INFLUENCE OF PLANT GROWTH REGULATORS AND WOUNDING TO STEM CUTTING OF GARDENIA (*Gardenia jasminoides*) IN WINTER AND SUMMER SEASON

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CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF PLANT GROWTH REGULATORS AND WOUNDING TO STEM CUTTING OF GARDENIA (*Gardenia jasminoides*) IN WINTER AND SUMMER SEASON"** submitted to the Faculty of Agriculture, 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 bonafide research work carried out by **MD. ARIF HOSEN SADDAM,** Registration No. **14-06212** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2021
Dhaka, Bangladesh

Prof. Dr. Mohammad Humayun Kabir
Supervisor

It is a fact that the remembrance of Allah brings peace in the heart. It is better to ponder over the verses to bring us even closer to Allah (swt).

DEDICATED TO-

MY BELOVED PARENTS

ABBREVIATIONS

ABBREVIATION	MEANING
C.V	Coefficient of Variance
Cm	Centimeter
cv.	Cultivar
DAP	Days After Planting
DAT	Days After Transplanting
et al.	and others (at elli)
Fig.	Figure
i.e.	That is
L	Liter
Mg	Milligram
Ml	Milliliter
No.	Number
Temp.	Temperature
R.H.	Relative Humidity
RCBD	Randomized Complete Block Design
Vit.	Vitamine
^{0}C	Degree Celsius or Centigrade
%	Percent

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- Author

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INFLUENCE OF PLANT GROWTH REGULATORS AND WOUNDING TO STEM CUTTING OF GARDENIA (*Gardenia jasminoides*) IN WINTER AND SUMMER SEASON

BY

Md. Arif Hosen Saddam

ABSTRACT

The present experiment was conducted to find out the "influence of plant growth regulators and wounding to stem cutting of gardenia (*Gardenia jasminoides*) in winter and summer season", conducted at Horticulture farm, Sher-e-Bangla Agricultural University, Dhaka. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replication comprising with one cultivar (*Gardenia Jasminoides*) and the research work was conducted with one set of treatment consisting of four growth regulator namely, T_0 = Control, T_1 = Mixed plant growth regulators (1000 ppm IBA + 1000 ppm NAA), T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators. The effect of these treatments on percentage of rooting, percentage of shooting, shoot no. and length, root no. and length and survival percentage were studied. The results revealed that the, growth regulators exerted significant influence on different parameters studied. Among the growth regulators T_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 such as number of shoots and roots, length of shoot and root and survival percentage in both winter and summer season. On the basis of the results obtained, it was concluded that the T_3 recorded the highest shooting, rooting and survival percentage of cutting and was found most useful, healthy and vigorous planting materials of *Gardenia Jasminoides*.

CHAPTER I
INTRODUCTION

Gardenia (*Gardenia jasminoides*) belongs to the family Rubiaceae, native to the tropical and subtropical regions of Africa, Asia, Madagascar and Pacific Islands is a flower plant. It is native to the West Indies, but naturalized in South Asia. It is evergreen bushy shrub and widely grown in subtropical regions as an ornamental plant for their flowers are heavily perfumed at night. Propagation by cutting is commonly used in the commercial production of ornamental flowers. Cuttings of some species root readily without an auxin treatment, while cuttings of other species benefit from auxin treatment through enhanced promotion of rooting; benefits may be dependent upon the species and cultivar, condition of the cutting wood, time of year, and other factors (Griffith, 1998 and Hartmann *et al.*, 2002).

This flower plant is generally propagated by stem cutting. This process is easy but some problems arise when cuttings are planted in soil. Some cutting becomes dried, wilted and some become rotten. As a result propagation percentage is reduced. Rooting hormones are very necessary for easy to root and improve the quality of root system developed, decrease rooting time and improve the percentage of cutting rooted (Salman, 1988), countless studies have been done proving effectiveness of auxin treatment of cuttings. There are now several commercial synthetic forms of rooting hormones for nursery industry. These typically include IBA or NAA or a mixture of both (Blazich, 1988). Wounding to cuttings base is a common practice in commercial production of rooted cuttings. Wells (1962) stated that wounding was used for: first, to speed up the rooting processes, second, to increase the number and quality of roots, and third, to improve attachment points between roots and the cuttings. Al-Noaimy (1999) found by wounding the terminal cuttings of *Cotoneaster prostrate* taken at November to March (except those taken at December) treated with a mixture of IBA and NAA at concentration 1000 mg/L for both by quick-dip method gave the best result for rooting percentage 100%, higher number of roots/cutting 12.08-23.05, in addition to enhancing vegetative growth. Many investigators emphasized that the time of the year have a dramatic influence on rooting cuttings, with many plant species there is an optimal period of the year for rooting, thus by rooting cuttings during optimal periods were maximized the rooting process and speed up the production liners (Anand and Heberlein, 1975).

Root-promoting chemicals for cutting propagation commonly contain indole-3-butyric acid (IBA), 1-naphthaleneacetic acid (NAA), or a combination of the two, and are available in liquid, talc, tablet, and gel formulations. Commercial root-promoting chemicals are normally applied to the basal portion of cuttings using a liquid or talc formulation of auxin. The quick-dip method is often preferred by commercial propagators for application of liquid auxin formulations for reasons of economy, speed, ease, and uniformity of application and results. An extended basal soak may be utilized for some difficult-to-root species (Hartmann *et al*., 2002).

Application of auxin by means of complete immersion of cuttings in an auxin solution has been reported as effective in comparison to a basal quick-dip treatment in an auxin powder (Van Bragt *et al.*, 1976). Several crops have been rooted effectively when the foliage of the cuttings was dipped into an auxin-containing solution (Anuradha and Sreenivasan, 1993; McGuire, 1967; McGuire and Sorenson, 1966). However, both of these techniques involve application of auxin prior to sticking, and so require subsequent handling of the treated cuttings.

Among the vegetative means, stem cutting is one of the easiest, cheapest and least time consuming methods of plant propagation (Bose and Mukharjee, 1977). The root ability of cutting of different plant species is different. There are certain plant species (for example apple, phalsha, etc.) which form roots easily on cutting while some others give root when external manipulating treatment is given.

