INFLUENCE OF PLANT GROWTH REGULATORS ON ROOTING AND SURVIVAL OF STEM CUTTINGS OF CHINA ROSE AND BOUGAINVILLEA

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Dedicated To

My Beloved Parents

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CERTIFICATE

This is to certify that thesis entitled**, INFLUENCE OF PLANT GROWTH REGULATORS ON ROOTING AND SURVIVAL OF STEM CUTTINGS OF CHINA ROSE AND BOUGAINVILLEA** 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 **DEPARTMENT OF HORTICULTURE,** embodies the result of a piece of bona fide research work carried out by Md. Gulam Kibria Nayem, Registration No. 13-05485 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 availed of during the course of this investigation has duly been acknowledged.

Dated: December, 2021
Dhaka, Bangladesh

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Supervisor

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The Author

INFLUENCE OF PLANT GROWTH REGULATORS ON ROOTING AND SURVIVAL OF STEM CUTTINGS OF CHINA ROSE AND BOUGAINVILLEA

ABSTRACT

The experiment was conducted at the Germplasm center of Horticulture farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh to evaluate the influence of plant growth regulators on rooting and survival of stem cuttings of china rose and bougainvillea during the period from June 2021 to March 2022. The duration of the experiment was 5th June to,2021 to 5th September,2021 in rainy season and 15th December, 2021 to 15th March, 2022 in winter season. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Three treatments, viz. G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250 ppm and Naphthalene Acetic Acid (NAA) @250 ppm were included in this study. In the case of different treatments performance, G_2 showed best performance in terms of days to shoot initiation, number of roots per cutting, length of roots (cm), rooting percentage, shooting percentage, number of shoots per cutting, number of branches, shoot Length (cm), number of leaves, sprouting percentage and survival percentage of China rose and Bougainvillea cuttings. G_2 showed best performance in bougainvillea in terms of rooting percentage in winter season 71.26% and in rainy season 86.74% and survival percentage in winter season 76.67% and in rainy season 85.20%. G_2 showed best performance in china rose in terms of rooting percentage in winter season 74.77% and in rainy season 89.50% and survival percentage in winter season 73.33% and in rainy season 92.36%. In comparison to rainy and winter season, plant growth regulators on rooting and survival of china rose and bougainvillea has found superior result in rainy season. Cuttings also established in winter with the help of plant growth regulators. From the study, it may be concluded that treatment G_2 has more efficacy among different treatments for the influence of plant growth regulators on rooting and survival of stem cuttings of china rose and bougainvillea which was followed by G_1.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

LIST OF SYMBOLS AND ABBREVIATION

SYMBOLS AND ABBREVIATIONS	MEANING
%	Percent
et all	And others
J	Journal
No.	Number
cm	Centimeter
Agric.	Agriculture
ºC	Degree centigrade
Etc.	Etcetera
TSP	Triple Super Phosphate
MP	Muriate of Potash
BARI	Bangladesh Agricultural Research Institute
LSD	Least Significant Difference
RCBD	Randomized Completely Block Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Viz.	Namely
@	At the rate of
BRRI	Bangladesh Rice Research Institute
i.e.	That is
BBS	Bangladesh Bureau of Statistics
CV %	Percentage of Co-efficient of Variance
g	Gram
kg	Kilogram
mg	Milligram
Agril.	Agricultural
BARC	Bangladesh Agricultural Research Council
UNDP	United Nations Development Program
AEZ	Agro-ecological Zones

CHAPTER I

INTRODUCTION

In the present world, flowers and ornamentals have become important not only for its aesthetic and social values but also for its economic contribution. Production and trade with these crops are now very much specialized in the developed countries with a significant contribution to their national economy.

Plant propagation is an important aspect of agriculture, particularly in horticulture. Plants can propagate either sexually (by seed) or asexually (by vegetative means). A few horticultural plants especially ornamental plants are propagated commercially by vegetative means. Many ornamental plants (for example rose, China rose, gardenia etc.) do not normally produce any viable seed. On the other hand, this unique characteristic may be deteriorated due to cross pollination when it is propagated through seed.

The utility and importance of ornamental plants like flowering shrub in a garden or a landscape is universally acknowledged (Randhawa and Mukhopadhyay, 1986). A garden or a park without shrub will lose much of its charm, attraction and beauty. Even in small home garden where planting of trees is not possible, some selected shrubs must find a place. Many flowering shrubs arc also used as cut-flowers drawing considerable demand for flower shops. Among different flowering shrubs, China rose and Bougainvillea are the most common ornamental plant species grown in Bangladesh.

Bougainvillea is an evergreen, climbing shrub with thorny stems. It belongs to the Family Nyctaginaceae. It usually grows 10–12 ft tall, occasionally up to 30 ft. Tiny white flowers usually appear in clusters surrounded by colorful papery bracts, hence the name paper flower. And China rose is a woody perennial flowering plant of the genus *Hibiscus*, from the family Malvaceae. They form a group of plants that can be erect shrubs, climbing, or trailing.

China roses are conventionally propagated by cutting, budding, grafting and layering methods. Among these the use of stem cuttings is the most easy and common method for growing China roses (Anderson & Woods, 1999). But except for the low yielding wild varieties most of the varieties of roses does not show better seedling establishment and growth from stem cuttings in Bangladesh. In case of *Bougainvillea* the success of propagation by cutting is very limited in most of the varieties. Several research workers used growth regulators to induce rooting of cuttings. Singh and Rathore (1977) treated cuttings with IBA and found low survival of rooted softwood cuttings should be in comparison with hardwood cuttings. Mishra and Singh (1984) observed that varietal differences and weather conditions affect rooting in *Bougainvillea* cuttings. The establishment and growth rate of cutting depends upon many factors like season of cutting, age and portion of the branch, growth media, moisture and nutrient status. Keisling and Kester (1979) concluded that poor rooting of the cutting has been attributed to marginal condition of growing media.

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.

Therefore, many kinds of chemicals have been used with the aim to induce root formation in species which are difficult to propagate or increase the number and extent of roots in others that develop slowly. Synthetic root promoting chemicals that have been found most reliable in stimulating adventitious root production in cuttings are the auxins i.e., indole acetic acid (IAA), naphthalene acetic acid (NAA) and indole butyric acid (IBA) (Arteca, 1996).

The genus Bougainvillea has 14 species, with three that are horticulturally important. Bougainvillea is used to decorate fences and arbors with explosions of color in the house corridor, office and playground. A bougainvillea tree can make guarding the entry or framing a window. Bougainvillea is a great vine for large containers to decorate hot patios and plazas. Bougainvillea is also used to create beautiful flowering bonsai specimens (Sharif Hossain *et al*., 2007). Bougainvillea is native to South America. The name comes from Louis Antoine de Bougainville, a French navigator and military commander who was the first European to take note of the plant, in Brazil, in 1768 (Kobayashi *et al*., 2007). Softwood terminals, maturing green wood, and matured intermediate wood stem pieces can be used for propagation of Bougainvillea flower (Hacket *et al*., 1972). Softwood terminals of easy-to-root cultivars do not require a rooting hormone. With more mature wood, a rooting hormone such as IBA (3-indolebutryic acid) at 2000-6000 ppm is commonly used (Kobayashi *et al*., 2007). Higher concentrations may be needed with more difficult-to-root cultivars (Gilman, 1999). Moalemi and Chehrazi (2005) reported that high percentage of rooting were for leafy cutting. In that study, the highest number of roots was obtained in leafless cutting (9.23 roots per plant) at 2000 mg L-1 IBA. The best effect of different levels of auxin on root length (5.79 cm) was obtained leafless cuttings at 1000 mg L-1 NAA. In other study, under the influence of 0.2-0.4% of IBA the cutting rooted in 66-88%. In control treatment, without auxins, the cuttings rooted 22.5-93% but their root system was very poorly developed. In the former report, rooting medium has not been said, but in the latter one, rooting medium was sand (Czekalski, 1989) The purpose of this study is to improve rooting ability with more difficult-to-root cultivars of Bougainvillea flower.

Hibiscus rosa-sinensis L. of the family Malvaceae is native to East Africa. Locally known as Gurhal, this species has been officially honoured as the National Flower of Malaysia on 28 July 1960. This plant is native to tropical and southeastern Asia (China), this plant is commonly found throughout the tropics and as a house plant throughout the world. It requires porous soil, moderate temperature and severely high humidity.

The tropical Chinese hibiscus, or China rose (*Hibiscus rosa-sinensis*), which may reach a height of 4.5 meters (15 feet), rarely exceeds 2 meters in cultivation. It is grown for its large somewhat bell-shaped blossoms. Cultivated varieties have red, white, yellow, or orange flowers. The East African hibiscus (*H. schizopetalus*), a drooping shrub with deeply lobed red petals, is often grown in hanging baskets indoors.

Many species of Hibiscus are grown for their showy flowers or used as landscape shrubs. Hibiscus has also medicinal properties and takes part as a primary ingredient in many herbal teas. This plant is popular landscape shrub, creates a bold effect with its bed-textured, glossy dark green leaves and with 4- 6 inch wide and up to 8 inch long, showy flowers, produced throughout the year and grows up to 7-12. Sometimes its demand time to time increases during different Puja festivals. Hibiscus is propagated through vegetative methods by cutting and grafting for produce quality planting material on large scale.

Cutting is most convenient method of propagation. The cutting should be taken from new growth or softwood. Softwood is branches on the hibiscus that have not yet matured. The hibiscus cutting should be 4 to 6 inches (10 to 15 cm.) long. Remove everything but the top set of leaves. A slant cut give at the base of the cuttings and each cutting. A transverse cut give at top of each cutting. Dip the bottom of the hibiscus cutting in rooting hormone then place the cutting in well-drained soil and in partial shade. The cuttings should be rooted in about eight weeks.

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

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.

Considering the above perspective for the influence of plant growth regulators on rooting and survival of stem cuttings of china rose and bougainvillea the present study has been undertaken with fulfilling the following objectives.

