.; Dahale, M. H. and Bhusari, R. B. (2012). Propagational studies in fig as affected by plant growth regulator. *Asian J . Hort*., **7**(1): 118-120.

Lal, S.,Tiwari , J.P., Aswathi, P. and Singh, G. (2007). Effect of IBA and NAA on rooting potencial of stooled shoots of guava (*Psidium guajava* L.) cv. Sardar. *Acta Hort*., **7**(35): 193-196

Liaw, S. C., Shu, Z. H., Lin, H. L. and Lee, K. C. (1999). Effects of sugars on anthocyanin biosynthesis in wax apple fruit skin (in Chinese). *J. Agr. Assn*. China New Series, 185: 72–80.

Manan, A., Khan, M. A., Ahmed, W. and Sattar, A.(2002). Clonal propagation of guava (*Psidium guajava* L.). *Int. J. Agric. Bio.*, **4**(1): 143-144.

Moneruzzaman, K. M., Hossain, A. B. M. S., Normaniza, O. and Boyce, A. N. (2011). Growth, yield and quality responses to gibberellic acid (GA_3) of Wax apple *Syzygium samarangense* var. Jambu air madu fruits grown under field conditions. *Afric. J. Biol.* **10**(56):11911-11918.

Moneruzzaman, K. M., Al-Saif,A. M., Alebidi, A. I., Hossain,A. B. M. S., Normaniza ,O.and Boyce,A. N.(2011). An evaluation of the nutritional quality evaluation of three cultivars of *Syzygium samarangense* under Malaysian conditions. *Afric. J. Agric. Res*., **6**(3): 545-552.

Mercado-Silva, E., Benito-Bautista, P., Garcia-Velasco, M.A., (1998). Fruit development, harvest index and ripening changes of guavas produced in central Mexico. *Postharvest Biol. Technol.*, 13: 143–150.

Miami, F L. (1987)."Fruits of warm climates" Java Apple: 381–382.

Morton, J. F., (1987). Fruits of Warm Climates. Morton Collectanea, Miami, F L.

Moreno, N. H.; Herrera, J. G. A.; Lopez, H. E. B . and Fischer, G. (2009). Asexual propagation of cape gooseberry (Pyllanthus peruviana L.) using different substrates and auxin levels. Agronomia Colombiana , **27** (3): 241 - 248.

Nair, A. G. R., Krishnan, S., Ravikrishna, C. and Madhusudanan, K. P. (1999). New and rare flavonol gycosides from leaves of *Syzygium samarangense*. Fitoterapia, **70**(2): 148–151.

Nonaka, G.-i., Aiko, Y., Aritake, K. and Nishioka, I. (1992). Tanins and related compounds. CXIX. Samarangenins A and B, novel proanthocyanidins with doubly bonded structures, from Syzygium samarangense and S. aqueum. Chemical and Pharmaceutical Bulletin, **40**(10): 2671–2673.

Ozcan, M., Ozsan, M., Tuzcu, O., Kaplankiran, M. and Yesiloglu, T. (1990). The effects of plant growth regulators and different propagation times on the percentage rooting of semi - hardwood cuttings of same citrus rootstocks ., Turk Trımve Ormncılık Dergisi ,**14** (2): 139 - 148.

Pirlak, L.(2000). Effect of different cutting times and IBA doses on the rooting rate of hardwood cuttings of cornelian cherry (Cornusmas L.). *Anadolu J. AARI* ., **10** (1): 122 - 134.

Panggabean, G. (1992). *Syzygium aqueum* (Burm.f.) Alst., *Syzygium malaccense* (L.) M. & P, and *Syzygium samarangense* (Blume) M. & P. In Coronel, R.E., et al. (Eds.): PROSEA. No. 2: Edible fruits and nuts. Prosea Foundation, Bogor, Indonesia. pp. 292- 294.

Peter TD, Padmavathi R, Jasmin Sajini, Sarala A.(2011) *Syzygium samarangense*. A Review on Morphology, Phytochemistry & Pharmacological Aspects. *Asian J. Biochem. Pharma. Res.* **4**(1):2231-2560

Paul, R. and Aditi, Ch.(2009). IBA and NAA of 1000 ppm induce more improved rooting characters in air-layers of water apple(*Syzygium javanica* L.). *Bulg. J. Agric. Sci*., **15**(2):123-128.

Resurreccion-Magno, M. H. C., Villasenor, I. M., Harada, N. and Monde, K. (2005). Antihyperglycaemic flavonoids from *Syzygium samarangense* (Blume) merr. and perry. Phytotherapy Research, **19**(3): 246–253.

Severino, L. S., Lima R. L. S.,Lucena, A. M. A., Freire M. A. O.,Sampaio, L. R.,Veras , R. P., Medeiros, K. A. A. L., Sofiatti, V. and Arriel, N. H. C . (2011). Propagation by stem cuttings and root system structure of Jatropha curcaus. Biomass and Bioenergy.