Root initiation with the use of growth regulators occupies a significant position in the field of propagation (Mukherjee *et al.,* 1976). All the growth regulators are not equally suitable for rooting performances. Among the growth regulators Indole Butyric Acid (IBA) is the most commonly and widely used to achieve high percentage of rooting success for the ornamental species (Kundu *et al*., 1987). Other exogenous hormones which regulate plant growth arc Indole Acetic Acid (IAA), Napthalene Acetic Acid (NAA), 2, 4-Dichloro phenoxy acetic acid (2, 4-D), Indole Propionic Acid. When propagation through stem cutting becomes very difficult, treatments with growth regulators are applied in optimum concentration to promote rooting in stem cutting. Activity of growth regulators depends upon the amount of hormone applied and a particular concentration of growth regulator may be more effective for initiation of root in stem cutting. Thus, optimum concentration of growth regulator needs to be determined for different plant species. The objectives of this study are as follows:

Objectives

- To find out the suitable plant growth regulators of stem cutting of gardenia in winter and summer season,
- To available the seedlings of gardenia in winter and summer season; i.e. all the year round.

CHAPTER II
REVIEW OF LITERATURE

Cutting is the most important technique for the propagation of ornamental plants. It is the easiest method of propagation and has been attempted in certain species, particularly those grown on commercial scale. Often nursery men are facing trouble with the formation of root in plants having hard wood or semi-hard wood. Some plants have no ability to produce root in normal condition. Several factors like type of cutting, rooting media, environmental conditions etc., influence root formation in cuttings. The use of auxin in rooting has brought about a vast quantitative change in plant propagation. According to Hartmann and Kester (1972) the most commonly and widely used auxins are IBA (as best one), NAA and IAA in promoting rooting.

2.1 Effect of plant growth regulators on Gardenia and others

Hasan (2020) 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. 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.

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. jambumadu. 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 and 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.

Otiende *et al.* (2016) the study was conducted to determine the effects of cutting position (top, middle and bottom) of *Rosa hybrida* rootstocks ('Natal Briar' and 'Rosa

Progress') and auxins (0 %, 0.4 % IBA and 0.2 % NAA) on rooting and grafting take of rose cultivar 'Inca'. Changes in endogenous carbohydrate content during rooting were measured on days 0, 3 and 7 after sticking. The experiment was factorial in a completely randomized design. Interaction between cutting position and rootstock was significant ($P \leq 0.05$) for most of the parameters measured. The shoot height, root number, percent rooting and grafting take increased towards the basal position in 'Rosa Progress'. In 'Natal Briar', the shoot and root growth parameters increased towards the top though non significant except grafting take that significantly increased towards the basal position. The auxin treated cuttings recorded significantly ($P \leq 0.05$) higher grafting take and rooting percentage than the control. 0.4 % IBA exhibited higher shoot height, leaf number and root number than 0.2 % NAA. The rootstock 'Natal Briar' recorded significantly ($P \leq 0.05$) higher rooting percentage and grafting take than 'Rosa Progress'. Middle and top position cuttings of 'Rosa Progress' and 'Natal Briar' recorded higher carbohydrate content, respectively than bottom position cuttings. Bottom position recorded higher sucrose content on day 3 than days 0 and 7 after planting in 'Rosa Progress'. 'Natal Briar' exhibited significantly ($P \leq 0.05$) higher carbohydrate content than 'Rosa Progress'. The increase in growth with top position cuttings of 'Natal Briar' could be attributed to high carbohydrate content. The high growth responses in bottom position cuttings of 'Rosa Progress' could be attributed to high sucrose content on day 3 after planting. The stem cuttings of rootstocks for top grafting rose cultivar 'Inca' should be taken from bottom position cuttings of both rootstocks, and auxins should be applied to increase rooting and grafting take.

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 50 mg/L GA_3, 10 mg/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 50 mg/L GA_3, 10mg/L NAA, and 5 mg/L 2,4-D once a week from bud development to fruit maturation increased the physiochemical and phytochemical properties of wax apple fruits.

Rahbin *et al.* (2012) in order to evaluate of the cutting location on shoot and Indule butyric acid (IBA) on rooting of 'Night Jessamine' (*Cestrum nocturnum*) stem cuttings, this study was performed as factorial arrangement in randomized complete block design in mist greenhouse with 4 replications and 10 cuttings per replicate. For this purpose was prepared annual shoots of plant as cutting source and was divided from half. Then was prepared 15 cm long cuttings from each part of shoot and was treated by 0 (distilled water), 1000, 1500, 2000 and 4000 mg/L IBA for 5 seconds and was cultured in pots containing sand and peat-moss. After 75 days was recorded rooting percent; grown cutting percent; root number in each cutting; root length; root fresh and dry weight. Based on results, the cuttings of upper part of shoot significantly were better than the cutting of lower part of shoot especially in relation to rooting percent and grown cuttings percent. IBA 2000 and 4000 mg/L significantly were better than other concentrations.

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. The 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 the 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 GA_3, 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.

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.

Faghihi *et al*. (2013) studied the effect of different concentrations of hormones, IBA, IAA and NAA on rooting of the woody cuttings of MM_{106}, M_9 and MM_{111} apple rootstocks. After preparing woody cuttings of MM_{111}, MM_{106} and M_9, 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.

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 cm and 1.52 cm, respectively), number of sprouts, number of leaves and number of roots/cutting (17.**77** and 23.00 and 52.42, respectively) in hardwood cutting.

Khapare *et al*. (2012) propagation 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.

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 GA_3 once a week results in better yield and quality of jambu air madu fruits under field conditions.

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 root system arising from cutting and development of roots of *Citrus auriantifolia* cutting and can be used for massscale multiplication.

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.

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.

Blythe *et al.* (2003) research was conducted to determine whether a foliar spray application of the commercial root-promoting formulation Dip 'N Grow® [10,000 ppm indole-3-butyric acid (IBA) and 5,000 ppm 1-naphthaleneacetic acid] or the potassium (K) salt of IBA (K-IBA) would be as effective as a basal quick-dip for rooting stem cuttings of selected ornamentals. Cuttings of *Chrysanthemum pacficum* sprayed with Dip 'N Grow® at 50 + 25 ppm IBA + NAA or K-IBA at 0 to 50 ppm showed generally similar root development measures compared to a basal quick-dip; an exception was 10 ppm K-IBA which produced greater total root length. Cuttings of Forsythia x intermedia 'Lynwood Gold' typically did not differ in root development under the two application methods, but cuttings sprayed with Dip 'N Grow® at 0 + 0 to 10 + 5 ppm IBA + NAA exhibited greater shoot growth 80 days after sticking (insertion into the rooting substrate) than cuttings receiving a basal quick-dip. Root and shoot development measures were similar or lower for cuttings of *Abelia x grandiflora*, *Hydrangea paniculata*, and Lagerstroemia (*indica x fauriei*) 'Natchez' sprayed with auxin compared to a basal quick-dip.