Objectives:

- To find out suitable plant growth regulators for rooting of stem cutting and seedling establishment of *Bougainvillea glabra* and China rose (*Hibiscus rosa-sinensis*) in winter season
- To find out suitable plant growth regulators for rooting of stem cutting and seedling establishment of *Bougainvillea glabra* and China rose (*Hibiscus rosa-sinensis*) in rainy season

CHAPTER II

REVIEW OF LITERATURE

An attempt has been made to bring out review relating to the "influence of plant growth regulators on rooting and survival of stem cuttings of china rose and bougainvillea" A brief resume of the work done in the past by various researchers given in this chapter.

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.

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

Efficacy of growth regulators on Bougainvillea, China rose and others

Works of Mukhopadhyay and Bose (1972) revealed that retention of four leaves developed per cent rooting and a greater number of roots (22.00) per cuttings of *Hibiscus rosa-sinensis* L. with IBA 3000 ppm as compared to control.

Bhattacharjee and Balkrishna (1986) conducted experiment on the standardization of propagation of hibiscus (*Hibiscus rosa-sinensis* L.) and found that fifteen-centimeter tip cutting with four leaves of hibiscus treated with 4000 ppm IBA and planted in sand under mist give best performance in rooting and survival of rooted cuttings.

Gupta (1989) conducted an experiment to investigate rooting potentiality of semi-hard wood cuttings of Snowflake cultivar of *Hibiscus rosa-sinensis* L.

under intermittent mist with the application of auxins and concluded that IBA at 4000 ppm induced higher percentage of rooting (80), greater number of roots (18.25) per rooted cutting and produced longer roots (73.23 mm).

Ahir and Parmar (2007) studied on the rooting in *Hibiscus rosa-sinensis* L. Hawaii by air Layering with the aid of IBA, NAA and different colored polythene found that IBA at 3000 mgl^{-1} with black polythene wrappers was the most effective in early root initiation and increasing the rooting percentage, increasing the sprouting of rooted layers.

Ali Mohammadi Torkashvand and Vahid Shadparvar (2012) have conducted an experiment on rooting in Hibiscus by IBA and rooting substrates and obtain highest no. of roots in sand-perlite substrate with concentration of 4000 ppm mg/l IBA.

Savaliya Rohitkumar Rameshbhai (2016) studied on efficiency of IBA on different types of cutting for rooting in hibiscus (*Hibiscus rosa-sinensis* L.) cv. local found that maximum percentage of rooting by hardwood cutting with IBA 1000 mg/l

Chowdhuri, T. K *et al*., (2017) studied on the effect of different growth regulators on propagation of china rose (*Hibiscus rosa-sinensis* L.) in subtropical zone of West Bengal found that NAA at all concentrations (1000-3000 ppm) may take for rooting of China rose, but higher doses is more beneficial in this aspect during rainy season in subtropical zone, the second-best growth regulator is IBA at 3000 ppm. Semi hardwood cutting is better than tip cutting for propagation of China rose.

Dombeya natalensis and *D. tilliaceal* cuttings 15 cm in length were taken for healthy vigorous shoots treated with IAA, IBA or NAA, all at 1000, 2000, 3000, 4000 and 5000 ppm., and kept under intermittent mist for rooting. The optimum treatment for maximum rooting (90.00%) and survival of roo ted cuttings (89.00%) were recorded with IBA at 4000 ppm. This treatment also gave a greater number of roots (19.81) and more root length (15.98 cm) per cutting than treatments with IAA or NAA. (Gupta *et. al* 1989).

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.

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).

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 2000 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.

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 hours. Dipping of cuttings in 1000 ppm IBA for 24 hours 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).

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 par with that of 2000 ppm NAA. All cuttings treated with various concentration of PBRs were statistically superior to control as 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.

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 th e 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.

A study was carried out to assess the effect of auxins on rooting behavior of stem cuttings of *Berberis aristata.* The 9 treatments consisted of solutions of 250, 500, 1000, 2000 and 2500 ppm IBA; 2000 ppm IBA + 2000 ppm NAA; 2000 ppm IBA + 2000 ppm IAA; 2000 ppm IBA + 2000 ppm NAA + 200 ppm IAA and a control (water). IBA (500 ppm) showed the maximum number of roots per cutting (10.66 and 9.66), highest root length (6.40 cm and 5.50 cm) and highest rooting percentage (86.66 and 83.33) in comparison to other treatments during the year 1992 and 1993, respectively. (Shah *et al,* 1999).

Basavarajeshwari *et al.* (1998) conducted an experiment to study the relative efficiency of different growth substances on the rooting and survival of rooted cuttings of *Jasminum grandiflorum, J. auriculatum* and *J. sambac.* Hardwood cuttings, 15-20 cm long, were prepared from the basal portion of matured stems. The cuttings were dipped for 2 seconds in 2000, 4000 and 6000 ppm IBA and

NAA. Treatments with the growth regulators significantly promoted rooting and survival and recorded higher number of roots per cutting over the untreated cuttings for all China rose species. Treatment with 4000 ppm IBA recorded the maximum percentage of rooting and the highest number roots with increased length. Rooted cuttings obtained by treatment with 4000 ppm IBA also resulted in the highest percentage of survival in all the three species. In *J. grandiflorum* and *J. sambac*, the beneficial effects of growth regulator on rooting of the cuttings were highest (84.33 and 84.75%, respectively) upon treatment with 4000 ppm NAA, while in *J. auriculatum*, 2000 ppm NAA was the best. In terms of cutting survival percentage, the highest in *J. grandiflorum* was recorded upon treatment with 4000 ppm NAA, while the highest in *J. auriculatum* and *J. sambac* was observed upon treatment with 2000 ppm NAA.

Panwar *et al.* (1994) worked with hard wood and semi hard wood cuttings of *bougainvillea cv.* Alok at 2000 ppm of IBA and observed that hard wood cuttings gave better growth than semi hard wood cuttings.

Singh (1993) worked with 4 concentrations of IBA (1000, 2000 3000 and 4000 ppm in quick dip solution) and found that IBA at 3000 or 4000 ppm gave more root per cutting than other treatment regardless of the season in semi hard wood cutting of bougainvillea.

Sari and Qrunfleh (1995) carried out an experiment where 10 cm long hard - wood cuttings of J. *grandiflorum* cv. were taken in January, March, May, June or July for 2 successive years. The cuttings were treated with IBA, NAA, IAA, Abscisic Acid (ABA) or Alar (daminozide), each at 0, 500 or 1000 ppm. Rooting percentage of untreated controls was highest for cuttings taken in June and July. NAA treatments (500 or 1000 ppm) were found most effective in January having 20% rooting while 500 ppm Alar was found as best treatment in March and May having 70% rooting for hard wood cutting. In case of soft wood cutting the most effective treatment in January was 500 ppm. NAA and in March and May was 1000 ppm Alar. All or almost all (94 -100%) of the soft wood cutting taken in

July and treated with 1000 ppm NAA, 500 or 1000 ppm IAA or 50 ppm Alas rooted. ABA was the least effective treatment overall.

Maurya *et al.* (1996) carried out an investigation with hard wood and semi - hard wood cuttings of *Jasminum sambac* (cultivars single Mohra, double Mohra and a local strain) and *J. auriculatum*. Three were planted in sand, soil or a 1:1 mixture of sand + soil. Of the growing media, sand resulted in the highest percentage rooting and survival, number of root/cutting and root length (68.68%, 55.00%, 5-8 and 8.5 cm, respectively) followed by sand + soil. Of the 2 cutting types of hard wood cuttings were superior to semi hard wood ones in terms of rooting (59.17 vs 47.50%), number of roots per cuttings (4.859 vs 3.711), root length (6.126 vs 4.358 cm) and survival (50.28 vs 42.22%). Of the genotypes, *J. sambac* cv double Mohra generally gave the best results (75%) rooting and 65.55% survival), followed by the local strain of the same species, then cultivar single Mohra and finally J. *auriculatum* (37.7 8% rooting and 24.44%), survival).

An experiment was conducted by Verma *et al* (1992) with 3 cultivars Pal (easy to root), Mahara (difficult to root) and Arjuna (failed to root) with IBA and ascorbic acid (0, 10, or 100 pm) and sucrose (0, 10, 10%) in all possible combinations. The best rooting of the stem cuttings of bougainvillea was obtained at 100 ppm IBA.

Harris and Singh (1991) observed in their experiment in both spring and rainy season, that the semi hard wood cuttings of bougainvillea gave the highest percentage of rooting across cultivars and number of roots per cutting treated with IBA at 1000 ppm. Cuttings were dipped in IBA or NAA at 100, 200 or 400 ppm for 12 hours, cuttings were planted at 450 in a mist chamber and rooting success was noted down after 45 days of planting.

Gupta and Kher (1991) conducted an experiment in India with shoot tip cutting of bougainvillea var. Garnet Glory under intermittent mist. The cuttings were dipped in IAA, IBA or NAA (2000, 4000 or 6000 ppm in 50% alcohol) for 10 sec. IBA at 4000 ppm gave the best rooting (the highest root number and the greatest root length) in 37 days after planting.

Nagaraja *et al.* (1991) carried out an experiment where hard wood, semi hard wood and soft wood cuttings of *Jasminum grandiflorum* were taken from one-year-old shoots and treated with 3000, 4000 or 5000 ppm IBA or NAA. Cuttings were placed in coarse sand and kept under intermittent mist for 60 days. Percentage of rooting, number of roots/cutting, length and thickness of longest root, number of sprouts/cutting and length of longest shoot were transplanted for survival studies. After further 60 days, survival % was recorded. IBA at 4000 ppm significantly increased % rooting in hard wood, semi hard wood and soft wood cuttings (100, 73.33 and 80%, respectively). Treatment with 4000 ppm IBA also resulted in the highest % survival of rooted cuttings in hard wood and semi hard wood cuttings (90 and 80%, respectively).

Thimmappa *et al.* (1990) studied that in stem cuttings of *Pelargonium graveolens* cultivars Algerian and Reunion, the effects of IAA, IBA and NAA at 1000, 2000 and 3000 ppm on the formation of adventitious roots was studied. Of the growth regulators, IBA gave the best results, as measured by percentage of rooted cuttings, number of roots/cutting and length of the longest root; the optimum concentration was 2000 ppm. To study the effect of woodiness of cuttings, rooting of cuttings of cv. Algerian taken from the tip, middle and basal portion of stems was compared. Root formation was best in tip shoot cuttings. Of the rooting media tested, vermiculite gave the best results, sand was next best and loamy soil was poorest.

Hossain (1990) observed that bougainvillea and ixora gave the highest success (99%) when the cuttings were treated at 400 ppm IBA for 24 hours. Me also found that this treatment also increased the number of root and shoots, length of roots and shoots and fresh and dry weight of roots and shoots.

Zaghloul *et al.* (1990) conducted an experiment during February 1988 and 1989. Stem cutting of a double flowered strain of *J. sambac* were dipped in NAA (500, 750 or 1000 ppm) for 2 hours or in kinetin (50, 75 or 100 ppm) for 2 hours, or in the 2 growth regulators successively (all concentration combinations). The

untreated controls had the lowest rooting percentage (10%) while the highest success (90%) was achieved with combination of 750 ppm NAA and 75 ppm kinetin.

Cutting taken from apical, sub-apical and basal parts of current season's shoots were dipped in a solution of IBA +NAA, each at 1000, 2000 or 4000 ppm., and planted in sand under intermittent mist. The cuttings were assessed 35 days later for rooting success, number of roots/cutting, root length, and shoot length. The best results generally were obtained with sub -apical cuttings dipped in IBA + NAA, each at 2000 ppm. (36.66% rooting, compared with 6.66% in the control (Gowda *et al*, 1989).

Gupta and Kher (1989) obtained highest percentages (86.7) of rooting, the highest number of primary roots (24.6) and highest cutting survival (96.16%o) in Ixora. They also observed the performance of Ixora treated with 1000, 2000, 3000, 5000 ppm by using dip method for 10 seconds.

IBA increased rooting in cutting of *Bougainvillea glabra* taken in September or in March (Czekalshi, 1989). It was showed that for IBA treatment on cuttings the rooting percentage was reduced but improved the quality of the root system. The highest rooting percentage was obtained in September.

Joshi *et al.* (1989) worked with hard wood cuttings of 5 bougainvillea cultivars and treated with IBA, NAA or IAA at 4000 or 6000 ppm. Cuttings treated with IBA at 6000 ppm gave 52.89% rooting. There was no significant difference between cultivars in rooting percentage

Rooting of shoot cuttings 1.5 cm or 2.0 cm in diameter was tested with different concentration of Indole Acetic Acid (IAA; at 50 or 100 ppm.) or Indole Butyric Acid (IBA; at 50 100, 500, 1000 or 2000 ppm.). Best rooting was obtained with 50 ppm. IBA and 100 ppm. IAA. Cuttings 2 cm in diameter with 50 ppm IBA were best, having the longest roots, greatest number of foliar shoots per cutting, highest percentage of cuttings with foliar shoots, and greatest number of transplantable foliar shoots. (Guzman *et al.,* 1989).

Indole Butyric Acid alone at 50 ppm and 100 ppm gave the good rooting and the best survival (96.6%) of stem cutting of *Hibiscus rosa sinensis* treated with IBA or NAA each at 0-500 ppm. This experiment was conducted by Widiastoety and Secbijanto (1988). Survival of rooted cutting was much better than in control.

The 15-cm long cuttings were treated with IAA, IBA or NAA, each at 1000, 2000, 3000, 4000 or 5000 ppm using 10-second dip method. The best rooting (86.7%), the highest number of primary roots (24 .6) and the highest cutting survival (96.16% were obtained with IBA at 2000 ppm.; the corresponding control figures were 40%, 5.25 and 66.7%. (Gupta *et. al.,* 1989).

Mukhopadhaya and Bankar (1988) studied in their experiment the effects of different concentration of IBA with the cutting of newly matured wood of “Queen Elezabeth roses”. They showed that the cuttings untreated (control) and the cutting treated with 1000 ppm IBA as a quick basal dip failed to root. Cuttings treated with 2000 ppm IBA gave 88% rooting.

Stoltz and Anderson (1988) conducted an experiment with single node cutting of 8 cultivars of rose. They treated each cultivar with IBA at concentration of 125, 250, 500 and 750 ppm. They found that the rooting response differed between the cultivars and IBA concentration.

Widiastoetye and Soebijanto (1988) observed that stem cuttings of *Hibiscus rosa-sinensis* treated with IBA and NAA each at 0-500 ppm IBA alone at 50 ppm and 100 ppm gave good rooting and best survival (96.6%o) while the survival was 70% in the control cuttings.

Better result was obtained by submerging the cuttings in solution of IBA over the powder form reported by Henting and Gruber (1988). They conducted an experiment on cutting of *Correa feflexa* cv. *Manii* with 4 -8% IBA powder and 50-100 ppm IBA solutions.

Kundu *et al.* (1987) observed that growth regulator mainly IBA was very much effective to achieve high percentage of success in rooting and higher number and length of roots per cutting were produced by *Ixora cocceinia.* They worked with IBA at different concentrations and found that 400 ppm was the best concentration for propagation of Ixora by stem cutting.

Gcorgakopoulou Vogiatzi (1987) conducted two experiments to find out the accurate rate of IBA, one without leaf and other with leaves of rose cvs. Verhage and Arlene Francis each of which was treated with IBA at 0, 100, 200, 500, 1000, 2000, 4000 and 8000 ppm and placed for rooting under mist. Higher rooting percentage for leafless Dr. Verhage was observed at 100, 200 or 500 ppm of IBA and for Arlene franc is 100 or 200 ppm of IBA. For leafy cuttings 100 ppm IBA for Dr. Verhage and 200 ppm for Arlene francis showed increased rooting percentage.

Season showed greater influence on the rooting of cuttings of *Codiaeum variegatum* with IBA stated by Khattab *et al.* (1987) from their experiment. They showed that rooting was best (95.8 and 100%) in cutting taken in August and September, respectively with IBA at the concentrations of 10 and 20 ppm. They soaked the terminal cuttings with 0 -100 ppm IBA for 24 hours.

Srivastava (1987) conducted an experiment where terminal cuttings of *Jasminum grandiflorum* treated with four growth regulators (unspecified) were planted in a mixture of soil, sand and compost and covered with polythene bags. Over 81% rooting was obtained in 34 days.

Basu *et al.* (1986) observed that tannic acid and galic acid promoted rooting in leafy cutting of *Eratbenum tricolour* in combination with NAA and IBA. They also observed salicylic acid in combination with IAA, IBA promoted rooting in the same species.

Dechcva *et al.* (1985) conducted an experiment with Kazanlyk rose, soft wood cutting of which was treated with IBA at six concentrations. All treatments gave good rooting and increased number of root per cutting. Improved the rooting rate up to 1-17% of the treatment were given by IBA at 1 g per liter for 5-6 seconds or at 100 or 200 mg/L for 10 minutes.

To show the effect of IBA on rooting of Kazanluk rose Dccheva *et al* (1985) conducted an experiment with six concentrations of IBA. All IBA treatments gave the good rooting and increased the number of root per cutting. IBA at gm/liter for 5-6 sec. or at 100 or 200 mg/liter for 10 minutes improved the rooting rate by 6 to 17%.

Veeraragavathatham *et al.* (1985) conducted an experiment where soft wood, semi-hard wood and hard wood cuttings of *Bougainvillea glabra* (difficult to root) cv. Parimullai which were treated with IBA or NAA at different concentrations. Cuttings in all treatments were rooted under intermittent mist. The best rooting (60%) was observed by treating with IBA at 1000 ppm for 10 seconds.

Bhattacharjee and Balakrishna (1983) worked with 25 cultivars of bougainvillea cuttings (15 cm long) with 4 leaves were treated with IBA each at 4000 ppm in dip method. Twelve cultivars responded better to IBA and others 4 to NAA.

The effect of different IBA concentrations (500, 1000 and 2000 ppm) on the rooting response of rose cvs. Baccara and Concerto hardwood cuttings with or without a heel at their base, was investigated in two years experiments by Oikonomou (1982). All parameters were increased with the increase of IBA concentrations. The most effective IBA concentration was 1000 ppm for rooting percentage and root length.

Philip and Gopalakrishnon (1981) in their experiment on cuttings of bougainvillea var. Mahara with IBA in dip method, obtained the highest percentage in rooting of cuttings when treated with 6000 ppm IBA. Data were collected 45 days after planting.

Singh and Motial (1981) worked with soft wood, semi hard and hard wood cuttings of the *Bougainvillea glabra,* treated with IBA at 1000-4000 ppm were struck in coarse sand under intermittent mist. The best rooting (97.5 -100%) and survival of rooted cuttings (100%) of all three types were obtained with IBA at 4000 ppm.

Jayapal *et al.* (1980) conducted an experiment with three commercial Jasmine species. They were propagated by 5 nodes apical or semi-hard woodcutting. The cuttings were struck in sand under mist. *Bougainvillea glabra* and *J. sambac* rooted best (98%) and 94%o, respectively) when propagated by semi hardwood cuttings.

Singh (1980) conducted an experiment with *Allamanda catbertica* by different types of stem cuttings, viz., softwood, semi hard wood and hard wood with 4 leaves per cutting in each case. The cuttings were treated with IBA at 100 to 4000 ppm for 15 second. After 30 days of planting, soft wood cuttings treated with 2000 ppm IBA gave the highest rooting followed by semi hard wood and hard wood cuttings with 3000 ppm of IBA.

Khosh-khul and Tatazoli (1979) stated that root number, length and dry weight per cutting of rose were significantly increased by acid treatment prior to application of 0, 1000, 2000 or 3000 ppm IBA or NAA.

Singh (1979) stated that the best concentration of IBA for rooting *Bougainvillea glabra* cv. Madan ban, Mogra, Motia under mist was 4000 ppm. For the cv. Palampur 3000 ppm was better. Singh (1976) also reported that application of IBA at 4000 ppm to the cuttings of *Bougainvillea glabra* having 3-4 leaves caused the highest percentage of rooting under intermittent mist.

Singh and Motial (1979) in their experiment showed IBA at the concentration of 3000 ppm gave the highest percentage of rooting (65%) and subsequent plant survival (100%). They also observed that soft wood cuttings were rooted better than semi hard wood cutting of bougainvillea.

Bose *et al.* (1975) studied that the percentage of rooting and root numbers per cutting were highest with cuttings of 15 cm length having two leaves, taken from the middle portion of the shoot (Semi -hard wood), treated with IBA at 300 ppm and planted in sand under mist. In another trial with tip cuttings of 10, 15 or 20 cm in length, rooting was better with 20 cm cuttings than the others.

Bose *et al.* (1973) studied the effects of IAA and NAA on rooting of soft and hardwood cuttings. The highest rooting of 90 percent was recorded in softwood cuttings treated with IAA 1000 ppm and in hard wood cuttings treated with 500 ppm. also confirmed the effectiveness of IAA and NAA in rooting of cuttings of this species. They also found that IBA at 5000 ppm stimulated rooting in cuttings.

Bose *et al.* (1973) conducted an experiment with ten species and cvs. of Ixora, 1 1 cvs. of *Hibicus rosa-sinensis and Bougainvillea glabra* which failed to root from cuttings or show a low percentage of rooting. Under ordinary propagation facilities they developed roots under intermittent mist. Treatment with IBA and NAA further increased the rooting percentage and number of roots.

Cuttings of *Bougainvillea glabra* which failed to root or show a low percentage of rooting under ordinary propagation facilities showed high percentage of rooting under intermittent mist. Better survival and satisfactory growth after transplanting was also observed in cutting rooted under mist (Bose *et al.*, 1973). Veeraragha vathatham *et al* (1985) reported better rooting in cutting of *Bougainvillea glabra* by etiolation, girdling and treatment with IBA.

Kale and Bhujbal (1972) conducted an experiment to study the response of IBA on root formation of Marypalmer variety of bougainvillea. They showed that hard wood cutting of that variety gave higher percentage of rooted cuttings at the concentration of 1500 ppm by quick dip method. They also stated that it was the easiest and most convenient method of propagation of Marypalmer of bougainvillea over other traditional methods.

Mukhopadhaya and Bose (1966) in their experiment with 4 bougainvillea varieties using IBA, NAA, Seradix -3 and control separately, showed that IBA produced greater number of roots per cutting than other treatments. In variety "H. C. Buck" beneficial effects were recorded with both the concentration (10 and 100 ppm) of IBA. In variety Scarlet Queen, only IBA 100 ppm produced roots.

Auxin was the most important factor for enhancing roots of semi hardwood and hardwood cuttings of sapota, guava and straw berry plants. The number of roots always increased with the increase of growth regulator concentration was stated by Leopold (1963).

Srivastava (1962) reported that a set of hard wood cuttings of Jasmine were treated by dipping the basal ends for 12 or 24 hours in 100 ppm and 200 ppm concentration of NAA and IBA. In general, NAA treatment was more effective than IBA. The best results were obtained with 12 hours dipping 100 ppm of NAA followed by IBA at the same concentration and duration.

Teaotia and Pandey (1961) stated that IBA at 100 ppm gave the satisfactory result in Govt. Research Station Basti, U.P., India but the same concentration gave unsatisfactory result in semi hardwood and hardwood cuttings and etiolated cutting.

Singh and Bhatnagar (1955) in *J. grandiflorum*, studied the effects of IAA and NAA on rooting of soft and hard wood cuttings. The highest rooting of 90 percent was recorded in softwood cutting treated with IAA 1000 ppm and in hardwood cuttings treated with NAA 500 ppm. Bose *et al.* (1973) also confirmed the effectiveness of IAA and NAA in rooting of cuttings of this species IBA at 5000 ppm in 91 per cuttings.

Root formation was activated by using phenoxy compound even at low concentration (Hitchcock and Zimmermann, (1937). IBA increased the rooting percentage and number of roots per cutting in fig as observed by Crans and Mollah (1952).

From the above review of literature, it was observed that IBA and NAA were more effective in the propagation of shrubby ornamental plants by stem cutting than other hormones. Further it was noted that IBA was used in two ways viz, quick dip method at a very high concentration and soaking method at lower concentration.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study the influence of plant growth regulators on rooting and survival of stem cuttings of china rose and bougainvillea during the period from June 2021 to March 2022.

Experiment-I (Influence of plant growth regulators on rooting and survival of stem cuttings of bougainvillea**)** was conducted for Bougainvillea in winter and rainy season.

Experiment-II (Influence of plant growth regulators on rooting and survival of stem cuttings of china rose**)** was conducted for China rose in winter and rainy season.

A brief description of the experimental site, climatic condition, soil characteristics, experimental design, treatments, cultural operations, data collection and analysis of different parameters were used for conducting this experiment are presented under the following headings:

3.1. Description of the experimental site

The experiment was conducted during the period from June 2021 to March 2022.The present piece of research work was conducted in the experimental area of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The location of the site is 23˚74/N latitude and 90˚35/E longitude with an elevation of 8.2 meter from sea level. The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by heavy scanty rainfall during the rabi season. The soil belonged to “The Modhupur Tract”, AEZ-28. The experimental area was flat having available irrigation and drainage system and above flood level.

3.2. Weather condition during the cutting season

The climate of experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). The average maximum and minimum temperature were 29.45ºC and 13.86º C respectively during the experimental period. In our country winter season is characterized by plenty of sunshine and rainy season is characterized by plenty of rainfall. The duration of the experiment was 5th June, 2021 to 5th September, 2021 in rainy season and 15th December, 2021 to 15th march, 2022 in winter season.

3.3. Planting materials

Bougainvillea and China rose stem cuttings were used as the planting material in this experiment. stem cuttings were collected from Germplasm center of Horticulture Farm at SAU (Sher-e-Bangla Agricultural University), Dhaka-1207, Bangladesh.

3.4. Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. A plot area was divided into three equal blocks. Each block was divided into 6 plots, where 3 treatments were allocated at random for two species. There were 18-unit plots altogether for two experiments. The size of each unit plot was 1.25 m × 1.00 m. The distance maintained between two blocks and two plots were 0.50 m and 0.50 m respectively.

3.5. Bed preparation and intercultural operation

The land was first opened with the tractor drawn disc plough. Then the soil was ploughed and cross ploughed. Ploughed soil was then brought into desirable fine tilth by the operations of ploughing, harrowing and laddering. The stubble and weeds were removed. Experimental land was divided into unit plots following the design of experiment. During final land preparation sand and 8 t/ha decomposed cow dung were mixed with soil.

Irrigation and drainage were provided when required. Weeding was done every week to keep the plots free from weeds, which ultimately ensured better growth and development.

3.6. Preparation of stem cutting

For preparation of stem cutting, about one year old healthy and disease-free stems were selected and separated from the mother plants of species Bougainvillea and China rose. Cuttings were prepared 15 cm length having 2-3 nodes depending on the species. All the leaves were cut off and 30 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 plant growth regulators 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 and ethanol only in case of control treatments.

3.7. Planting of cuttings

Cuttings of two species of ornamental shrubs (Bougainvillea and China rose) were planted in the beds at a spacing of 15cm X 15cm. Two thirds of the length of the cuttings was inserted into the soil at an angle of 45°. Top portion of each cutting was covered with wax droplets for moisture conservation. Immediately after inserting watering was done uniformly by watering 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 4 weeks.

3.8. Treatments of the experiments

Being a single-factor experiment, present study consisted of single factor i.e. plant growth regulator. Details of Plant growth regulators are given below:

The treatments of the present study were assigned as follows:

i. G_0 = Control (treated with water)
ii. G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm
iii. G_2 = Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm

3.9. Preparation of growth regulators

3.9.1 lndole Butyric Acid (IBA)

To prepare 125 ppm of Indole Butyric Acid solution 125 mg of IBA was dissolved in 1.5 ml of ethanol measured with Eppendrof tube and then the volume was made to one liter by adding required amount of distilled water followed by frequent stirring. A 250 ppm IBA solution was prepared by dissolving 250 mg of IBA powder in 1.5 ml of ethanol and then taking in a volumetric flask, the volume was made to one liter by adding sufficient distilled water with frequent stirring.

3.9.2 Naphthalene Acetic Acid (NAA)

To prepare 125 ppm of NAA, solution 125 mg of NAA was taken, 1.5 ml of ethanol was taken in an Eppendrof tube and then the volume was raised to one liter in a volumetric flask by adding distilled water with frequent stirring. Similarly, 250 mg of NAA powder was dissolved in 1.5 ml of ethanol taking in a volumetric flask and then the volume was made to one liter by adding enough distilled water with frequent stirring to prepare 250 ppm of NAA solutions.

3.10. Experimental observations

The cuttings were kept under observation for 90 days. After that 10 cuttings were collected randomly from each of the 9 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 clear water without damaging the roots. Then data were collected for the following parameters-

i. Days to shoot initiation
ii. Number of roots per cutting at 60 DAP
iii. Length of roots (cm) at 60 DAP
iv. Rooting percentage at 60 DAP
v. Shooting percentage at 60 DAP
vi. Number of shoots per cutting at 60 DAP
vii. Number of branches at 60 DAP
viii. Shoot length (cm) at 60 DAP
ix. Number of leaves at 60 DAP
x. Sprouting percentage at 15 DAP
xi. Survival percentage at 60 DAP

3.10.1 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.

3.10.2 Number of roots per cutting and length of roots (cm)

The number of main roots per cutting and length of roots (cm) were recorded 60 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.

3.10.3 Percentage of rooting

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

$$\text{Rooting \%} = \frac{\text{Number of successfully rooted cuttings}}{\text{Number of cuttings planted per treatment}} \times 100$$

3.10.4 Percentage of shooting

The percentage of shooting was calculated 60 days after planting. It was calculated by given formula:

$$\text{Shootings \%} = \frac{\text{Number of successfully shooted cutttings}}{\text{Number of cuttings planted per treatment}} \times 100$$

3.10.5 Number of shoots per cuttings

The number of shoots was recorded 60 days after planting.

3.10.6 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.

3.10.7 Number of leaves per cutting

The number of leaves per cutting were counted 60 DAT from 5 randomly selected plants and the average number of leaves produced per cutting was recorded.

3.10.8 Sprouting percentage

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

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

3.10.9 Survival Percentage:

The survival percentage was calculated after 60 DAP. It was calculated by given formula:

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

3.11. Data analysis

Recorded data were entried and compiled on MS excel spreadsheet. Later on, data were analyzed by using STATISTICS 10 software for analysis of variance. ANOVA was made by F variance test and the mean value comparisons were performed by LSD test.

CHAPTER IV

RESULTS AND DISCUSSION

The present study was carried out on influence of plant growth regulators on rooting and survival of stem cuttings of china rose and bougainvillea. Performance of three treatments was investigated and the findings of the present study have been discussed under different characters of plant growth. Experiment-I was conducted for Bougainvillea and Experiment-II was conducted for China rose. The result of the study showed marked variation in different characters and the variation of different characters are presented in the following Tables and Figures.

Experiment-I

4.1 Influence of plant growth regulators on rooting and survival of stem cuttings of bougainvillea

4.1.1 Effect of plant growth regulators on number of days to shoot initiation per cutting, sprouting percentage and number of shoots per cutting of bougainvillea

The data regarding the number of days taken to the first shooting, sprouting percentage and number of shoots per cutting of cuttings as influenced by plant growth regulators are presented in Table 1.

The perusal of data presented in Table 1 clearly indicated that the number of days taken for the first shooting, sprouting percentage at 15 DAP and number of shoots per cutting was significantly different due to different plant growth regulators both in winter season and rainy season. Among the different growth regulators of IBA and NAA Mixed hormone, significantly the minimum days (10.50 days in winter season and 9.78 days in rainy season) taken for the shooting were recorded in G_2 (Equally mixed Indole Butyric Acid (IBA) @250 ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) and significantly different from G_1 (16.00 days in winter season and 13.42 days in rainy season) (Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid

(NAA) @ 125 ppm). While maximum days recorded for the first shooting was noted (25.50 days in winter season and 18.16 days in rainy season) in G_0 (Control (treated with water)). Increased level of plant growth regulators resulted in earlier completion of physiological processes in shooting of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest sprouting percentage at 15 DAP (78.28% in winter season and 86.81% in rainy season) taken for the shooting were recorded in G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) and significantly different from G_1 (70.56% in winter season and 77.82% in rainy season) (Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm). While lowest sprouting percentage was recorded (68.84% in winter season and 74.65% in rainy season) in G_0 (Control (treated with water)). Increased level of plant growth regulators resulted in earlier completion of physiological processes in sprouting percentage of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest number of shoots per cutting (3.40 in winter season and 5.23 in rainy season) were recorded in G_2 and significantly different from G_1 (2.67 in winter season and 3.86 in rainy season). While lowest number of shoots per cutting was recorded (2.02 in winter season and 2.87 in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes number of shoots per cutting.

Table 1. Effect of plant growth regulators on number of days to shoot initiation per cutting, sprouting percentage and number of shoots per cutting of bougainvillea

Growth regulators	Days to shoot initiation		Sprouting percentage at 15 DAP		Number of shoots per cutting	
	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
G_0	25.50 a	18.16 a	68.84 b	74.65 c	2.02 c	2.87 c
G_1	16.00 b	13.42 b	70.56 b	77.82 b	2.67 b	3.86 b
G_2	10.50 c	9.78 c	78.28 a	86.81 a	3.40 a	5.23 a
$LSD_{(0.05)}$	**3.22**	**0.41**	**5.68**	**1.12**	**0.16**	**0.37**
CV(%)	**8.20**	**1.27**	**3.46**	**0.62**	**2.60**	**3.64**

In a column having similar letters (s) are statistically similar and those having dissimilar letter (s) differ significantly at 0.05 level of probability.

[G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm]

From the above findings (**Table 1**) it is revealed that the number of days taken to the first shooting, sprouting percentage and number of shoots per cutting of bougainvillea G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) was more effective among the plant growth regulators. Least performance of treatment was G_0 (Control (treated with water)). As a result, the order of rank of study the influence of plant growth regulators on rooting and seedling establishment of bougainvillea in winter and rainy season by number was $G_2 > G_1 > G_0$.

4.1.2. Effect of plant growth regulators on number of roots per cutting at 60 DAP, length of roots (cm) at 60 DAP and shooting percentage of bougainvillea

The data regarding the number of roots per cutting at 60 DAP, length of roots (cm) at 60 DAP and shooting percentage of cuttings as influenced by plant growth regulators are presented in Table 2.

The perusal of data presented in Table 2 clearly indicated that the number of roots per cutting at 60 DAP, length of roots (cm) at 60 DAP and shooting percentage was significantly different due to different plant growth regulators both in winter season and rainy season. Among the different growth regulators of IBA and NAA Mixed hormone, significantly the maximum number of roots (11.65 in winter season and 17.36 in rainy season) were recorded in G_2 and significantly different from G_1 (7.61 in winter season and 13.92 in rainy season). While minimum number of roots were noted (4.71 in winter season and 8.56 in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes and increase number of roots of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest length of roots (13.45 cm in winter season and 15.34 cm in rainy season) was recorded in G_2 and significantly different from G_1 (10.33 cm in winter season and 11.83 cm in rainy season). While lowest length of roots was noted (5.75 cm in winter season and 8.57 cm in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes and increase length of roots of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest shooting percentage (93.39% in winter season and 96.67% in rainy season) was recorded in G_2 and significantly different from G_1 (83.39% in winter season and 83.34% in rainy season). While lowest shooting percentage was noted (76.67% in winter season and 80.00% in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes shooting percentage of cuttings.

Table 2. Effect of plant growth regulators on number of roots per cutting at 60 DAP, length of roots (cm) at 60 DAP and shooting percentage of bougainvillea

Growth regulators	Number of roots per cutting at 60 DAP		Length of roots (cm) at 60 DAP		Shooting percentage	
	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
G_0	4.71 c	8.56 c	5.75 c	8.57 c	76.67 c	80.00 b
G_1	7.61 b	13.92 b	10.33 b	11.83 b	83.39 b	83.34 b
G_2	11.65 a	17.36 a	13.45 a	15.34 a	93.39 a	96.67 a
$LSD_{(0.05)}$	**0.77**	**1.62**	**0.85**	**2.18**	**6.24**	**9.75**
CV(%)	**4.24**	**5.39**	**3.81**	**8.08**	**3.26**	**4.96**

In a column having similar letters (s) are statistically similar and those having dissimilar letter (s) differ significantly at 0.05 level of probability.

[G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm]

From the above findings (**Table 2**) it is revealed that number of roots per cutting at 60 DAP, length of roots (cm) at 60 DAP and shooting percentage of bougainvillea G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) was more effective among the plant growth regulators. Least performance of treatment was G_0 (Control (treated with water)). As a result, the order of rank of study the influence of plant growth regulators on rooting and seedling establishment of bougainvillea in winter and rainy season by number was $G_2 > G_1 > G_0$.

4.1.3. Effect of plant growth regulators on rooting percentage and survival percentage at 60 DAP of bougainvillea

The data regarding the rooting percentage per cutting 60 DAP and survival percentage at 60 DAP of cuttings as influenced by plant growth regulators are presented in Table 3.

The perusal of data presented in Table 3 clearly indicated that the rooting percentage per cutting 60 DAP and survival percentage at 60 DAP was significantly different due to different plant growth regulators both in winter season and rainy season. Among the different growth regulators of IBA and NAA Mixed hormone, significantly the maximum rooting percentage (71.26% in winter season and 86.74% in rainy season) were recorded in G_2 and significantly different from G_1 (60.42% in winter season and 74.62% in rainy season). While minimum rooting percentage was recorded (45.42% in winter season and 60.90% in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes rooting percentage of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest survival percentage (76.67% in winter season and 85.20% in rainy season) were recorded in G_2 and significantly different from G_1 (73.46% in winter season and 69.53% in rainy season). While lowest survival percentage was recorded (43.57% in winter season and 58.59% in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes survival percentage of cuttings.

Table 3. Effect of plant growth regulators on rooting percentage and survival percentage at 60 DAP of bougainvillea

Growth regulators	Rooting percentage		Survival percentage at 60 DAP	
	Winter season	Rainy season	Winter season	Rainy season
G_0	45.42 c	60.90 c	43.57 c	58.59 c
G_1	60.42 b	74.62 b	73.46 b	69.53 b
G_2	71.26 a	86.74 a	76.67 a	85.20 a
$LSD_{(0.05)}$	**2.19**	**10.37**	**3.02**	**6.14**
CV(%)	**1.64**	**6.17**	**2.06**	**3.81**

In a column having similar letters (s) are statistically similar and those having dissimilar letter (s) differ significantly at 0.05 level of probability.

[G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm]

From the above findings (**Table 3**) it is revealed that rooting percentage per cutting 60 DAP and survival percentage at 60 DAP of bougainvillea G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) was more effective among the plant growth regulators. Least performance of treatment was G_0 (Control (treated with water)). As a result, the order of rank of study the influence of plant growth regulators on rooting and seedling establishment of bougainvillea in winter and rainy season by number was $G_2 > G_1 > G_0$.

4.1.4. Effect of plant growth regulators on average shoot length (cm), number of leaves at 60 DAP and number of branches of bougainvillea

The data regarding number of shoot length (cm), number of leaves at 60 DAP and number of branches of cuttings as influenced by plant growth regulators are presented in Table 4.

The perusal of data presented in Table 4 clearly indicated that shoot length (cm), number of leaves at 60 DAP and number of branches was significantly different due to different plant growth regulators both in winter season and rainy season. Among the different growth regulators of IBA and NAA Mixed hormone, significantly the maximum shoot Length (cm) per cutting (18.51 cm in winter season and 23.61 cm in rainy season) were recorded in G_2 and significantly different from G_1 (15.59 cm in winter season and 20.63 cm in rainy season). While minimum shoot Length (cm) per cutting was recorded (11.30 cm in winter season and 15.43 cm in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes shoot Length (cm) per cutting.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest number of leaves (24.48 in winter season and 32.43 in rainy season) was recorded in G_2 and significantly different from G_1 (19.30 in winter season and 25.58 in rainy season). While lowest number of leaves was recorded (13.79 in winter season and 17.44 in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes number of leaves of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest number of branch (5.76 in winter season and 5.92 in rainy season) was recorded in G_2 and significantly different from G_1 (4.39 in winter season and 4.46 in rainy season). While lowest number of branches was recorded (2.54 in winter season and 2.62 in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes number of branch of cuttings.

Table 4. Effect of plant growth regulators on average shoot length (cm), number of leaves at 60 DAP and number of branches of bougainvillea

Growth regulators	Shoot length (cm)		Number of leaves		Number of branches	
	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
G_0	11.30 c	15.43 c	13.79 c	17.44 c	2.54 c	2.62 c
G_1	15.59 b	20.63 b	19.30 b	25.58 b	4.39 b	4.46 b
G_2	18.51 a	23.61 a	24.48 a	32.43 a	5.76 a	5.92 a
$LSD_{(0.05)}$	**1.98**	**2.88**	**0.96**	**4.69**	**0.71**	**0.51**
CV(%)	**5.76**	**6.38**	**2.21**	**8.23**	**7.40**	**5.19**

In a column having similar letters (s) are statistically similar and those having dissimilar letter (s) differ significantly at 0.05 level of probability.

[G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm]

From the above findings (**Table 4**) it is revealed that on average shoot length (cm), number of leaves at 60 DAP and number of branches of bougainvillea G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) was more effective among the plant growth regulators. Least performance of treatment was G_0 (Control (treated with water)). As a result, the order of rank of study the influence of plant growth regulators on rooting and seedling establishment of bougainvillea in winter and rainy season by number was $G_2 > G_1 > G_0$.

Experiment-II

4.2 Influence of plant growth regulators on rooting and survival of stem cuttings of china rose

4.2.1. Effect of plant growth regulators on number of days to shoot initiation per cutting, sprouting percentage and number of shoots per cutting of China rose

The data regarding the number of days to shoot initiation per cutting, sprouting percentage and number of shoots per cuttings as influenced by plant growth regulators are presented in Table 5.

The perusal of data presented in Table 5 clearly indicated that the number of days taken for the first shooting and sprouting percentage at 15 DAP was significantly different due to different plant growth regulators both in winter season and rainy season. Among the different growth regulators of IBA and NAA Mixed hormone, significantly the minimum days (6.67 days in winter season and 7.34 days in rainy season) taken for the shooting were recorded in G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) and significantly different from G_1 (9.50 days in winter season and 9.67 days in rainy season) (Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm). While maximum days recorded for the first shooting was noted (13.00 days in winter season and 11.25 days in rainy season) in G_0 (Control (treated with water)). Increased level of plant growth regulators resulted in earlier completion of physiological processes in shooting of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest sprouting percentage at 15 DAP (76.62% in winter season and 83.56% in rainy season) taken for the shooting were recorded in G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) and significantly different from G_1 (64.58% in winter season and 72.92% in rainy season) (Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm). While lowest sprouting percentage was recorded (60.82% in winter season and 69.51% in rainy season) in G_0 (Control (treated with water)). Increased level of plant growth regulators resulted in earlier completion of physiological processes in sprouting percentage of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest number of branch (5.56 in winter season and 6.96 in rainy season) was recorded in G_2 and significantly different from G_1 (3.89 in winter season and 5.59 in rainy season). While lowest number of branches was recorded (2.34 in winter season and 3.47 in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes number of branch of cuttings.

Table 5. Effect of plant growth regulators on number of days to shoot initiation per cutting, sprouting percentage and number of shoots per cutting of China rose

Growth regulators	Days to shoot initiation		Sprouting percentage at 15 DAP		Number of shoots per cutting	
	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
G_0	13.00 a	11.25 a	60.82 b	69.51 c	3.32 c	4.34 c
G_1	9.50 b	9.67 b	64.58 b	72.92 b	5.23 b	6.27 b
G_2	6.67 c	7.34 c	76.62 a	83.56 a	6.26 a	7.76 a
$LSD_{(0.05)}$	1.31	0.99	8.06	1.02	0.38	0.93
CV(%)	5.93	4.65	5.28	9.60	3.37	6.68

In a column having similar letters (s) are statistically similar and those having dissimilar letter (s) differ significantly at 0.05 level of probability.

[G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm]

From the above findings (**Table 5**) it is revealed that the number of days taken to the first shooting, sprouting percentage and number of shoots per cutting of China rose G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) was more effective among the plant growth regulators. Least performance of treatment was G_0 (Control (treated with water)). As a result, the order of rank of study the influence of plant growth regulators on rooting and seedling establishment of China rose in winter and rainy season by number was $G_2 > G_1 > G_0$.

4.2.2. Effect of plant growth regulators on number of roots per cutting at 60 DAP, length of roots (cm) at 60 DAP and shooting percentage of China rose

The data regarding the number of roots per cutting at 60 DAP, length of roots (cm) at 60 DAP and shooting percentage of cuttings as influenced by plant growth regulators are presented in Table 6.

The perusal of data presented in Table 6 clearly indicated that the number of roots per cutting 60 DAP and length of roots (cm) 60 DAP was significantly different due to different plant growth regulators both in winter season and rainy season. Among the different growth regulators of IBA and NAA Mixed hormone, significantly the maximum number of roots (15.25 in winter season and 21.60 in rainy season) were recorded in G_2 and significantly different from G_1 (10.33 in winter season and 14.44 in rainy season). While minimum number of roots were noted (6.75 in winter season and 11.87 in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes and increase number of roots of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest length of roots (13.00 cm in winter season and 14.46 cm in rainy season) was recorded in G_2 and significantly different from G_1 (11.87 cm in winter season and 12.61

cm in rainy season). While lowest length of roots was noted (8.65 cm in winter season and 9.87 cm in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes and increase length of roots of cuttings.

Among the different growth regulators of IBA and NAA mixed hormone, significantly the highest shooting percentage (96.67% in winter season and 100.00% in rainy season) was recorded in G_2 and significantly different from G_1 (86.67% in winter season and 96.67% in rainy season). While lowest shooting percentage was noted (80.00% in winter season and 90.03% in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes shooting percentage of cuttings.

Table 6. Effect of plant growth regulators on number of roots per cutting at 60 DAP, length of roots (cm) at 60 DAP and shooting percentage of China rose

Growth regulators	Number of roots per cutting at 60 DAP		Length of roots (cm) 60 DAP		Shooting percentage	
	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
G_0	6.75 c	11.87 b	8.65 c	9.87 c	80.00 c	90.03 b
G_1	10.33 b	14.44 ab	11.87 b	12.61 b	86.67 b	96.67 ab
G_2	15.25 a	21.60 a	13.00 a	14.46 a	96.67 a	100.00 a
$LSD_{(0.05)}$	**0.60**	**8.69**	**0.89**	**0.95**	**1.42**	**7.29**
CV(%)	**2.45**	**8.99**	**3.53**	**3.42**	**5.71**	**3.37**

In a column having similar letters (s) are statistically similar and those having dissimilar letter (s) differ significantly at 0.05 level of probability.

[G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm]

From the above findings (**Table 6**) it is revealed that the number of roots per cutting at 60 DAP, length of roots (cm) at 60 DAP and Shooting percentage of China rose G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) was more effective among the plant growth regulators. Least performance of treatment was G_0 (Control (treated with water)). As a result, the order of rank of study the influence of plant growth regulators on rooting and seedling establishment of China rose in winter and rainy season by number was $G_2 > G_1 > G_0$.

4.2.3. Effect of plant growth regulators on rooting percentage and survival percentage at 60 DAP of China rose

The data regarding the rooting percentage and survival percentage at 60 DAP of cuttings as influenced by plant growth regulators are presented in Table 7.

The perusal of data presented in Table 10 clearly indicated that the rooting percentage per cutting 60 DAP and shooting percentage at 60 DAP was significantly different due to different plant growth regulators both in winter season and rainy season. Among the different growth regulators of IBA and NAA Mixed hormone, significantly the maximum rooting percentage (74.77% in winter season and 89.50% in rainy season) were recorded in G_2 and significantly different from G_1 (64.24% in winter season and 78.54% in rainy season). While minimum rooting percentage was recorded (58.75% in winter season and 65.22% in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes rooting percentage of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest survival percentage (73.33% in winter season and 92.36% in rainy season) were recorded in G_2 and significantly different from G_1 (67.10% in winter season and 78.77% in rainy season). While lowest survival percentage was recorded (50.83% in winter season and 67.65% in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes survival percentage of cuttings.

Table 7. Effect of plant growth regulators on rooting percentage and survival percentage at 60 DAP of China rose

Growth regulators	Rooting percentage		survival percentage at 60 DAP	
	Winter season	Rainy season	Winter season	Rainy season
G_0	58.75 c	65.22 c	50.83 c	67.65 c
G_1	64.24 b	78.54 b	67.10 b	78.77 b
G_2	74.77 a	89.50 a	73.33 a	92.36 a
$LSD_{(0.05)}$	**3.13**	**7.04**	**0.49**	**7.41**
CV(%)	**2.09**	**3.99**	**7.34**	**4.10**

In a column having similar letters (s) are statistically similar and those having dissimilar letter (s) differ significantly at 0.05 level of probability.

[G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm]

From the above findings (**Table 7**) it is revealed that the rooting percentage and survival percentage at 60 DAP of China rose G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) was more effective among the plant growth regulators. Least performance of treatment was G_0 (Control (treated with water)). As a result, the order of rank of study the influence of plant growth regulators on rooting and seedling establishment of China rose in winter and rainy season by number was $G_2 > G_1 > G_0$.

4.2.4. Effect of plant growth regulators on average shoot length (cm), number of leaves at 60 DAP and number of branches of China rose

The data regarding on average shoot length (cm), number of leaves at 60 DAP and number of branches of cuttings as influenced by plant growth regulators are presented in Table 8.

The perusal of data presented in Table 8 clearly indicated that the shoot Length (cm) and number of leaves at 60 DAP was significantly different due to different plant growth regulators both in winter season and rainy season. Among the different growth regulators of IBA and NAA Mixed hormone, significantly the maximum shoot Length (cm) per cutting (12.38 cm in winter season and 16.83 cm in rainy season) were recorded in G_2 and significantly different from G_1 (9.46 cm in winter season and 12.50 cm in rainy season). While minimum shoot Length (cm) per cutting was recorded (6.87 cm in winter season and 8.15 cm in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes shoot Length (cm) per cutting.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest number of leaves (16.35 in winter season and 20.08 in rainy season) was recorded in G_2 and significantly different from G_1 (13.58 in winter season and 17.77 in rainy season). While lowest number of leaves was recorded (9.74 in winter season and 12.66 in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes number of leaves of cuttings.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest number of shoots per cutting (6.26 in winter season and 7.76 in rainy season) were recorded in G_2 and significantly different from G_1 (5.26 in winter season and 6.27 in rainy season). While lowest number of shoots per cutting was recorded (3.32 in winter season and 4.34 in rainy season) in G_0. Increased level of plant growth regulators resulted in earlier completion of physiological processes number of shoots per cutting.

Table 8. Effect of plant growth regulators on average shoot length (cm), number of leaves at 60 DAP and number of branches of China rose

Growth regulators	Shoot length (cm) at 60DAP		Number of leaves		Number of branches	
	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
G_0	6.87 c	8.15 c	9.74 c	12.66 c	2.34 c	3.47 c
G_1	9.46 b	12.50 b	13.58 b	17.77 b	3.89 b	5.59 b
G_2	12.38 a	16.83 a	16.35 a	23.08 a	5.56 a	6.96 a
$LSD_{(0.05)}$	**0.39**	**0.95**	**1.13**	**1.51**	**0.37**	**0.40**
CV(%)	**1.80**	**3.36**	**3.76**	**3.74**	**4.18**	**3.28**

In a column having similar letters (s) are statistically similar and those having dissimilar letter (s) differ significantly at 0.05 level of probability.

[G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125ppm and Naphthalene Acetic Acid (NAA) @ 125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm]

From the above findings (**Table 8**) it is revealed that the average shoot length (cm), number of leaves at 60 DAP and number of branches of China rose G_2 (Equally mixed Indole Butyric Acid (IBA) @250ppm and Naphthalene Acetic Acid (NAA) @ 250 ppm) was more effective among the plant growth regulators. Least performance of treatment was G_0 (Control (treated with water)). As a result, the order of rank of study the influence of plant growth regulators on rooting and seedling establishment of China rose in winter and rainy season by number was $G_2 > G_1 > G_0$.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the experimental area of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh to evaluate the influence of plant growth regulators on rooting and survival of stem cuttings of China rose and Bougainvillea during the period from June 2021 to March 2022. The experiment consists to control measures and plant growth regulators.

Three treatments, viz. G_0 = Control (treated with water), G_1 = Equally mixed Indole Butyric Acid (IBA) @125 ppm and Naphthalene Acetic Acid (NAA) @125 ppm, G_2 = Equally mixed Indole Butyric Acid (IBA) @250 ppm and Naphthalene Acetic Acid (NAA) @250 ppm were included in this study. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Results showed that the significant variations were observed among different days to shoot initiation, number of roots per cutting 60 DAP, length of roots (cm) 60 DAP, rooting percentage, shooting percentage, number of shoots per cutting, number of branch 60 DAP, shoot Length (cm) 60 DAP, number of leaves, sprouting percentage and survival percentage of China rose and Bougainvillea cuttings.

In case of different treatments performance, G2 (Equally mixed Indole Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) @ 500 ppm) showed best performance in all growing stages.

For Bougainvillea, among the different growth regulators of IBA and NAA Mixed hormone, significantly the minimum days (10.50 days in winter season and 9.78 days in rainy season) taken for the shooting were recorded in G_2 and significantly different from G_1 (16.00 days in winter season and 13.42 days in rainy season). While maximum days recorded for the first shooting was noted (25.50 days in winter season and 18.16 days in rainy season) in G_0.

Among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest sprouting percentage at 15 DAP (78.28% in winter season and 86.81% in rainy season) taken for the shooting were recorded in G_2 and significantly different from G_1 (70.56% in winter season and 77.82% in rainy season). While lowest sprouting percentage was recorded (68.84% in winter season and 74.65% in rainy season) in G_0. Similar trend of result found to influence of plant growth regulators on rooting and seedling establishment of China rose in winter season and rainy season.

For Bougainvillea, the maximum number of roots (11.65 in winter season and 17.36 in rainy season) were recorded in G_2 and significantly different from G_1 (7.61 in winter season and 13.92 in rainy season). While minimum number of roots were noted (4.71 in winter season and 8.56 in rainy season) in G_0.

The highest length of roots (13.45 cm in winter season and 15.34 cm in rainy season) was recorded in G_2 and significantly different from G_1 (10.33 cm in winter season and 11.83 cm in rainy season). While lowest length of roots was noted (5.75 cm in winter season and 8.57 cm in rainy season) in G_0. Similar trend of result found to influence of plant growth regulators on rooting and seedling establishment of China rose in winter season and rainy season.

For Bougainvillea, the maximum rooting percentage (71.26% in winter season and 86.74% in rainy season) were recorded in G_2 and significantly different from G_1 (60.42% in winter season and 74.62% in rainy season). While minimum rooting percentage was recorded (45.42% in winter season and 60.90% in rainy season) in G_0.

The highest shooting percentage (93.39% in winter season and 96.67% in rainy season) was recorded in G_2 and significantly different from G_1 (83.39% in winter season and 83.34% in rainy season). While lowest shooting percentage was noted (76.67% in winter season and 80.00% in rainy season) in G_0. Similar trend of result found to influence of plant growth regulators on rooting and seedling establishment of China rose in winter season and rainy season.

For Bougainvillea, the highest number of shoots per cutting (3.40 in winter season and 5.23 in rainy season) were recorded in G_2 and significantly different from G_1 (2.67 in winter season and 3.86 in rainy season). While lowest number of shoots per cutting was recorded (2.02 in winter season and 2.87 in rainy season) in G_0.

The highest number of branch (5.76 in winter season and 5.92 in rainy season) was recorded in G_2 and significantly different from G_1 (4.39 in winter season and 4.46 in rainy season). While lowest number of branches was recorded (2.54 in winter season and 2.62 in rainy season) in G_0. Similar trend of result found to influence of plant growth regulators on rooting and seedling establishment of China rose in winter season and rainy season.

For Bougainvillea, the maximum shoot Length (cm) per cutting (18.51 cm in winter season and 23.61 cm in rainy season) were recorded in G_2 and significantly different from G_1 (15.59 cm in winter season and 20.63 cm in rainy season). While minimum shoot Length (cm) per cutting was recorded (11.30 cm in winter season and 15.43 cm in rainy season) in G_0.

The highest number of leaves (24.48 in winter season and 32.43 in rainy season) was recorded in G_2 and significantly different from G_1 (19.30 in winter season and 25.58 in rainy season). While lowest number of leaves was recorded (13.79 in winter season and 17.44 in rainy season) in G_0. Similar trend of result found to influence of plant growth regulators on rooting and seedling establishment of China rose in winter season and rainy season.

For Bougainvillea, among the different growth regulators of IBA and NAA Mixed hormone, significantly the highest survival percentage (76.67% in winter season and 85.20% in rainy season) were recorded in G_2 and significantly different from G_1 (73.46% in winter season and 69.53% in rainy season). While lowest survival percentage was recorded (43.57% in winter season and 58.59% in rainy season) in G_0. Similar trend of result found to influence of plant growth regulators on rooting and seedling establishment of China rose in winter season and rainy season.

Conclusion

From the above description, it can be concluded that, spraying G_2 (Equally mixed Indole Butyric Acid @250pmm and Naphthalene Acetic Acid @ 250 ppm) showed best performance to influence of plant growth regulators on rooting and survival of stem cuttings of China rose and Bougainvillea in winter and rainy season.

CHAPTER VI

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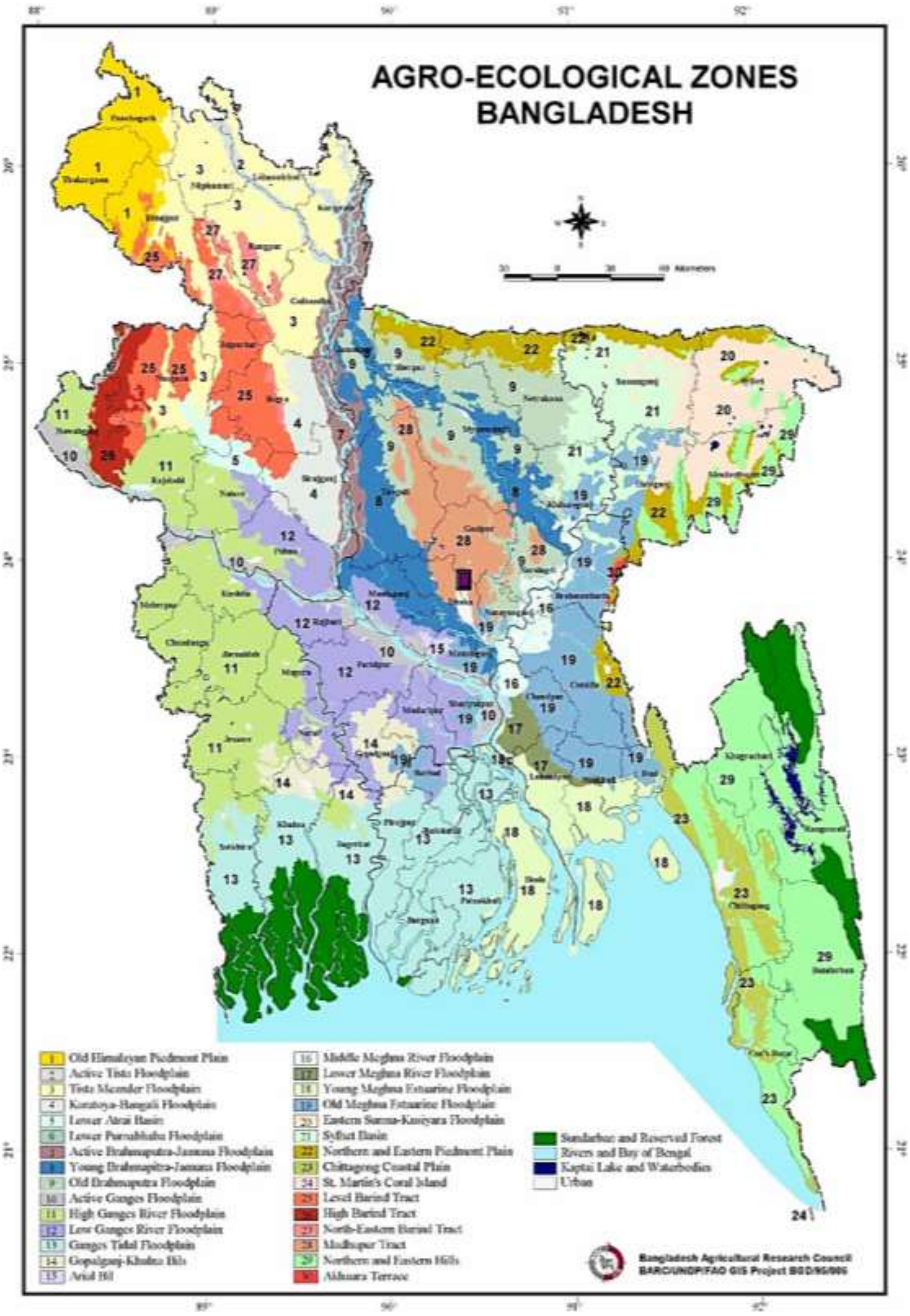
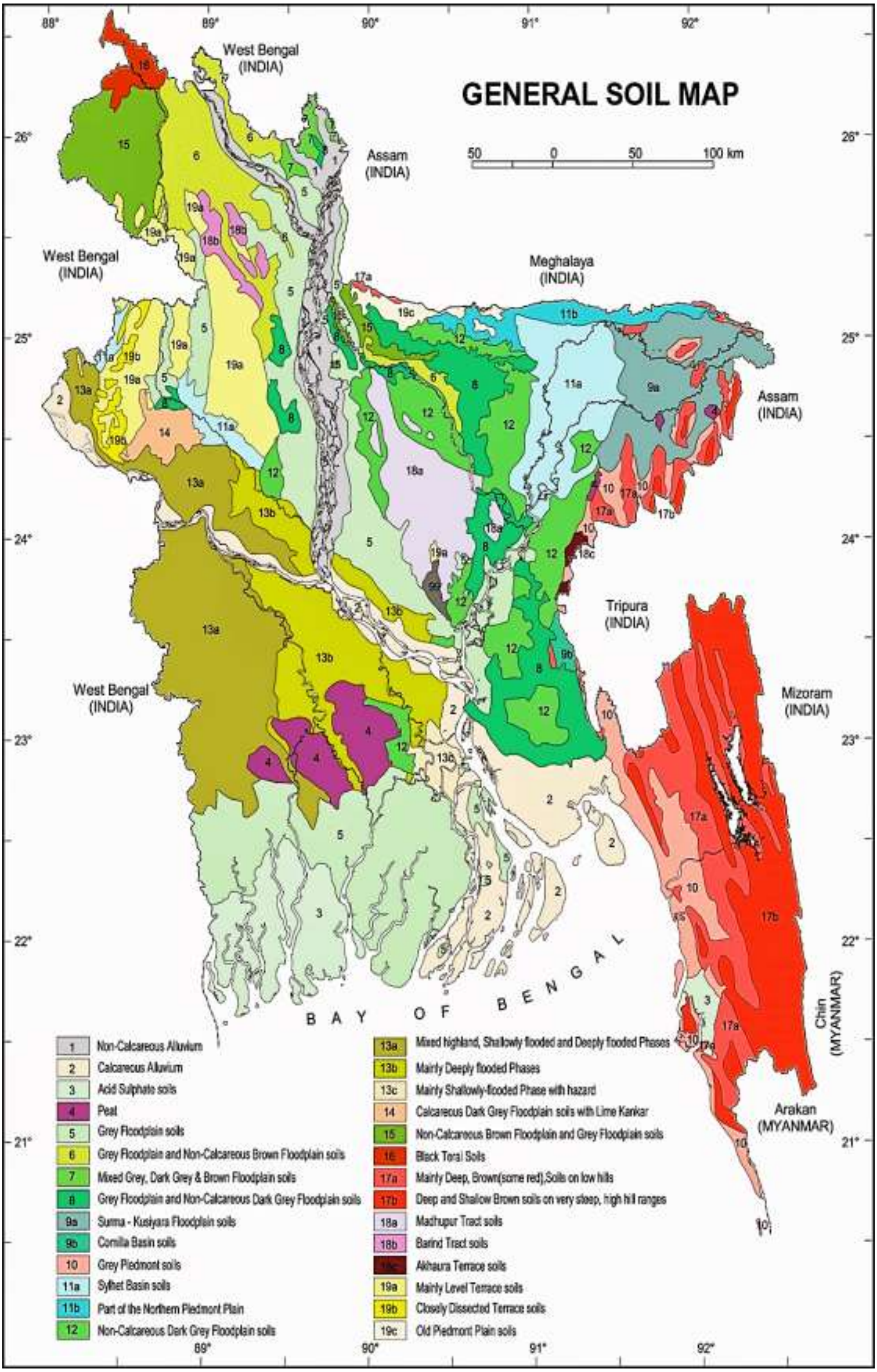
APPENDICES

Appendix I (A): Map showing the experimental sites under study



Appendix I (B): Map showing the general soil types in Bangladesh



Appendix II: Characteristics of Horticulture Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm, 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	Potato-Aus rice-T.aman rice

B. Physical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30

Source: Soil Resource Development Institute (SRDI), Khamarbari, Farmgate, Dhaka-1215

Appendix III: Monthly average temperature, relative humidity, and total rainfall of the experimental site during the period from June 2021 to March 2022

Year	Month	Temperature			Relative Humidity (%)	Total Rainfall (mm)	Sunshine (Hour)
		Max (°C)	Min (°C)	Mean (°C)			
2021 - 2022	June	34	28	30	73	88.6	300
	July	33	27	30	76	46.53	268
	August	34	27	30	76	66.92	302
	September	34	27	30	71	64.14	292.5
	October	33	26	30	59	33	238
	November	33	25	29	51	12.3	210.5
	December	30	20	25	49	11.1	205
	January	27	15	21	45	8	201
	February	28	18	23	47	9	203
	March	32	22	27	54	13	207

Source: Bangladesh Metrological Department (Climate and Weather Division) Agargaon, Dhaka.

Appendix IV: Mean sum- square values for days to shoot initiation, sprouting percentage at 15 DAP, number of roots per cutting 60 DAP and length of roots (cm) 60 DAP for bougainvillea in winter season and rainy season from Analysis of Variance (ANOVA)

Source of variation	df	Days to shoot initiation		Sprouting percentage at 15 DAP		Number of roots per cutting 60 DAP		Length of roots (cm) 60 DAP	
		Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
Replication	2	0.333	4.272	1.142	12.285	12.454	4.763	1.401	0.108
Different plant growth regulator	2	172.750**	41.950**	75.949^{NS}	119.418**	36.476**	59.001***	45.00	34.390
Error	4	2.021	0.031	6.288	0.245	0.115	0.512	0.140	0.926

NS= non-Significant

* *Significant at 0.05 level of probability

Appendix V: Mean sum- square values for days to rooting percentage, shooting percentage, number of shoots per cutting and number of branches for bougainvillea in winter season and rainy season from Analysis of Variance (ANOVA)

Source of variation	df	Rooting percentage		Shooting percentage		Number of shoots per cutting		Number of branches	
		Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
Replication	2	32.329	7.741	6.903	0.145	0.1162	0.371	1.280	0.042
Different plant growth regulator	2	504.847**	501.672**	212.458**	233.367^{NS}	1.422**	4.238**	8.203	7.851
Error	4	0.937	20.921	7.580	18.505	0.005	0.026	0.050	0.098

NS= non-Significant

* *Significant at 0.05 level of probability

Appendix VI: Mean sum- square values for days to shoot length (cm), number of leaves, survival percentage at 60 DAP for bougainvillea in winter season and rainy season from Analysis of Variance (ANOVA)

Source of variation	df	Shoot length (cm)		Number of leaves		Survival percentage at 60 DAP	
		Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
Replication	2	7.013	2.595	7.149	2.681	8.965	5.877
Different plant growth regulator	2	39.491**	51.379**	85.733**	168.791**	999.784**	536.803**
Error	4	0.761	1.609	0.180	4.285	1.774	7.331

NS= non-Significant

* *Significant at 0.05 level of probability

Appendix VII: Mean sum- square values for days to shoot initiation, sprouting percentage at 15 DAP, number of roots per cutting 60 DAP and length of roots (cm) at 60 DAP for China rose in winter season and rainy season from Analysis of Variance (ANOVA)

Source of variation	df	Days to shoot initiation		Sprouting percentage at 15 DAP		Number of roots per cutting at 60 DAP		Length of roots (cm) at 60 DAP	
		Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
Replication	2	1.470	2.100	2.278	6.107	3.006	31.669	2.161	4.917
Different plant growth regulator	2	30.169**	11.606**	204.490^{NS}	161.144**	54.631**	76.328^{NS}	15.302**	15.996**
Error	4	0.332	0.192	12.642	0.201	0.069	14.68	0.155	0.177

NS= non-Significant

* *Significant at 0.05 level of probability

Appendix VII: Mean sum- square values for days to rooting percentage, shooting percentage, number of shoots per cutting and number of branches for China rose in winter season and rainy season from Analysis of Variance (ANOVA)

Source of variation	df	Rooting percentage		Shooting percentage		Number of shoots per cutting		Number of branches	
		Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
Replication	2	51.875	83.043	20.909	2.755	0.126	1.280	0.229	0.398
Different plant growth regulator	2	198.831**	443.422**	211.189**	77.2892**	6.666**	8.838**	7.779**	9.289**
Error	4	1.901	9.638	0.391	10.345	0.027	0.167	0.027	0.030

NS= non-Significant

* *Significant at 0.05 level of probability

Appendix IX: Mean sum- square values for days to shoot length (cm), number of leaves, survival percentage at 60 DAP for China rose in winter season and rainy season from Analysis of Variance (ANOVA)

Source of variation	df	Shoot length (cm)		Number of leaves		Survival percentage at 60 DAP	
		Winter season	Rainy season	Winter season	Rainy season	Winter season	Rainy season
Replication	2	1.664	5.057	3.927	4.502	21.371	3.412
Different plant growth regulator	2	22.798**	56.508**	33.062**	81.338**	404.725**	459.702**
Error	4	0.029	0.175	0.247	0.446	0.047	10.671

NS= non-Significant

* *Significant at 0.05 level of probability