Shandu ,A.S. and Zora Singh (1986). Effect of auxins on the rooting and sprouting behaviour of stem cuttings of sweet lime (Citrus limettioides Tanaka). *Ind.J. Hort*.,**43**(4): 224-226.

Singh,K. K., Choudhary, T. and Kumar,P. (2013) Effect of IBA concentrations on growth and rooting of Citrus limon cv. Pant lemon cuttings. *Hort Flora Res. Spectrum*, **2** (3): 268 -270

Singh, K. K., Chaudhary, T. and Kumar, A. (2014). Effect of various concentrations of IBA and NAA on the rooting of stem cuttings of mulberry (*Morus alba* L.) under house condition in garhwal hill region. *Ind. J. Hill Farming*, **27**(1) :125 - 131.

Singh, K. K., Choudhary, T. and Kumar , P. (2013) Effect of IBA concentrations on growth and rooting of Citrus limon cv. Pant lemon cuttings. HortFlora Res. Spectrum, **2** (3): 268 - 270.

Srivastava, R., Shaw, A. K. and Kulshreshtha, D. K. (1995). Triterpenoids and chalcone from *Sysygium samarangense*. Phytochemistry, **38**(3): 687–689.

Sharma , J. , Band yopadhya y, A. And Sen, S. K. (1989). Effect of auxinic and non- auxinic chemicals on rooting of rose apple (*Syzygium jambos* Alston) stem cuttings. *South Ind.Horti*. **37** (2):108 – 111.

Singh, K. K.; Choudhary, T. and Kumar , P. (2013) Effect of IBA concentrations on growth and rooting of Citrus limon cv. Pant lemon cuttings. *Hort Flora Res*. Spectrum, **2** (3): 268-270.

Thakur, M.; Sharma , D. D. and Singh, K. (2014). Studies on the effect of girdling, etiolation and auxin on rooting of olive (*Olea europaea* L.) cuttings. *Int. J. Farm Sci.,* 4(2):39-46.

Thantirige, M. K. and Karunaratna, M. S. (2005). Propagation of seedless wax apple (*syzygium samarangense*). *Annals Sri Lanka Dept. Agri.*, 7: 271-278.

Wang, X. and Below, F. E. (1996). Cytokinins in enhanced growth and tillering of wheat induced by mixed nitrogen source. *Crop Sci.*, 36:121-126.

Wang, D. N. (1991). Past, present and future of wax-apple production in Taiwan. (in Chinese) p.339-355. In: Proceedings of the Symposium on Fruit Production, Research and Development in Taiwan. CR Yang (ed.) Chia-Yi Agric. Exp. Sta., Taiwan *Agri. Res. Ins.*, Taichung Hsien, Taiwan.

CHAPTER VII

APPENDICES

Appendix I. Characteristics of the soil of experimental field analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the soil of experimental field

Morphological features	Characteristics
Location	Horticultural Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Drainage	Well drained

B.Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
Ph	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI, 2020

Appendix II. Monthly record of air temperature, rainfall, relative humidity, rainfall and Sunshine of the experimental site during the period from September,2019 to March,2020

Month	*Air temperature (^{o}c)		*Relative humidity (%)	*Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
September,2019	24.32	17.22	75	13	7.2
October, 2019	25.82	16.04	78	00	6.8
November, 2019	22.40	13.50	74	00	6.3
December, 2019	24.50	12.40	68	00	5.7
January, 2020	27.10	16.70	67	30	6.7
February, 2020	31.40	19.60	54	11	8.2
March,2020	34.20	23.40	61	112	8.1

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III : Analysis of variance (ANOVA) of the data on days to shoot initiation and days to root initiation of water apple under different cultivar, growth regulator and their integrated effect

Source of variation	**Degrees of freedom**	**Mean square**	
		Days to shoot initiation	**Days to root initiation**
Replication	2	16.667	3.081
Cultivar(C)	2	30.125**	47.167*
Growth regulator(H)	3	174.944**	231.167*
C X H	6	1.069	4.500
Error	10	0.939	1.182

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix IV : Analysis of variance (ANOVA) of the data on number of shoot of water apple at different days after transplanting (DAT) under different cultivar, growth regulator and their integrated effect

Source of variation	Degrees of freedom	Mean square					
		Number of shoot at					
		15DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Replication	2	3.792	0.000	0.001	0.000	0.003	0.041
Cultivar(C)	2	7.042^{NS}	0.003*	0.002*	0.005*	0.046*	0.041^{NS}
Growth regulator (H)	3	2.623*	2.509*	9.797**	9.784**	19.151*	18.682**
C X H	6	2.771	0.002	0.003	0.006	0.038	0.104
Error	10	3.364	0.000	0.000	0.001	0.001	0.050

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix V : Analysis of variance (ANOVA) of the data on percentage of shoot of water apple at different days after transplanting (DAT) under different cultivar, growth regulator and their integrated effect