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 (A_1, A_{16} and A_{18}) on the rooting capacity of wild sour cherry (*Prunuscerasus* 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 of IBA 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%).

Tripathi *et al.* (2003) conducted an experiment in Uttar Pradesh, India, in 1998 to investigate the effect of auxins on rooting and rooting quality of poinsettia. Poinsettia cuttings were treated with NAA (100, 200, 1000 and 2000ppm), IAA (100, 200, 2000 and 4000 ppm), IBA (100, 200, 2000 and 4000 ppm), and 2, 4, 5-TP [fenoprop] (5, 10, 50 and 100 ppm). The cuttings treated with 100 ppm IBA recorded the earliest number of days (15 days) for sprouting which is significantly lower than control (20 days). The highest number of leaves per cutting was recorded in 50 ppm 2,4,5-TP (28.39) while the lowest was recorded in 200 ppm NAA (15.53). The various concentrations of IAA and IBA increased the number of leaves, which ranged from 19.76 to 28.39 and are significantly superior to the control (17.51). The highest rooting was observed in IAA treated cuttings (97.78%) while the highest number of roots per cutting was observed in 1000 ppm NAA. The longest root was observed in 200 ppm IAA, whereas, the highest root fresh weight was recorded with 100 ppm IAA (2.30 g).

Parminader and Kushal (2003) conducted an experiment in January 2000, at Ludhiana, Punjab, India semi-hardwood cuttings of Bougainvillea cv. Cherry Blossom were treated with 16 possible combinations of NAA (0, 1000, 1500 and 2000 ppm) and IBA (0, 1000, 1500 and 2000 ppm) by dipping the basal ends of the cuttings (5 cm) in the growth regulator solutions for 5 seconds. Data were recorded for rooting percentage, number of roots per cutting, root length, root fresh weight and root dry weight. NAA at 1500 ppm + IBA at 1000 ppm were identified as the best treatment.

Sharma *et al.* (2002) conducted an experiment to determine the effect of IBA and IAA on the stem cuttings of *Acalypha wilkesiana*. cv. Tahiti. Upon dipping the basal ends of freshly prepared cuttings in 1000, 1500 and 2000 ppm IBA and IAA solutions for 5 seconds, 10 cuttings were planted for each treatment. The rooting percentage and average length of roots per cutting were highest upon treatment with 2000 ppm IBA, followed by 72000 ppm IAA. The number of roots per cutting and the fresh weight of roots were highest upon treatment with 2000 ppm IBA, followed by 1500 ppm IBA. All the shoot growth parameters (including the leaf number per cutting, sprout number per cutting and longest branch length) were higher in cuttings treated with 2000 ppm IBA, followed by cuttings treated with 2000 ppm IAA.

Navjot and Kahlon (2002) studied that the effects of cutting type (basal, middle and sub-apical portion of the shoots) and IBA concentration (0, 50, 100 and 200 ppm) on the rooting and growth of pomegranate (cv. Kandhari) were investigated during 2000/2001 at Amritsar, Punjab, India. Middle cuttings treated with 100 ppm IBA recorded the highest values for root number (32.72), root length (34.00 cm), fresh root weight (1048.24 g), plant height (49.79 cm), total leaf area (293.00), shoot girth (1.36 cm), shoot number (4.76) and shoot length (13.75 cm), while basal cuttings treated with 100 ppm IBA recorded the highest plant girth (4.21 cm).

Semi-hardwood cuttings from one-year-old gamma ray-induced mutants of bougainvillea cv. Los Banos Variegata were treated with 1000, 2000, 3000, 4000 and 5000 ppm IBA for 10 seconds and with 250, 500, 750 and 1000 ppm IBA for 24 hour. Dipping of cuttings in 1000 ppm IBA for 24 hour resulted in 100% rooting. Dipping of cuttings in 500 ppm IBA resulted with the highest number of root and shoots per cutting (Gupta *et al.*, 2002).

Panwar *et al.* (2001) conducted an experiment with the basal end of hardwood and semi-hardwood Bougainvillea sp. cv. Mary palmer cuttings were dipped in 250, 500, 1000 and 2000 ppm IBA, NAA and IAA before transplanting in nursery beds to determine the effects of plant growth regulators (PGR) on the rooting of bougainvillea cuttings. The highest number of sprouted buds in the hardwood (1.20) and semi-hardwood cuttings (1.13) was recorded in cuttings dipped in 1000 and 2000 ppm IBA, respectively, although differences in the effects of the different PGR treatments on the number of sprouted buds were not significant. The number of leaves and roots, rooting percentage and root length increased with increasing concentration of auxins, with 2000 ppm IBA recording the most marked effect.

Singh (2001) conducted an experiment in Nagaland, India during 1998 to study the effects of wood type and growth regulators on the rooting ability of *B.* peruviana *cv. Thimma*. Three types of wood, viz. hard, semi-hard and soft wood cuttings, and five concentration of plant biological regulators (PBRs), i.e. IBA and NAA (each at 1000 and 2000 ppm) and control, were evaluated. Hardwood cuttings and 2000 ppm IBA significantly increased in rooting, number of sprouts per cutting, number of leaves per cutting, length of sprout, diameter of sprout and number of roots per cutting.

However, no significant differences among different types of wood was observed for days to sprouting, while 2000 ppm IBA markedly induced early sprouting and resulted in maximum rooting percentage which was at per with that of 2000 ppm NAA. All cuttings treated with various concentration of PBRs were statistically superior to control as 9 regards all parameters. The interaction between wood type and PBR concentration was significant; with the highest interaction recorded for the number of leaves per cutting, length of sprout number of roots per cutting, length of roots and fresh weight of roots per cutting under hardwood cutting and 2000 ppm IBA combinations.

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 diameter 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.

Curir *et al. (1992) Genista monosperma* Lam. can be propagated by herbaceous cuttings, but seasonal fluctuations in rooting ability can be observed. These appear to be correlated with the ratio of two main endogenous phenols, 3-hydroxymandelic acid and luteolin-7-O-glucoside, accumulating in the tissues, the first acting as an inhibitor and the second as a promoter of adventive rhizo genesis. Their biological activity has been tested and evaluated on *G. monosperma in vitro* micropropagated explants. The inhibitory effect on rooting of 3-hydroxymandelic acid accumulation in cutting basal tissues can be lessened by a soaking treatment with distilled water, applied to the basal part of the cuttings before planting in rooting benches.

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%).

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.

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 eight years 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.

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.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted at Germplasm Center at Horticultural Farm in Sher-e-Bangla Agricultural University to study the "influence of plant growth regulators and wounding to stem cutting of Gardenia (*Gardenia jasminoides*) in winter and summer season". 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 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 .

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 Resource 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 Duration of the Experiment

In winter the experiment was continued from December/2020 to March/2021 and in summer from mid March/2021 to mid June/2021.

3.5 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.

3.6 Cutting Bed

Cutting beds having the size of 3 m (length) x l m (breadth) x 15 cm (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.

3.7 Treatment Details

The research work was conducted with one set of treatment consisting of four growth regulator. The factor with their growth regulator is as follows:

Different growth regulators:

T_0 = Control,

T_1 = Mixed plant growth regulators (1000 ppm IBA +1000 ppm NAA)

T_2 = Wounding to cutting base,

T_3 = Wounding to cutting base + Mixed plant growth regulators

3.8 Layout of the Experiment

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks containing 8 plots in a block. There were 24 plots in total. The size of each plot is 16 cm x 30 cm.

3.9 Preparation of Plant Growth Regulators

3.9.1 Preparation of 1000 ppm IBA solution

To prepare 1000 ppm of IBA solution, 1000 mg IBA powder and 10ml of ethanol was taken in a volumetric flask and then the volume was raised to one (1) liter by adding distilled water with frequent stirring to prepare 1000 ppm of IBA solutions.

3.9.2 Preparation of 1000 ppm NAA

To prepare 1000 ppm of NAA solution, 1000 mg of NAA powder and was 10 ml of ethanol was taken in a volumetric flask and then the volume was raised to one (1) liter by adding distilled water with frequent stirring to prepare 1000 ppm of NAA solutions.

Then the both IBA and NAA solution were mixed and prepared (1000 ppm IBA+ 1000 ppm NAA) plant growth regulator solution.

3.9.3 Wounding to cutting base

Basal parts of the cuttings were wounded with surgical blade.

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 Gardenia *(Gardenia jasminoides)* situated at the Horticulture Germplasm Center at Horticulture Farm in Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh. These 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. 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 Gardenia *(Gardenia jasminoides)* were planted in the beds on 1^{st} December, 2020 in case of winter and In case of summer cuttings were planted at 15^{th} March, 2021 at a spacing of 10 cm x 10 cm. 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 cane.

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).Hasan (2020)

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 Watering to cutting

Water was given by observing the soil moisture condition. Water was provided to cuttings in polythene bags using water cane 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 30 , 45 and 60 DAP. The cuttings were kept under observation for 60 days. After that 5 cuttings were collected randomly from each of the 24 plots for data collection. Cuttings were uprooted from each plot by digging soils without tearing the roots. Base of each cutting was washed carefully in a bucket of dear water without damaging the roots. Then data were collected for the following parameters-

- Days to shoot initiation
- Number of shoot per cutting
- Length of shoot (cm) per cutting
- Percentage of shooting
- Number of new shoot at 30 DAT in polybag
- Length of root (cm) per cutting
- Number of roots per cutting
- Percentage of rooting
- Survival percentage

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 Number of shoots per cuttings

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

3.14.3 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.

3.14.4 Percentage of shooting

The percentage of shooting was calculated 30, 45, and 60 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 Number of new shoot at 30 DAT in polybag

The numbers of new shoot at 30 DAT were counted at 30 DAT from 5 randomly selected plants and the average number of new shoot produced per cutting was recorded.

3.14.6 Length of roots (cm) per cutting

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

3.14.7 Number of roots per cutting

The number of roots per cutting was recorded at 60 days after planting and average was calculated.

3.14.8 Percentage of rooting

The percentage of rooting was calculated at 60 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 Survival percentage

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

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

3.15 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

The present experiment was conducted to find out the "influence of plant growth regulators and wounding to stem cutting of gardenia (*Gardenia jasminoides*) in winter and summer season", conducted at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka is presented in this chapter. The observations pertaining to growth and yield attributes of Stem Cutting of Gardenia (*Gardenia jasminoides*) recorded during the course of investigation were statistically analyzed and significance of results verified. The analyses of variance for all data have been presented in Appendices III to VI at the end. The results of all the main effects and only significant data have been presented in succeeding paragraphs. Some of the characters have also been represented graphically to show the treatment effect wherever necessary to provide better understanding of the results.

4.1 Days to Shoot Initiation

Significant variation among the growth regulators had been observed in days to shoot initiation of stem cutting of Gardenia (*Gardenia jasminoides*) (Appendix III). The maximum days to shoot initiation in winter (35.66) was found from T_0 (control) treatment which was identical to T_2 and T_1 (34.33 and 34.00) treatment while the minimum days to shoot initiation (33.00) was recorded from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment. The maximum days to shoot initiation in summer (34.33) was found from T_0 (control) treatment which was identical to T_1 and T_2 (33.33 and 33.00) treatment while the minimum days to shoot initiation (31.00) was recorded from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment.

Table 1. Effect of different growth regulators on days to shoot initiation in winter and summer

Treatment	Days to shoot initiation	
	Winter	Summer
T_0	35.66 a	34.33 a
T_1	34.00 bc	33.33 b
T_2	34.33 b	33.00 b
T_3	33.00 c	31.00 c
CV (%)	1.68	1.08
LSD (0.05)	1.0843	0.6685

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly at 0.05 level of probability
Here,T_0 = Control, T_1 = Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators

4.2 Number of Shoot per Cutting

Growth regulators exhibited a significant influence on number of shoot per cutting in winter and summer of stem cutting of Gardenia (*Gardenia jasminoides*) (Appendix III). The maximum shoot per cutting in winter (3.33) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical to that of T_2 and T_1 (3.08 and 3.01) treatment while the minimum shoot per cutting in winter (2.08) was recorded from T_0 (control) treatment. The maximum shoot per cutting in summer (3.92) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically similar to that of T_1 and T_2 (3.33 and 3.25) treatment while the minimum shoot per cutting in summer (2.75) was recorded from T_0 (control) treatment.

Table 2. Effect of different growth regulators on number of shoot per cutting in winter and summer

Treatment	Number of shoot per cutting	
	Winter	Summer
T_0	2.08 c	2.75 c
T_1	3.01 b	3.33 b
T_2	3.08 ab	3.25 b
T_3	3.33 a	3.58 a
CV (%)	5.29	3.92
LSD (0.05)	0.2867	0.2385

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability
Here, T_0 = Control, T_1 = Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base +Mixed plant growth regulators

4.3 Length of Shoot per Cutting

The effect of different growth regulators was significant influenced on length of shooting per cutting in winter and summer of stem cutting of gardenia at 30, 45 and 60 DAP (*Gardenia jasminoides*) (Appendix IV). In winter, at 30 DAP, the longest length of shooting per cutting was obtained from T_3 (1.30 cm) treatment which was statistically identical to T_1 (1.20 cm) treatment and the minimum length of shooting per cutting (0.69 cm) was measured in T_0 (control) treatment. At 45 DAP, the longest length of shooting per cutting was obtained from T_3 (1.89 cm) treatment which was statistically similar to T_1 (1.75 cm) treatment and the minimum length of shooting per cutting (1.26 cm) was measured in T_0 (control) treatment. At 60 DAP, the longest length of shooting per cutting was obtained from T_3 (2.84 cm) treatment which was statistically similar to T_1 (2.51 cm) treatment and the minimum length of shooting per cutting (2.02 cm) was measured in T_0 (control) treatment. In summer, at 30 DAP, the longest length of shooting per cutting was obtained from T_3 (2.61 cm) treatment which was statistically identical to T_2 and T_1 (1.68 and 1.51 cm) treatment and the minimum length of shooting per cutting (1.32 cm) was measured in T_0 (control) treatment. At 45 DAP, the longest length of shooting per cutting was obtained from T_3 (4.03 cm) treatment which was statistically identical to T_1 and T_2 (2.93 and 2.67 cm) treatment and the minimum length of shooting per cutting (2.49 cm) was measured in T_0

(control) treatment. At 60 DAP, the longest length of shooting per cutting was obtained from T_3 (5.91 cm) treatment which was statistically identical to T_1 and T_2 (4.61 and 4.16 cm) treatment and the minimum length of shooting per cutting (3.95 cm) was measured in T_0 (control) treatment.

Table 3. Effect of different growth regulators on length of shoot per cutting in winter and summer

Treatment	Winter			Summer		
	30 DAP	45 DAP	60 DAP	30 DAP	45 DAP	60 DAP
T_0	0.69 c	1.26 b	2.02 c	1.32 c	2.49 c	3.95 c
T_1	1.20 ab	1.75 a	2.51 ab	1.68 b	2.93 b	4.61 b
T_2	1.05 b	1.57 ab	2.32 bc	1.51 bc	2.67 bc	4.16 bc
T_3	1.30 a	1.89 a	2.84 a	2.61 a	4.03 a	5.91 a
CV $_{(\%)}$	8.37	11.51	7.90	8.11	6.47	7.25
LSD $_{(0.05)}$	0.1672	0.3505	0.3604	0.2717	0.3692	0.6354

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability
Here,T_0 = Control, T_1 =Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators

4.4 Percentage of Shooting

Considering the percentage of shooting of stem cutting of gardenia (*Gardenia jasminoides*) significant variation was found in different growth regulators in winter and summer (Figure 1). In winter, the maximum percentage of shooting (33.33 %) were observed in T_3 which was statistically identical to T_2 and T_1 (30.83 and 30.00 %) treatment whereas minimum percentage of shooting was obtained in T_0 (20.83 %) treatment. In summer, the maximum percentage of shooting (33.83 %) were observed in T_3 which was statistically identical to T_1 and T_2 (33.33 % and 32.50 %) treatment whereas minimum percentage of shooting was obtained in T_0 (27.50 %) treatment.

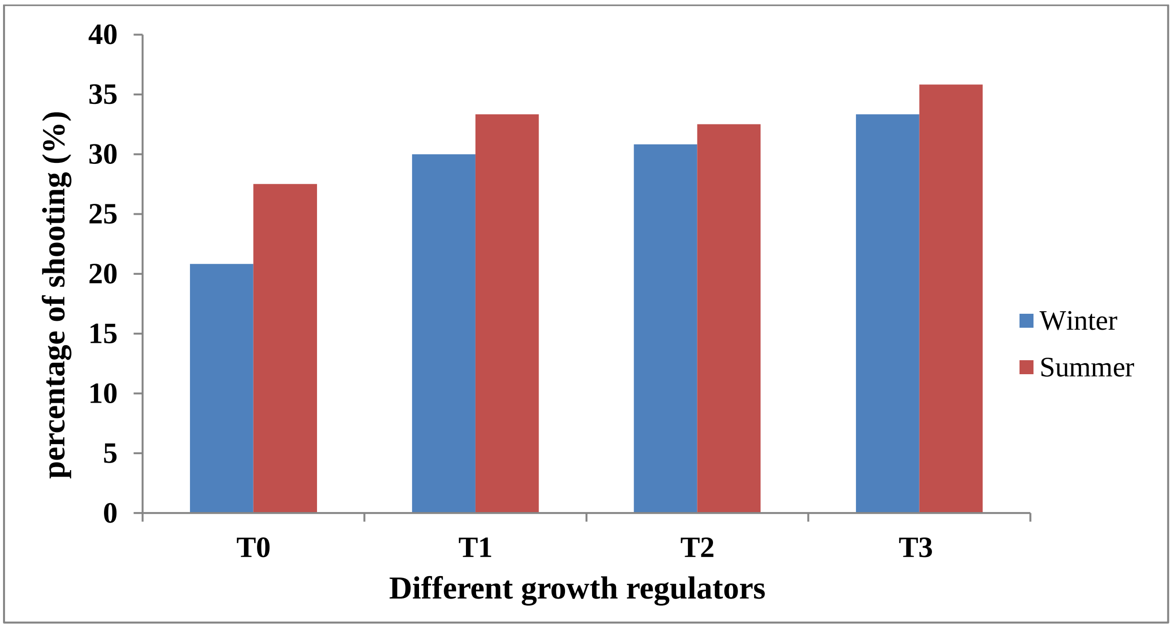

Figure 1. Effect of different growth regulators on percentage of shooting in winter and summer

Here, T_0 = Control, T_1 = Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators

4.5 Number of New Shoot at 30 days after Transplanting in Polybag

Number of new shoot at 30 days after transplanting in polybag is an important parameter for crop plant because of its physiological role in photosynthetic activities. Number of new shoot at 30 days after transplanting in polybag varied significantly due to different growth regulators in winter and summer of stem cutting of Gardenia (Appendix V). At winter, the maximum number of new shoot at 30 days (3.58) was recorded from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment, which was statistically similar with T_1 and T_2 (3.25 and 3.25) treatments, while the minimum number of new shoot at 30 days (2.50) was obtained from T_0 (control). At summer, the maximum number of new shoot at 30 days (3.83) was recorded from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical with T_1 (3.50) and similar with T_2 (3.41) treatments, while the minimum number of new shoot at 30 days (2.91) was obtained from T_0 (control).

Table 4. Effect of different growth regulators on number of new shoot at 30 days after transplanting in polybag winter and summer

Treatment	Number of new shoot at 30 DAT in polybag	
	Winter	Summer
T_0	2.50 c	2.91 c
T_1	3.25 b	3.50 ab
T_2	3.25 b	3.41 b
T_3	3.58 a	3.83 a
CV $_{(\%)}$	5.74	6.34
LSD $_{(0.05)}$	0.3332	0.4076

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability
Here, T_0 = Control, T_1 = Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators

4.6 Length of Root per Cutting

Growth regulators exhibited a significant influence on length of root per cutting in winter and summer of stem cutting of gardenia (*Gardenia jasminoides*) (Appendix VI). The maximum length of root per cutting in winter of stem cutting of Gardenia (4.81 cm) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical to that of T_2 and T_1 (3.85 and 3.80 cm) treatment while the minimum length of root per cutting (2.77 cm) was recorded from T_0 (control) treatment. The maximum length of root per cutting in summer of stem cutting of Gardenia (6.25 cm) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical to that of T_1 and T_2 (5.36 and 5.34 cm) treatment while the minimum length of root per cutting (3.24 cm) was recorded from T_0 (control) treatment.

Table 5. Effect of different growth regulators on length of root per cutting in winter and summer of stem cutting of Gardenia

Treatment	Length of root per cutting (cm)	
	Winter	Summer
T_0	2.77 c	3.24 c
T_1	3.80 b	5.36 b
T_2	3.85 b	5.34 b
T_3	4.81 a	6.25 a
CV (%)	7.81	6.37
LSD (0.05)	0.5608	0.6055

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability
Here,T_0 = Control, T_1 = Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators

4.7 Number of Roots per Cutting

Growth regulators exhibited a significant influence on number of root per cutting in winter and summer of stem cutting of gardenia (*Gardenia jasminoides*) (Appendix VI). In winter, the maximum number of root per cutting (6.79) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical to that of T_2 (6.38) treatment while the minimum number of root per cutting (4.16) was recorded from T_0 (control) treatment. In summer, the maximum number of root per cutting (7.83) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically higher than that of T_2 and T_1 (6.58 and 6.47) treatment while the minimum number of root per cutting (4.51) was recorded from T_0 (control) treatment.

Table 6. Effect of different growth regulators on number of roots per cutting in winter and summer

Treatment	Number of roots per cutting	
	Winter	Summer
T_0	4.16 c	4.51 c
T_1	6.16 b	6.47 b
T_2	6.38 ab	6.58 b
T_3	6.79 a	7.83 a
CV $_{(\%)}$	5.18	8.26
LSD $_{(0.05)}$	0.5731	0.9875

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability
Here,T_0 = Control, T_1 = Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators

4.8 Percentage of Rooting

Significant variation among the growth regulators had been observed in percentage of rooting of stem cutting of gardenia in winter and summer (*Gardenia jasminoides*) (Appendix III). The maximum percentage of rooting in winter (67.93 %) was found from T_3 (Wounding to cutting base + Mixed plant growth regulators) treatment which was identical to T_2 and T_1 (63.86 % and 61.66 %) treatment while the minimum percentage of rooting (37.66 %) was recorded from T_0 (control) treatment. The maximum percentage of rooting in summer (78.33 %) was found from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was higher than T_2 and T_1 (66.03 % and 64.70 %) treatment while the minimum percentage of rooting (43.66 %) was recorded from T_0 (control) treatment.

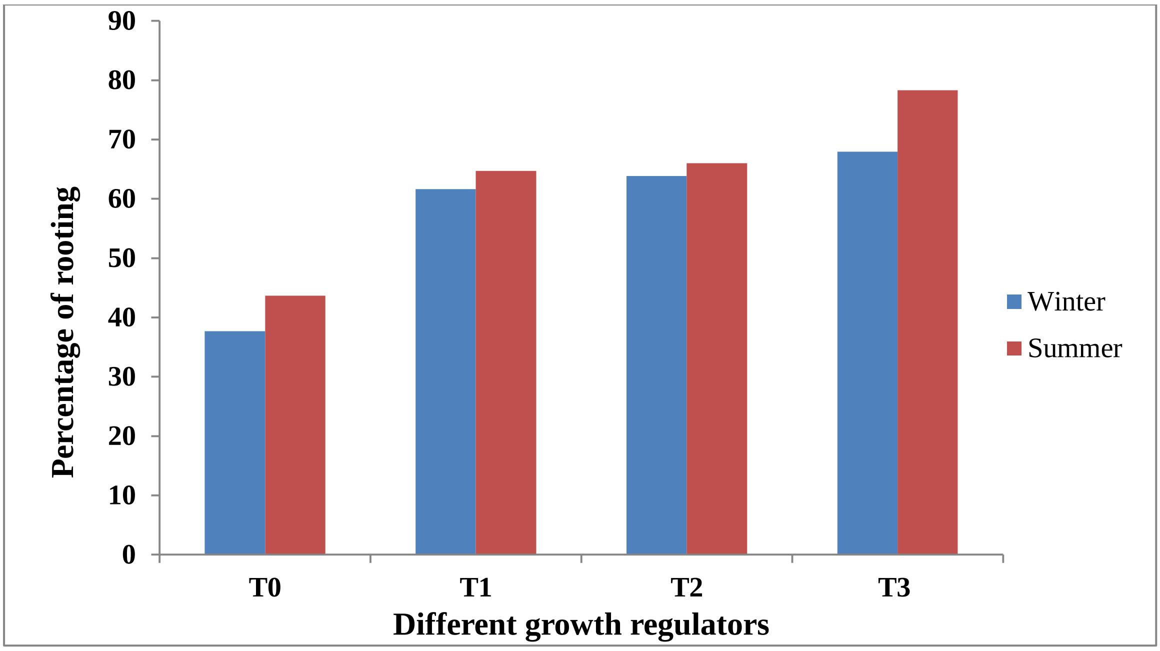

Figure 2. Effect of different growth regulators on percentage of rooting in winter and summer

Here, T_0 = Control, T_1 = Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators

4.9 Survival Percentage

Considering the survival percentage of stem cutting of gardenia (*Gardenia jasminoides*) significant variation was found in different growth regulators in winter and summer (Appendix V). In winter, the maximum percentage of survival (81.61%) were observed in T_3 (Wounding to cutting base + Mixed plant growth regulator) which was statistically identical to T_1 and T_2 (72.06 % and 69.99 %) treatment whereas minimum percentage of survival was obtained in T_0 (60.50 %) treatment. In summer, the maximum percentage of survival (88.42 %) were observed in T_3 (Wounding to cutting base + Mixed plant growth regulator) which was statistically identical to T_1 and T_2 (79.53 % and 78.91 %) treatment whereas minimum percentage of survival was obtained in T_0 (70.69 %) treatment.

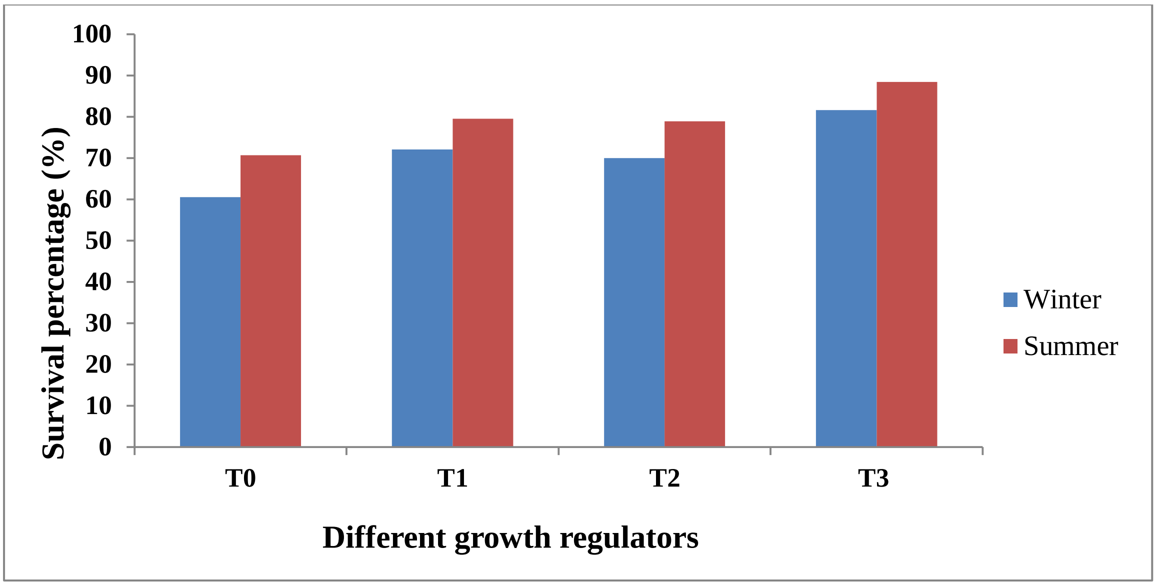

Figure 3. Effect of different growth regulators on survival percentage in winter and summer

Here, T_0 = Control, T_1 = Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators

CHAPTER V
SUMMARY AND CONCLUSION

The present experiment was conducted to find out the "influence of plant growth regulators and wounding to stem cutting of Gardenia (*Gardenia jasminoides*) in winter and summer season", conducted at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replication comprising with one cultivar (*Gardenia jasminoides*) and the research work was conducted with one set of treatment consisting of four growth regulator namely, T_0 = Control, T_1 = Mixed plant growth regulators, T_2 = Wounding to cutting base and T_3 = Wounding to cutting base + Mixed plant growth regulators. The effect of these treatments on shooting and rooting percentage, shoot no. and length, root no. and length and survival percentages were studied. The salient features of the experimental findings are summarized and concluded in this chapter.

The maximum days to shoot initiation in winter (35.66) was found from T_0 (control) treatment which was identical to T_2 and T_1 (34.33 and 34.00) treatment while the minimum days to shoot initiation (33.00) was recorded fromT_3 (Wounding to cutting base + Mixed plant growth regulator) treatment. The maximum days to shoot initiation in summer (34.33) was found from T_0 (control) treatment which was identical to T_1 and T_2 (33.33 and 33.00) treatment while the minimum days to shoot initiation (31.00) was recorded from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment.

The maximum no. of shoot per cutting in winter (3.33) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical to that of T_2 and T_1 (3.08 and 3.01) treatment while the minimum no. of shoot per cutting in winter (2.08) was recorded from T_0 (control) treatment. The maximum no. of shoot per cutting in summer (3.92) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically similar to that of T_1 and T_2 (3.33 and 3.25) treatment while the minimum no. of shoot per cutting in winter (2.75) was recorded from T_0 (control) treatment.

In winter, at 30 DAP, the longest length of shooting per cutting was obtained from T_3 (1.30 cm) treatment which was statistically identical to T_1 (1.20 cm) treatment and the minimum length of shooting per cutting (0.69 cm) was measured in T_0 (control) treatment. At 45 DAP, the longest length of shooting per cutting was obtained from T_3 (1.89 cm) treatment which was statistically similar to T_1 (1.75 cm) treatment and the minimum length of shooting per cutting (1.26 cm) was measured in T_0 (control) treatment. At 60 DAP, the longest length of shooting per cutting was obtained from T_3 (2.84 cm) treatment which was statistically similar to T_1 (2.51 cm) treatment and the minimum length of shooting per cutting (2.02 cm) was measured in T_0 (control) treatment. In summer, at 30 DAP, the longest length of shooting per cutting was obtained from T_3 (2.61 cm) treatment which was statistically identical to T_2 and T_1 (1.68 and 1.51 cm) treatment and the minimum length of shooting per cutting (1.32 cm) was measured in T_0 (control) treatment. At 45 DAP, the longest length of shooting per cutting was obtained from T_3 (4.03 cm) treatment which was statistically identical to T_1 and T_2 (2.93 and 2.67 cm) treatment and the minimum length of shooting per cutting (2.49 cm) was measured in T_0 (control) treatment. At 60 DAP, the longest length of shooting per cutting was obtained from T_3 (5.91 cm) treatment which was statistically identical to T_1 and T_2 (4.61 and 4.16 cm) treatment and the minimum length of shooting per cutting (3.95 cm) was measured in T_0 (control) treatment.

In winter, the maximum percentage of shooting (33.33 %) were observed in T_3 which was statistically identical to T_2 and T_1 (30.83 % and 30.00 %) treatment whereas minimum percentage of shooting was obtained in T_0 (20.83 %) treatment. In summer, the maximum percentage of shooting (33.83 %) were observed in T_3 which was statistically identical to T_1 and T_2 (33.33 % and 32.50 %) treatment whereas minimum percentage of shooting was obtained in T_0 (27.50%) treatment.

At winter, the maximum number of new shoot at 30 days after transplanting (DAT) in polybag (3.58) was recorded from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment, which was statistically similar with T_1 and T_2 (3.25 and 3.25) treatments, while the minimum number of new shoot at 30 DAT (2.50) was obtained from T_0 (control). At summer, the maximum number of new shoot at 30 DAT (3.83) was recorded from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical with T_1 (3.50) and similar with T_2 (3.41) treatments, while the minimum number of new shoot at 30 DAT (2.91) was obtained from T_0 (control).

The maximum length of root per cutting in winter of stem cutting of Gardenia (4.81 cm) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical to that of T_2 and T_1 (3.85 and 3.80 cm) treatment while the minimum length of root per cutting (2.77 cm) was recorded from T_0 (control) treatment. The maximum length of root per cutting in summer of stem cutting of Gardenia (6.25 cm) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical to that of T_1 and T_2 (5.36 and 5.34 cm) treatment while the minimum length of root per cutting (3.24 cm) was recorded from T_0 (control) treatment.

In winter, the maximum number of root per cutting (6.79) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical to that of T_2 (6.38) treatment while the minimum number of root per cutting (4.16) was recorded from T_0 (control) treatment. In summer, the maximum number of root per cutting (7.83) was measured from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was statistically identical to that of T_2 and T_1 (6.58 and 6.47) treatment while the minimum number of root per cutting (4.51) was recorded from T_0 (control) treatment.

The maximum percentage of rooting in winter (67.93) was found from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was identical to T_2 and T_1 (63.86 and 61.66) treatment while the minimum percentage of root initiation (37.66) was recorded from T_0 (control) treatment. The maximum percentage of rooting in summer (78.33) was found from T_3 (Wounding to cutting base + Mixed plant growth regulator) treatment which was identical to T_2 and T_1 (66.03 and 64.70) treatment while the minimum percentage of root initiation (43.66) was recorded from T_0 (control) treatment.

In winter, the maximum percentage of survival (81.61 %) were observed in T_3 (Wounding to cutting base + Mixed plant growth regulator) which was statistically identical to T_1 and T_2 (72.06 % and 69.99 %) treatment whereas minimum percentage of survival was obtained in T_0 (60.50%) treatment. In summer, the maximum percentage of survival (88.42 %) were observed in T_3 (Wounding to cutting base + Mixed plant growth regulator) which was statistically identical to T_1 and T_2 (79.53 % and 78.91 %) treatment whereas minimum percentage of survival was obtained in T_0 (70.69 %) treatment.

Conclusion

On the basis of results of the present investigation, it can be concluded that the T_3 (Wounding to cutting base + Mixed plant growth regularors) were significantly proved superior in all the studied. The growth regulators revealed that the treatment (Wounding to cutting base + Mixed plant growth regulators) had recorded significantly the highest growth parameter in terms of shooting and rooting percentage, number and length of shoots, number and length of roots per cutting and survival percentage of cuttings. Therefore, the use of gardenia cultivar cuttings with a combination of mixed plant growth regulators (IBA and NAA) can be utilized for multiplication of healthy and vigorous planting materials of *Gardenia jasminoides*.

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APPENDIX

Appendix I. Monthly record of air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from July 2020 to June 2021

Year	Month	Air temperature (°c)			Relative humidity (%)	Precipitation (mm)
		Maximum	Minimum	Average		
2020	July	32.88	27.83	30.35	80.88	304.4
	August	32.45	26.97	29.71	80.16	306.5
	September	31.54	26.25	28.89	78.34	206.6
	October	30.97	23.31	27.14	77.25	110.7
	November	29.45	18.16	23.80	69.52	12.6
	December	26.85	16.23	21.54	70.61	1.9
2021	January	24.52	13.86	19.19	68.46	3.5
	February	28.88	17.98	23.43	61.04	8.1
	March	31.85	22.43	27.14	55.98	12.3
	April	34.25	25.31	29.78	65.33	73.4
	May	34.45	26.86	30.65	73.15	178.5
	June	33.52	27.60	30.56	79.07	274.8

Source: Bangladesh Meteorological Department (climate division) Agargoan, Dhaka-1207.

Appendix II. Characteristics of Horticulture Farm soil as analyzed by Soil Resource Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Horticulture Garden, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Fallow - Broccoli

Appendix II. (continued)

B. Physical and chemical properties of the initial soil

Characteristics	Value
Particle size analysis	
% 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 (mc/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI

Appendix III. Analysis of variance on percentage of rooting, days to shoot initiation and number of shoot per cutting of gardenia

Source of variation	Degree of freedom	Percentage of rooting		Days to shoot initiation		Number of shoot per cutting	
		Winter	Summer	Winter	Summer	Winter	Summer
Different growth regulators	3	559.79**	620.846**	12.22**	1.88**	0.36**	0.90**
Error	8	1.833	6.260	0.156	0.104	0.016	0.023

** Significant at 0.05 level of probability;

Appendix IV. Analysis of variance on l ength of shoot increasing of gardenia

Source of variation	**Degree of freedom**	Length of shoot increasing (cm)					
		Winter 30 DAP	Summer 30 DAP	Winter 45 DAP	Summer 45 DAP	Winter 60 DAP	Summer 60 DAP
Different growth regulators	3	0.214**	0.983**	0.221**	1.427**	0.353**	2.319**
Error	8	0.00788	0.02083	0.03465	0.03846	0.03663	0.11390

** Significant at 0.05 level of probability;

Appendix V. Analysis of variance on length of shoot, number of new shoot at 30 DAT in polybag and survival percentage of gardenia

Source of variation	Degree of freedom	Length of shoot (cm) per cutting		Number of new shoot at 30 DAT in polybag		Survival Percentage	
		Winter	Summer	Winter	Summer	Winter	Summer
Different growth regulators	3	0.306**	1.256**	0.43**	1.00**	157.363**	224.812**
Error	8	0.014	0.063	0.031	0.046	5.221	8.225

** Significant at 0.05 level of probability;

Appendix VI. Analysis of variance on percentage of shooting, length of root and number of roots per cutting of gardenia

Source of variation	Degree of freedom	Percentage of shooting		Length of root (cm) per cutting		Number of roots per cutting	
		Winter	Summer	Winter	Summer	Winter	Summer
Different growth regulators	3	36.63**	89.58**	2.07**	4.90**	4.11**	5.63**
Error	8	0.260	0.703	0.088	0.103	0.092	0.275

** Significant at 0.05 level of probability