Source of variation	Degrees of Freedom	Mean square					
		Percentage of shoot at					
		15DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Replication	2	4.601	0.007	0.023	4.167	0.065	1.021
Cultivar(C)	2	0.018^{NS}	0.070*	0.050*	0.091*	1.151*	1.020^{NS}
Growth regulator (H)	3	65.570*	62.716*	244.927**	244.203*	478.781*	467.055**
C X H	6	0.069	0.048	0.081	0.183	0.944	2.598
Error	10	8.409	0.006	0.005	0.025	0.016	1.237

**: Significant at 0.01 level of probability;*: Significant at 0.05 level of probability

Appendix VI : Analysis of variance (ANOVA) of the data on Length of shoot of water apple at different days after transplanting (DAT) under different cultivar, growth regulator and their integrated effect

Source of variation	Degrees of freedom	Mean square				
		Length of shoot at				
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Replication	2	0.004	0.006	0.035	0.175	0.002
Cultivar(C)	2	4.361*	3.007^{NS}	4.577^{NS}	5.160^{NS}	3.709**
Growth regulator (H)	3	1.357^{NS}	2.608**	2.401^{NS}	3.196^{NS}	4.001**
C X H	6	0.189	0.126	0.210	0.177	0.161
Error	10	0.053	0.018	0.015	0.040	0.013

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VII : Analysis of variance (ANOVA) of the data on number of leaves of water apple at different days after transplanting (DAT) under different cultivar, growth regulator and their integrated effect

Source of variation	Degrees of Freedom	Mean square					
		Number of leaves at					
		15DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Replication	2	0.044	0.094	7.704	0.016	0.187	0.443
Cultivar(C)	2	4.988^{NS}	5.025^{NS}	4.282**	7.015*	10.907**	37.035**
Growth regulator(H)	3	6.220^{NS}	8.293^{NS}	18.045^{NS}	29.757**	36.141*	43.833*
C X H	6	0.823	0.541	1.179	1.974	3.183	5.572
Error	10	0.393	0.277	0.109	0.128	0.144	0.284

**: Significant at 0.01 level of probability;*: Significant at 0.05 level of probability

Appendix VIII : Analysis of variance (ANOVA) of the data on Number of roots per cutting of water apple at different days after transplanting (DAT) under different cultivar, growth regulator and their integrated effect

Source of variation	Degrees of freedom	Mean square		
		Number of roots		
		30DAT	60DAT	90DAT
Replication	2	0.246	0.220	3.375
Cultivar(C)	2	2.283^{NS}	3.210**	2.380^{NS}
Growth regulator (H)	3	57.016*	161.397*	264.234*
C X H	6	0.117	0.700	0.624
Error	10	0.150	0.158	0.296

**: Significant at 0.01 level of probability;*: Significant at 0.05 level of probability

Appendix IX : Analysis of variance (ANOVA) of the data on percentage of roots per cutting of water apple at different days after transplanting (DAT) under different cultivar, growth regulator and their integrated effect

Source of variation	Degrees of freedom	Mean square		
		percentage of roots		
		30DAT	60DAT	90DAT
Replication	2	6.15	5.51	0.01
Cultivar(C)	2	57.07^{NS}	80.25**	59.50^{NS}
Growth regulator (H)	3	1425.40*	4034.92*	6605.85*
C X H	6	2.91	17.49	15.59
Error	10	3.75	3.96	7.41

**: Significant at 0.01 level of probability;*: Significant at 0.05 level of probability

Appendix X : Analysis of variance (ANOVA) of the data on length of root per cutting of water apple at different days after transplanting (DAT) under different cultivar, growth regulator and their integrated effect

Source of variation	Degrees of freedom	Mean square		
		Length of roots		
		30DAT	60DAT	90DAT
Replication	2	0.005	0.140	1.766
Cultivar(C)	2	0.148^{NS}	3.162*	4.507*
Growth regulator (H)	3	17.882*	30.477*	54.311*
C X H	6	0.234	0.091	0.708
Error	10	0.080	0.062	0.164

**: Significant at 0.01 level of probability;*: Significant at 0.05 level of probability

Appendix XI : Analysis of variance (ANOVA) of the data on Sprouting Percentage and Survival percentage of water apple at different days after transplanting (DAT) under different cultivar, growth regulator and their integrated effect

Source of variation	Degrees of freedom	Mean square	
		Sprouting percentage	Survival percentage
		30DAT	90DAT
Replication	2	26.04	0.69
Cultivar(C)	2	704.17*	609.61**
Growth regulator(H)	3	1701.04**	2230.77*
C X H	6	33.33	58.24
Error	10	16.95	10.76

**: Significant at 0.01 level of probability;*: Significant at 0.05 level of probability

Appendix XII : Analysis of variance (ANOVA) of the data on Fresh weight of plant(g) and Dry weight of plant (g) of water apple at 90 DAT under different cultivar, growth regulator and their integrated effect

Source of variation	Degrees of freedom	Mean square	
		Fresh weight of plant(g)	Dry weight of plant (g)
		90DAT	
Replication	2	7.393	6.201
Cultivar(C)	2	115.766*	8.581**
Growth regulator(H)	3	119.229**	90.032*
C X H	6	0.980	2.006
Error	10	2.076	0.326

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability