“STUDIES ON THE EFFECT OF PLANT GROWTH REGULATORS AND COCONUT WATER ON ROOTING OF BOUGAINVILLEA (*Bougainvillea spectabilis.* L) STEM CUTTINGS”

ASODU AISHWARYA DEEPTHI

B.Sc. (Hort.)

MASTER OF SCIENCE IN HORTICULTURE

(FLORICULTURE AND LANDSCAPE ARCHITECTURE)

DEPARTMENT OF FLORICULTURE AND LANDSCAPE ARCHITECTURE

COLLEGE OF HORTICULTURE, MOJERLA, WANAPARTHY– 509 382

SRI KONDA LAXMAN TELANGANA STATE HORTICULTURAL UNIVERSITY

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By

ASODU AISHWARYA DEEPTHI

B.Sc. (Hort.)

THESIS SUBMITTED TO SRI KONDA LAXMAN TELANGANA STATE HORTICULTURAL UNIVERSITY
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JANUARY, 2019

CERTIFICATE

Ms. A. AISHWARYA DEEPTHI has satisfactorily prosecuted the course of research and that the thesis entitled **"STUDIES ON THE EFFECT OF PLANT GROWTH REGULATORS AND COCONUT WATER ON ROOTING OF BOUGAINVILLEA (*Bougainvillea spectabilis.* L) STEM CUTTINGS"** submitted, is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any University.

Date : **(DR.P.PRASHANTH)**

Place: Mojerla, Wanaparthy. **Chairman**

CERTIFICATE

This is to certify that the thesis entitled **" STUDIES ON THE EFFECT OF PLANT GROWTH REGULATORS AND COCONUT WATER ON ROOTING OF BOUGAINVILLEA (*Bougainvillea spectabilis* L.) STEM CUTTINGS "** submitted in partial fulfilment of the requirements for the degree of Master of Science in Horticulture (Floriculture and Landscape Architecture) of Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, is a record of the bonafide research work carried out by **Ms. A. AISHWARYA DEEPTHI** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

Thesis approved by the Student Advisory Committee.

Chairman: **Dr. P. PRASANTH**
Senior Scientist and Head, (Horti.)
Floricultural Research Station,
Rajendranagar,Hyderabad. _____

Member: **Dr.N .SEENIVASAN**
Associate Professor,
College of Horticulture,
Mojerla, Wanaparthy. _____

Member: **Dr. D. SAIDA NAIK**
Associate Professor
College of Agriculture,
Rajendranagar, Hyderabad _____

Date of final viva – voce:

LIST OF SYMBOLS AND ABBREVIATIONS

Av.	:	Average
B: C ratio	:	Benefit cost ratio
et al.	:	(*et albeit*) and elsewhere
etc.	:	and so on; and other people / things
cm	:	Centimeter
C. D	:	Critical difference
Cv.	:	Cultivar
°C	:	Degree Celsius
Fig.	:	Figure
FCRD	:	Factorial Completely Randomized Design
g	:	Gram
g/mol	:	Gram per mole
hrs	:	Hours
i.e.	:	(*Id est.*) that is
viz.,	:	Namely
No.	:	Number
/	:	Per
%	:	Per cent
SKLTSHU	:	Sri Konda Laxman Telangana State Horticultural University
SE (m) ±	:	Standard error of mean
cm^2	:	Square centimeter
wt.	:	Weight

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Mojerla. **(A. AISHWARYA DEEPTHI)**

DECLARATION

I, **Ms. A. AISHWARYA DEEPTHI,** hereby declare that the thesis entitled **"STUDIES ON THE EFFECT OF PLANT GROWTH REGULATORS AND COCONUT WATER ON BOUGAINVILLEA (*Bougainvillea spectabilis* L.) STEM CUTTINGS"** submitted to Sri Konda Laxman Telangana State Horticultural University**,** Rajendranagar, for the Degree of Master of Science in Horticulture (Floriculture and Landscape Architecture) is the result of original research work done by me. I declare that no material contained in the thesis has been published earlier in any manner.

Place: Mojerla
Date:

Name: A. AISHWARYA DEEPTHI
I.D. No: MHM/16-01

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ABSTRACT

The present investigation entitled "Studies on the effect of plant growth regulators and coconut water on rooting of Bougainvillea (*Bougainvillea spectabilis* L.) stem cuttings'' was conducted at College of Horticulture, Mojerla, Wanaparthy (Dist) in the year 2017-18. The experiment consists of three different concentrations of IBA (1000 ppm, 1500 ppm and 2000 ppm) and NAA (1000 ppm, 1500 ppm and 2000 ppm) treated in combination with two different concentrations of coconut water (100 ml, 50 ml) along with control (alone treated with coconut water) dipped for two hours which were treated for root initiation in stem cutting of Bougainvillea. The experiment was laid out in Factorial Completely Randomized Design with three replications. Semi hardwood cuttings of Bougainvillea were planted in polybags containing one part of red soil, two parts of sand and one part of compost.

Among the treatments of plant growth regulators, IBA 2000 ppm recorded earlier sprouting (6.06), root formation (7.54) number of shoots (4.72), roots (16.91), leaves (47.82), highest leaf area (17.96 cm^2), longest length of the shoot (22.75 cm), root per cutting (33.86). Maximum fresh weight of shoot (27.04 g), root (27.54 g) and maximum dry weight of shoot (12.33 g) root (13.77 g) and survival percentage (93.71).

Concentration of coconut water significantly influenced almost all parameters. The results were observed more favorable with 100 ml coconut water than 50 ml coconut water. With 100 ml coconut water, early sprouting (9.29), early root formation (9.49), longer shoot (15.87cm), root (25.02 cm), more number of shoots (3.84), roots (11.71), leaves (34.03), highest leaf area (12.30 cm^2), increased fresh weight of shoot (18.43 g), root (19.70 g) and dry weight of shoot (8.64 g) and root (9.16 g) and survival percentage (82.52 %) per cutting were recorded.

The interaction between plant growth regulators and coconut water significantly influenced almost all parameters. The results revealed that plant growth regulator IBA and NAA in combination with coconut water had significantly affected root and shoot growth of bougainvillea. IBA 2000 ppm with 100 ml coconut water registered earlier sprouting (5.50), earlier root formation (7.36), more number of shoots (4.81), more number of roots (17.82) and maximum number of leaves (49.70) per cutting. Further, maximum leaf area (18.57 cm^2) longer shoot (23.73 cm), longer root (34.76 cm), fresh weight (28.13 g) and dry weight of the shoot (12.63 g), fresh weight (28.41 g) and dry weight of the root (14.11 g) and maximum survival percentage (94.95%) of rooted cuttings were also recorded under IBA 2000 ppm with 100 ml coconut water.

The data on the economics of plant growth regulator treatment showed that among the treatments NAA 2000 ppm (2.57) and IBA 2000 ppm (2.52) with 100 ml coconut water recorded the highest benefit cost ratio over other treatments.

Chapter - I

INTRODUCTION

Chapter I

INTRODUCTION

Bougainvillea is a spectacular ornamental plant which is appraised for its attractive blossoms, evergreen and variegated showy foliage. It is thorny hardy ornamental vine, bush and tree. It is quick growing evergreen plant in rainfall area or deciduous in dry season. Bougainvillea is originated in South America and was classified by Philibert Commerson, a French botanist in 1768. The name bougainvillea was coined after **Louis Antoine de Bougainville**, a French navigator and military commander who was the first person to identify the plant in Brazil.

Bougainvillea belongs to the Nyctaginaceae (Four 'O' clock) family and consists of 14 species among them three are horticulturally important: *B. spectabilis, B. glabra* and *B. peruviana.* Various crosses among the species have produced new hybrids and important Horticultural cultivars. One natural hybrid species (*B.* x *buttiana*) are horticulturally important. First developed variety of Bougainvillea in India was 'Scarlet Queen Variegata' in 1926 by S. Percy Lancaster (Roy *et al.,* 2015).

Bougainvillea is a thorny and woody climber. The actual bougainvillea flowers are very small and white but, a cluster of three flowers remain surrounded by three to six thin and showy colourful bracts. The colour of these bracts vary from white, pink, yellow and magenta to bright red, purple and orange. These colourful bracts make the bougainvillea flowers more attractive and appealing. As the bracts are very thin just like paper, bougainvillea flowers are also referred as paper flowers.

Bougainvillea performs best in full sun or light shade on well-drained, acid soils. It can tolerate hot, dry locations fairly well but flowers bountifully in full sun with regular watering. Because of their special characteristics, like; high variation in type of foliage, production of many flowering

inflorescence on single plant and continuous blooming with short production cycle made it very useful plant in the ornamental industry (Gordon, 2002). Bougainvillea is recommended for bedding purpose in landscaping and having great demand by soft landscape architects for development of home gardens, factory gardens, municipal gardens, multinational companies, indoor and outdoor landscape and historical monuments.

Besides its ornamental value in landscaping, recently it has been discovered that bougainvillea is a pollution tolerant plant and can help in the mitigation of air pollution. (Kulshreshtha *et al.,* 2009; Sharma *et al.,* 2005). The ability of bougainvillea to grow under high polluted conditions like traffic islands, roadsides and around industries make it an important ornamental plant in present situation. It is grown in tropical and subtropical zones and is enriched with different varieties having attractive shades. It's wide adaptability and multifarious usage has made this plant very popular all over the world (Fatma *et al.,* 2007). In Indian landscapes, due to its drought tolerance makes it ideal for year-round growing in warm conditions. Its high salt tolerance makes it a natural choice for high humid areas and saline soils. It has varied utility in landscapes like shrub, hedge, as a focal point, container plant, bonsai plant, hanging basket plant etc.,

Due to its ornamental importance, bougainvillea is considered to be excellent ornamental for utility and beauty. Because of its economic importance and good aesthetic value and its demand among the landscape architects and horticulturists as a garden plant, insists huge production of bougainvillea plants with ease of propagation at cheaper cost is need of the hour. The low genetic and physiological capacity for root formation, is limiting its commercial production, and making it as a difficult to root species. Hence, exploring the methods to increase the production is highly

imperative owing to its economic importance. Bougainvillea can be propagated by sexual as well as asexual methods of propagation, and it is propagated by stem cuttings, budding and layering. Compared to stem cuttings, air layering is a laborious and expensive method. Bougainvilleas are primarily propagated by stem cuttings are most commonly used for propagation but lack of competence to form adventitious roots by cuttings occurs routinely and is an obstacle for the vegetative propagation (Céline *et al.,* 2006). Adventitious root formation is a key step in vegetative propagation of woody or horticultural species and problems associated with rooting of cuttings frequently result in significant economic losses (De Klerk *et al*., 1999, Mohammed and Hamid, 2014).

The application of synthetic growth regulators to enhance rooting has been widely adopted (Srivastava, 2002). Rooting hormone hastens root initiation, increases number and percentage of cutting rooted (Okunlola and Oyedokun, 2016). Among the plant growth regulators auxins plays very significant role in inducing rooting. Majority of bougainvillea varieties often fail to produce roots and hence results in poor survival (Arvind Kumar 1999). Auxins promote adventitious root development of stem cuttings through their ability to promote the initiation of lateral roots, occasionally auxin treatment stimulates cell division which improved root initiation and increased uniformity of rooting.

Extraction of harmones from plants and their synthetic production has been an outstanding achievement in plant science and these hormones are playing very significant role in propagation of ornamental plants, mainly in initiation of rooting and increasing the number of roots per plant. Hence, exogenous application of auxins is the best-known growth stimulation in induction of rooting. Commercial use of auxins is popularized by synthetic forms like Indole butyric acid (IBA) and Naphthalene Acetic acid (NAA). The

use of IBA and NAA play an important role in stimulation and initiation of roots in bougainvillea (Nathulal *et al.,* 1972 and Maurya *et al.,* 1974).

Exploiting the advantage of use of auxins in induction of rooting in bougainvillea help in production of plants in larger scale by reducing the cost of production with more percentage of success ultimately leading to increased returns. Investigation in identification appropriate auxin (IBA or NAA) and concentration in rooting of bougainvillea stem cuttings is highly essential to produce single plant at lower cost.

Along with auxins, the natural compounds are also identified to stimulate rooting, which can be used alternatively as their prevelance and ease of availability is major advantage (Okunlola A.Ibironke, 2017). Further, it was reported by Ogunwa (2011) that a natural product coconut water influenced root initiation in cuttings of *B. spectabilis* and showed significant effects on the rooting ability. Coconut water serves as a natural reservoir of nutrients to promote tissue growth. The nutritional composition of coconut water is rich in proteins, amino acids sugars, vitamins, minerals and growth hormones essential to promote tissue growth (George and Sherrington 1993). The use of coconut water as a growth-promoting component was traced to more than half a century, when Van Overbeek *et al*. (1942) introduced it as a new component of the nutrient medium for callus cultures.

Coconut water which is easily available and organic in nature can also be effectively used to enhance the rooting of cuttings at cheaper cost. The coconut water and plant growth regulators had their role in giving better results individually. However, synergistic effects of plant growth regulators and coconut water is to be studied in early induction of rooting and increasing survival rate of cuttings.

The research on these aspects was meagre and will certainly benefit the nursery growers in production of quality planting materials at cheaper cost as success rate will be more.

Hence, considering the above facts and the present research work is formulated. to standardize the rooting induction by the combined effect of coconut water and plant growth regulators in bougainvillea cuttings with following objectives.

OBJECTIVES

1. To identify the suitable root inducing plant growth regulator on stem cuttings of bougainvillea.
2. To identify the appropriate concentration of coconut water to induce rooting on stem cuttings of bougainvillea.
3. To study the combined effect of plant growth regulators and coconut water in induction of rooting of stem cuttings of bougainvillea
4. To study the economics of root inducing plant growth regulators and coconut water on single plant production of bougainvillea.

Chapter - II

REVIEW OF LITERATURE

Chapter II

REVIEW OF LITERATURE

Plant growth regulators (PGR's) are used on a wide range of floricultural crops for various purposes. Plant growth regulators (PGRs) are chemicals that are designed to affect plant growth and/or development, they are applied for specific purposes to affect specific plant responses. The use of plant growth regulators is being practiced by the commercial growers of ornamental plants as a part of cultural practice. Adventitious root formation is a key step in vegetative propagation of woody or horticultural species and problems associated with rooting of cuttings frequently result in significant economic losses (De Klerk *et al*., 1999, Mohammed and Hamid, 2014). Among the plant growth regulators auxins plays very significant role in inducing rooting. Majority of bougainvillea varieties often fail to produce roots and hence results in poor survival (Arvind Kumar 1999). These hormones have placed very significant role in propagation of ornamental plants, mainly in initiation of rooting and increasing the number of roots per plant. Exogenous application of auxins is well known practice to induce rooting.

A contemplated research has been done on the effect of plant growth regulators and coconut water in induction of rooting in bougainvillea as well as other crops is reviewed in this chapter.

2.1 Plant Growth Regulators

2.1.1 Effect of Plant growth regulators on rooting of Bougainvillea cuttings

Nathulal *et al.*, (1972) has reported that in Bougainvillea maximum number of roots per cutting was observed with IBA 500 ppm. Similarly Maurya *et al.*, (1974) observed that NAA at 400 ppm is effective in increasing the percentage of rooting and number of roots per cutting in varieties of Mary Palmer. The use of IBA and NAA play an important role in stimulation and initiation of roots in bougainvillea.

Bhattacharjee and Balakrishna (1983) has reported that apical cuttings of 25 cultivars of bougainvillea when treated with IBA or NAA, each at 4000 ppm, the response to treatments differed with cultivars but rooting and survival were significantly greater in all treated cuttings as compared with control.

Awad *et al.* (1988) conducted an experiment using 20 cm long cuttings of bougainvillea of different diameters dipped in 0, 3000 and 6000 ppm IBA. The largest diameter and of highest auxin concentration resulted in the highest rooting percentage and number of roots per cutting but numbers of sprouted buds per cutting were not significantly affected.

In another experiment, Czekalski (1989) reported that growth regulators increased rooting in cuttings of *Bougainvillea glabra* Choisy when taken in September or in March.

Joshi *et al.* (1989) concluded that hard wood cuttings of five cultivars of bougainvillea treated with IBA, NAA and IAA each at 4000 and 6000 ppm, the average percentage of rooted cuttings was highest (70.89) with 4000 ppm IAA followed by 6000 ppm IBA (52.89).

Buraskar *et al.* (1990) observed that bougainvillea cv. Mary Palmer and Mahara, treated by soaking in 2500 ppm, IBA and 2500 ppm, frulic acid for 10 minutes. This treatment resulted in highest percentage (100 %) in Mahara cuttings, percentage survival in the both Mahara (73.33 %) and Mary Palmer (37.78 %) cuttings, final shoot length in Mahara (20.32 cm) and Mary Palmer (8.14 cm) cutting and number of roots per cuttings (13.11) in Mary Palmer.

Gupta and Kher (1991) reported that the best rooting (highest number and longest root length) was obtained with IBA at 4000 ppm applied as quick dip on cuttings of bougainvillea cv. "Garment Glory" as compared with 2000, 4000, 6000 ppm of IBA, IAA or NAA.

Harris and Singh (1991) conducted an experiment on the semi hardwood cuttings of bougainvillea cultivars Akola, Shubra, Refulgence, Formosa and Magnifica treated with IBA and NAA at 100, 200 and 400 ppm for 12 hrs in rainy and spring season, the highest mean percentage rooting across cultivars and number of roots per cuttings (34 and 60 % in rainy and spring season, respectively) were obtained with 100 ppm IBA, followed by 100 ppm NAA in both the seasons.

Panwar *et al.* (1994) carried out research with IBA, NAA and IAA on semi hardwood cuttings of bougainvillea cv. "Alok' dipped for two minutes in different concentration (250, 500, 1000 or 2000 ppm) and found that 2000 ppm IBA significantly increased more sprouting of cutting, more roots, longer root length and higher percentage of rooting. Similarly, Panwar *et al*. (1994) observed the best rooting in hard wood cuttings of bougainvillea treated with IBA 2000 ppm.

Gupta *et al.* (2002) reported that treatment of bougainvillea cuttings with 1000 ppm IBA gave maximum rooting (100 %) with higher number of roots in soaking method but its availability and cost of procuring by the

peasant gardeners made it of utmost importance to study and look for local and accessible alternatives which brought about the usage of coconut water and tetracycline.

Chovatia *et al.* (1995) had found that cuttings of cultivar "Mary Palmer dipped in IAA (1500 or 2000 ppm), NAA and IBA (each at 3000 or 4000 ppm) for 15 seconds gave the highest percentage of root initiation (88.55 %), longest roots (51.47 cm), shoots (36.78 cm) and highest number of roots per cutting (96.80) with 4000 ppm IBA concentration.

Sohair and Taleb (1995) observed in *Bougainvillea alba* stem cuttings that the highest percentage of roots and survival of cuttings were resulted when dipped for 24 hr in 500 ppm IBA + 10 ppm Co and planted in 2:1 mixture of Nile silt and sand.

Mishra and Sharma (1995) had reported that in difficult to root varieties of bougainvillea *i.e.* Dr. R.R. Pal and Mrs. H.C. Buck, highest concentration of 2000 ppm IBA significantly increased the rooting performance of stem cuttings.

Mukhopadhaya and Bose (1996) revealed that bougainvillea cv. Mary Palmer cuttings treated with NAA 400 ppm produced 12.5 per cent rooting, whereas, the cutting treated with NAA 100 ppm and control failed to exhibit rooting.

Adiga *et al.* (2004) experimented with bougainvillea hardwood cuttings treated with NAA 1000 ppm recorded the highest (85.42 %) mean per cent rooting in Vernonia, whereas, NAA 1000 ppm resulted in the highest average number of roots in Hibiscus. Whereas, in *Jasminum multiflorum*, the cutting treated with IBA 500 ppm resulted in the highest rooting (94.43 %).

Singh and Singh (2011) studied the influence of different concentration of IBA on rooting potential of *Bougainvillea glabra* var. Torch Glory during winter season and found that, the maximum (100 %) rooting and sprouting of cuttings were recorded in IBA 2000, 2500 and 3000 ppm

whereas, IBA 3000 ppm resulted in the maximum length of sprout per cutting (18.87 cm) and number of roots per cutting (21.22) in the month of February. The length of root per cutting was maximum (15.32 cm) with IBA 5000 ppm in February sampling.

Asl *et al.* (2012) investigated the effect of IBA treatment for seven seconds on the rooting ability of semi-hardwood cuttings of bougainvillea, and found that IBA 2000 ppm resulted in the highest number of roots (8.67 roots per plant) and the root length (151.42 mm).

Singh (2012) studied the effect of different concentrations of IBA on hardwood cuttings of different varieties of bougainvillea *i.e*. Louise Wathen, Thimma, Mrs. Butt and Shubra and observed that IBA concentration and variety had significant effect on sprouting, rooting, callusing and establishment of cuttings. Lousie Wathen cuttings treated with 1000 ppm IBA showed superior in respect to more sprouting (85.39 %), rooting (75.46 %) and callusing (80.78 %) and establishment (100 %).

Seyedi *et al.* (2013) investigated the effect of stem type and different levels of IBA on the rooting of *Bougainvillea glabra* and reported that cuttings treated with IBA 4000 mg/l showed the highest rooting compared to other treatments. The number and length of the roots and fresh weight of the roots were affected at a higher level of auxin treatment, semi-hardwood cuttings were found to be best for rooting of *Bougainvillea glabra*.

Memon *et al.* (2013) observed in bougainvillea that sprouting and rooting of stem cuttings were significantly influenced by various concentrations of NAA, whereas, varieties had non- significant influence on these characters with the exception of number of sprouts per cutting, sprouting and rooting percentage. The treatment of cuttings with NAA 6000 ppm resulted in the maximum sprouts per cutting (3.133), sprouting percentage (78.33), length of sprouts (0.680 cm), rooting percentage (75.00),

length of roots (13.862 cm), roots per cutting (27.833 cm) , leaves per cutting (28.02) and length of leaves (6.007 cm).

Sahariya *et al.* (2013) experimented the effect of IBA (0, 1000, 1500, 2000 ppm), on rooting of Bougainvillea var. Thimma cuttings in open field and poly house conditions. In poly house conditions, IBA showed to be more advantageous than open field conditions, however, increase in concentration of IBA from 1500 to 2000 ppm showed a significant effect in both the conditions but effects were more pronounced under poly house conditions. The treatment with IBA 2000 ppm resulted in the maximum number of rooted cuttings (6.33), percentage of rooting (63.33%), length of shoots per cutting after one month (3.07 cm), length of shoots per cutting after two month (14.73 cm), number of roots per cutting (30.00), length of roots (12.85 cm) and dry weight of roots (0.43 g).

Shabha and Alshammary (2013) reported that bougainvillea cv. Shubra that treated with IBA 500 ppm resulted in the highest rooting percentage (55.6 % after 12 hours and 59.4 % after 24hours of treatment), more number of roots per cutting (20.5 and 19.8 at 12 and 24 hours) and the highest establishment percentage (68.3 and 53.3 % after 12 and 24 hours, respectively). The effect of time of soaking (12 or 24 h) was not consistent and was different among individual treatments.

Zuairia Sulthana *et al.* (2006) studied rooting performance of three ornamentals stem cuttings of nerium, bougainvillea and jasminum which are influenced by growth regulators. Different concentration of growth regulators IBA, NAA had significant effects on the rooting performance of the ornamental plants. The longest root (23.53 cm) was produced at 400 ppm IBA in bougainvillea while nerium produced the shortest one (6.53 cm). Further, bougainvillea showed maximum percentage of success (95.60)

when treated with IBA 400 ppm and nerium showed minimum percentage of success (44.33).

2.1.2 Effect of Plant growth regulators on rooting of other crops

Shirol *et al*. (1992) reported that *Euphorbia pulcherimma* wild var. Alba Hort., gave highest per cent rooting (50.77 %) and length of longest primary root per cutting (8.33 cm) when treated with 3000 ppm IBA+NAA and planted immediately after treatment.

El-Shazly and El-Sabrout (1994) reported in Le conte pear that the best rooting percentage (32.75 %), number of roots per cutting (2.03) number of leaves per cutting (19.13) and average shoot length (17.63 cm) were observed in treatment with IBA 4000 ppm.

Gupta (1995) studied the effect of intermittent mist and auxins on rooting in semi hardwood cuttings of *Buddlea asiatica* and concluded that IBA at 4000 ppm proved significantly effective in per cent rooting, root length and survival of rooted cuttings.

Khan *et al.* (2005) experimented on Damask rose cuttings that average number of roots and rooting percentage gradually increased with the increase in the hormone concentration. The highest number of roots (15.72) and rooting percentage (94.17 %) were recorded in the cuttings treated with NAA (50 mg/l), while the maximum length of roots (7.30 cm) was in control.

Thorat *et al.* (2006) observed in nerium that the cuttings treated with IBA 100 ppm for 24 h resulted in highest sprouting, rooting and survival percentage of plants. On similar lines, Karimi (2011) conducted an experiment on Indole butyric acid (IBA) and reported that, rootstock type and IBA treatment influenced bud take and root formation. The highest bud-take percentage was obtained with ‘Gorj-e-Dadshi’ in combination with IBA 500 mg/l.

In contrast, Adekola and Akpan (2012) reported in *Jatropha curcas* that the stem cuttings treated with growth hormone had non-significant effect on survival and sprouting and the untreated cuttings (control) performed better than the hormone treated cuttings. However, in terms of rooting behaviors, significant effects treatment differences were observed and the cuttings treated with IBA were found to root better than those of NAA, however, the control resulted in the best performance.

Kako (2012) studied the effect of cutting diameter and IBA doses on hardwood cuttings of black Mulberry and concluded that, applications of IBA at 4000 ppm and kinetin gave significant effects on percentage of successful budding scion (%).

Rahbin *et al.* (2012) investigated the effect of location of shoot for taking stem cuttings and IBA on rooting in 'Night Jasmine' under mist greenhouse and treated with IBA 2000 and 4000 ppm for five seconds and planted in the pots containing sand and peat moss. The treatment with IBA (2000 and 4000 ppm) was found significantly better than all the other treatments.

Surekha *et al.*, (2012) experimented the response of IBA and rooting media on rooting of cutting in chrysanthemum cv.Piwali Rewadi and concluded that application of IBA 1000 ppm showed better and higher results in terms of days to rooting , fresh weight of roots , dry weight of roots, days to sprouting, fresh weight of shoots and dry weight of shoots. Similarly, Azar Seyedi *et al.* (2013) studied stem cuttings of *Bougainvillea glabra* with different levels of IBA and reported that treatment of semi hardwood cutting with IBA 4000 ppm showed better results in terms of rooting.

Abu-Zahra *et al.*, (2013) reported in rosemary, hedera, syngonium and gardenia that the cuttings treated with NAA 3000 ppm resulted in the highest per cent rooting in rosemary and hedera, whereas, NAA 1000 ppm

and 4000 ppm resulted in the best rooting in syngonium and gardenia respectively.

Alshammary *et al*. (2013) studied in *Bougainvillea peruviana* cv. Shubra and *Hamelia patens* and reported the highest bud break percentage (59.2 %), rooting percentage (28.4 %), number of roots per cutting (24.8), root length per cutting (27.2 mm), establishment percentage (42.3 %) and number of branches per cutting (5.4) was recorded with IBA 2000 ppm However, the response of hardwood cuttings to treatments was not consistent.

Kumari *et al*. (2013) reported in *Jatropha curcas* that IBA 200 ppm treatment resulted in early emergence of shoots (25.92 days), maximum number of shoots per cutting (5.58), shoot length (10.57 cm), sprouting (81.10 %) and rooting percentage (49.83 %).

Susila and Reddy (2013) experimented in *Adathoda vasica* and revealed that IBA 1500 ppm resulted in the maximum rooting percentage (67.50 %) and longest root length (22.18 cm), whereas, the treatment with NAA 1500 ppm recorded maximum roots per cutting (40.89), root fresh (3.22 g) and dry weight (1.12 g).

Ullah *et al*. (2013) conducted an experiment for optimization of auxins such as IBA and NAA on regeneration of marigold and concluded that, IBA 400 ppm has maximum effect on roots per plant (84.4), whereas root size increased at (6.50 cm) 100 ppm IBA concentration, while increasing the IBA concentration decreased root size.

Rahdari *et al*. (2014) reported in *Cordyline terminalis* that the highest fresh and dry weight of roots, root length and the number of branches were recorded in treatment NAA at 2000 ppm and IBA 1000 ppm.

Renuka and Sekhar (2014) studied the effect of IBA and NAA at different concentrations on the rooting of carnation (*Dianthus caryophyllus* L.) cuttings of cv. Dona. The treatment with IBA 200 ppm recorded less number of days for formation of root initials, highest percentage of rooting, maximum number of roots, cumulative length of roots per cutting and highest percentage of establishment of cuttings than the treatment IBA 100 ppm and NAA 50 ppm. IBA treatment recorded superior rooting parameters over NAA treatment and with increase in the concentration of IBA and NAA showed increase in the rooting.

Similarly, Singh *et al*. (2014) investigated the effect of IBA and NAA on rooting of stem cuttings of *Morus alba* and reported that, IBA 2000 ppm solutions by quick dip method recorded highest sprouted cuttings, length of roots per cutting, percentage of rooted cuttings.

Wazir (2014) studied the effect of NAA and IBA on rooting of three types of camellia cuttings with NAA 250, IBA 500 and 1000 ppm dipped for 5 minutes before planting. Among all, IBA 1000 ppm was found most effective whereas, types of cutting had no effect on the parameters recorded.

Akhtar *et al*. (2015) reported in *Rosa centifolia* cuttings that rooting percentage was increased by applying plant growth regulator. IBA 450 ppm concentration produced maximum shoot length (10.67 cm), shoot dry weight (3.02 g), number of roots (14.00), root length (11.90 cm) and root dry weight (0.50 g). It was concluded that, lower concentrations of plant growth regulators produced better results as compared to higher concentrations.

2.2 Coconut water

2.2.1 Effect of Coconut water on rooting of bougainvillea

Ogunwa (2011) studied the stimulation of rooting in *Bougainvillea spectabilis* and *Bougainvillea glabra* using coconut water and revealed that dipping duration had significant ($P<0.05$) effects on the rooting ability of *Bougainvillea spectabilis* with cuttings dipped for one hour in coconut water. Therefore, root initiation in cuttings of *B. spectabilis* could be enhanced when dipped in coconut water for one hour.

Okunlola A.Ibironke (2016) studied propagation of bougainvillea by rooting hormones and revealed that cuttings treated with coconut significantly increased shoot length, shoot girth, number of leaves, wet root weight, dry root weight and root length. The results showed that the Indole -3-butric acid and the coconut water had significant effect on the root emergence and root growth of bougainvillea species compare to the other hormone.

2.2.2 Effect of coconut water on rooting of other crops.

Asma *et al*. (2008) conducted an experiment on *in vitro* propagation of kiwi fruit (*Actinidia deliciosa*) using coconut water and observed that the root induction was highly effected by the addition of coconut water to the culture media and resulted in maximum shoot length, hence facilitating the efficient root formation.

Abdullahil Baque *et al*. (2011) reported on effect of light, sucrose and coconut water on micropropagation of Calanthe hybrids (‘Bukduseong’ x ‘Hyesung’ and ‘Chunkwang’ x ‘Hyesung’) as a source of natural product and concluded that 50 ml per litre coconut water effectively enhanced plantlets growth.

Rafaeli *et al.* (2013) studied the effect of coconut water on growth of olive embryos cultured *in vitro* and observed that isolated embryos of the olive seeds were immersed on culture medium of fresh and sterile coconut water and kept for 45 days under controlled environment out of which 100 ml/l gave the best result in increasing percentage of germination, shoot length, number of roots, number of leaves and number of internodes.

Richard (2015) studied coconut water as root setting medium for *Rhizospora stylosa* hypocotyl propagation, the length of the roots was measured after six weeks and concluded that coconut water was comparable to commercial rooting hormone and can be utilized as rooting medium.

Usman and Akinyele (2015) experimented on growth media and hormones on the sprouting and rooting ability of *Massularia acuminata* and results showed that growth media and hormonal concentration significantly affected percentage sprouting, shoot length, callusing, number of leaves, rooting, number of roots and length of root per cutting. The highest number of roots (3.18) and root length (3.66 cm) was recorded with NAA 1500 ppm and has the highest shoot length (1.63 cm) with IBA 1000 ppm.

Brintha Karunarathna and Kumuthini (2016) studied the effect of coconut water on the cutting establishment of ixora (*Ixora coccinea)* and observed that 100 ml of coconut water poured once in five days resulted in increased length of roots (52%), the number of roots (63 %) and root initials.

Jualang Azlan Gansau *et al.* (2016) carried out an experiment on the effect of organic additives and plant growth regulators on protocorm development of *Dendrobium lowi* and observed that addition of 2 g/l peptone or 15% (v/v) coconut water had significantly induced 16.7 per cent protocorms proliferation.

Chapter - III

MATERIAL AND METHODS

Chapter III

MATERIAL AND METHODS

The present investigation on **"Studies on the effect of plant growth regulators and coconut water on rooting of Bougainvillea (*Bougainvillea spectabilis.* L) stem cuttings''** was carried out at College of Horticulture, Mojerla, during the year 2017-18.

The materials used, techniques adopted, methodology and statistical analysis for conducting the experiment and observations recorded during the course of investigation are described in this chapter.

3.1 GEOGRAPHICAL AND WEATHER CONDITIONS OF THE EXPERIMENTAL SITE:

The experiment was laid out in shade net house (Plate 1) and the site is situated at an altitude of 346 m above mean sea level on 78.02° East longitude and 16.42° North latitude. The climate of Mojerla is semi arid. the data on weather parameters during the period of investigation were recorded at the Meteorological Research Station located at Krishi Vignan Kendra, Madanapuram, Kothakota Mandal (Appendix I).

3.2.1 PREPARATION OF MEDIA

The media was prepared in the ratio of 1:2:1 of red soil, sand and vermicompost. The sand was taken as a major part has low water retention but excellent aeration. The media was prepared by mixing the equal parts *i.e.*, one part of red soil and vermicompost and two parts of sand and the media was filled in nine inches polybags.

3.3 DESCRIPTION OF *Bougainvillea spectabilis* L.

Great Bougainvillea (*Bougainvillea spectabilis*. L) is a spectacular species of Bougainvillea. It is a woody perennial vine, with stout spines. Leaves are

Plate 1 : Overview of the experimental field

alternate, simple, ovate to somewhat elliptic, up to 10 cm long. Flowers arise in leaf axils, in clusters of threes, each flower with a purple, red, pink, or orange bract beneath, up to 3-4 cm long. Sepal cup is tubular with 5 sepals, up to 2 cm long, tube the same color as the bracts, with white sepals, 3 mm long. Real petals are absent. Fruit is an achene, elongate, 5-ribbed.

3.2.2 PREPARATION OF CUTTINGS

Semi hard wood cuttings with thickness of 7.5 mm and 15 cm long of bougainvillea were taken, the length is measured by scale and thickness is by Vernier callipers. (Plate 2 a & b).

3.2.3 PLANT GROWTH REGULATORS (PGR'S) AND ORGANIC SUBSTITUTE USED IN EXPERIMENTATION

All PGR's were procured from Pavani Hybrid Seeds Basheerbagh, Hyderabad and coconut water was from the local market.

Table: 3.1 Plant Growth Regulators and Organic Substitute used in Experimentation

S.no.	Growth regulator (Auxins) / Organic substitute	Molecular Formula	Molecular Weight (g/mol)	Nature of the solubility
1.	Indole-3-butyric acid (IBA)	$C_{12}H_{13}NO_2$	203.24	Alcohol (Polar solvents)
2.	1-Naphthelene acetic acid (NAA)	$C_{12}H_{10}O_2$	186.21	Alcohol (Polar solvents)
3.	Coconut water	___	___	Water

Plate 2 : Preparation of the cuttings for imposing treatment

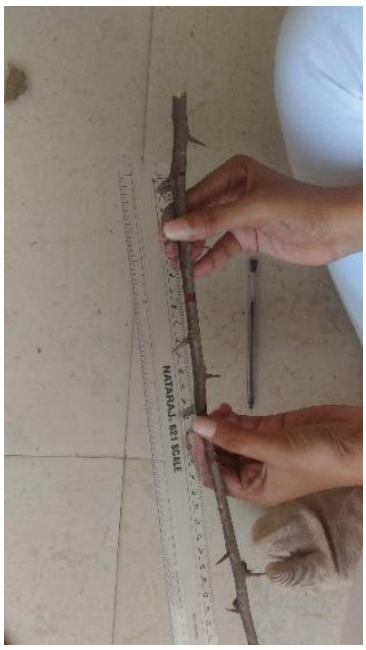


Plate 2 (a): Measuring the diameter of the cuttings

Plate 2 (b): Measuring the length of the cuttings

Plate 3: Dipping the cuttings in treatment solutions

3.2.4 PREPARATION OF TREATMENT SOLUTIONS

To prepare one ppm solution - one milligram of plant growth regulators was dissolved in 1000 ml of distilled water.

3.2.5 PREPARATION OF PLANT GROWTH REGULATORS WITH COCONUT WATER

Plant growth regulators of 1000 ppm, 1500 ppm and 2000 ppm of IBA and NAA were prepared by dissolving calculated quantity of chemical in small quantity of ethyl alcohol and volume was made up to one litre. Further, coconut treatment was prepared by dissolving 50 ml and 100 ml of coconut water in 100 ml of water.

3.2.6 TREATMENT OF CUTTINGS

Different concentrations of NAA, IBA their combination with coconut water were used for dip (2 hours) treatment by dipping basal end of cuttings in jars containing 100 ml growth regulator solution (Plate 3).

3.2.7 EXPERIMENTAL DETAILS

The experiment was laid out in FCRD (Factorial Completely Randomized Design) with fourteen treatment combinations replicated thrice.

Name of the Crop	: Bougainvillea
Botanical name	: *Bougainvillea spectabilis*
No. of treatments	: 14
No. of cuttings per treatments	: 10
No. of replications	: 03
Location	: PG Research Block, COH-Mojerla,

Experimental design : Factorial Completely Randomized Design

Date of planting : November 2017

Method of planting : Polybag

Treatment details

Treatments: 14

Factor 1

G_1- IBA - 1000 ppm

G_2- IBA - 1500 ppm

G_3- IBA - 2000 ppm

G_4- NAA -1000 ppm

G_5- NAA -1500 ppm

G_6- NAA -2000 ppm

G_7- Control (Coconut water alone)

Factor 2

C_1 – Fresh coconut water – 50 ml in 100ml of distilled water

C_2 – Fresh coconut water –100 ml in 100 ml of distilled water

Treatment combinations:

T_1 – IBA 1000 ppm in combination with Coconut Water 50 ml **(**$G_1 + C_1$)

T_2 – IBA 1500 ppm in combination with Coconut Water 50 ml ($G_2 + C_1$)

T_3 - IBA 2000 ppm in combination with Coconut Water 50 ml **(**$G_3 + C_1$**)**

T_4 - NAA 1000 ppm in combination with Coconut Water 50 ml **(**$G_4 + C_1$)

T_5 - NAA 1500 ppm in combination with Coconut Water 50 ml **(**$G_5 + C_1$)

T_6 - NAA 2000 ppm in combination with Coconut Water 50 ml **(**$G_6 + C_1$)

T_7 – Control with only Coconut Water 50 ml ($G_7 + C_1$)

T_8 - IBA 1000 ppm in combination with Coconut Water 100 ml **(**$G_1 + C_2$)

T_9 - IBA 1500 ppm in combination with Coconut Water 100 ml **(**$G_2 + C_2$)

T_{10} - IBA 2000 ppm in combination with Coconut Water 100 ml **(**$G_3 + C_2$)

T_{11} – NAA 1000 ppm in combination with Coconut Water 100 ml **(**$G_4 + C_2$)

T_{12} - NAA 1500 ppm in combination with Coconut Water 100 ml **(**$G_5 + C_2$)

T_{13} - NAA 2000 ppm in combination with Coconut Water 100 ml **(**$G_6 + C_2$)

T_{14} - Control with only Coconut Water 100 ml **(**$G_7 + C_2$)

3.2.8 METHODOLOGY

Treatments were evaluated in a factorial completely randomized design (FCRD) with three replications, each replication consisted of ten cuttings. Semi-hardwood bougainvillea cuttings used in this study were taken in November from shoots originating from branches without flowers. (Hartman *et al.*2002).

Red soil + sand + vermicompost in the ratio of 1:2:1 was used as a rooting media. Auxins are widely used for promoting rooting of hardwood cuttings (Hartman *et al.* 2002), IBA and NAA along with coconut water were used as a rooting hormones. The formulations of auxins were prepared by dissolving the pure compound in 95% ethanol and adding distilled water. And then 50 ml and 100 ml of coconut water was added to the respective solutions so as to study the individual effect of coconut water at both concentrations, control treatment was maintained without combination of auxins. Cutting of 4-5 buds were prepared after discarding the non-hardened upper parts. In order to reduce the transpiration, the leaf area was reduced to 50-80 per cent. The basal end of cuttings was dipped briefly in a fungicide solution 0.1% of Captan prior to imposing rooting hormone treatments.

3.3 DETAILS OF OBSERVATIONS RECORDED

Five randomly chosen cuttings in each replication of all treatments were labelled and used for recording the observations. The mean of these five cuttings were used for statistical analysis. The parameters studied and techniques adopted to record the observations are given below:

3.3.1 Number of days taken to sprouting

Number of days taken from the day of planting to the appearance of the first bud on any of the cuttings in each treatment was recorded and expressed in number of days.

3.3.2 Number of days taken to root formation

Number of days taken from the day of planting to the formation of root in any of the cuttings in each treatment was recorded and expressed in number of days.

3.3.3 Number of shoots per cutting

The number of shoots that have emerged from the cutting was counted on five selected plants.

3.3.4 Number of roots per cutting

The cuttings were uprooted carefully to avoid any damage to root system. The roots of each cutting were thoroughly washed to remove sand in running tap water and number of roots on each cutting was recorded.

3.3.5 Length of the shoot per cutting (cm)

Shoot length (cm) of all the cuttings was measured by using a measuring scale from base level to the growing tip.

3.3.6 Length of the root per cutting (cm)

The cuttings were uprooted carefully to avoid any damage to root system. The roots of each cutting were thoroughly washed to remove sand in running tap water and length of the root was measured with a centimeter scale.

3.3.7 Number of leaves per cutting

Number of leaves per cutting was counted on five selected plants and the mean was calculated.

3.3.8 Leaf area (cm^2)

The well-developed leaf of five selected cuttings of each treatment were taken and leaf area was measured by the portable leaf area meter (Model Bio-Science CI -110) and average leaf area per plant was calculated.

3.3.9 Survival percentage of the cuttings (per cent success)

Per cent survival of cuttings was recorded in each treatment after four months by counting the total number of surviving plants out of number of treated cuttings.

3.3.10 Fresh weight of shoot per cutting (g)

Total number of shoots from the selected cuttings were taken for weighing and fresh weight was recorded by electronic balance.

3.3.11 Fresh weight of the root per cutting (g)

The cuttings uprooted to record number of roots per cutting were used to note this parameter. Roots were detached from the cuttings and fresh weight was taken with the help of electronic balance.

3.3.12 Dry weight of the shoot per cutting (g)

After recording the fresh weight of shoot and root the separated material was kept for drying. Then shoots were kept in perforated paper bags which were kept in oven and dried till constant weight was obtained.

3.3.13 Dry weight of root per cutting (g)

Roots detached from the cuttings for which fresh weight was taken were kept in paper bags and later in oven and dried till constant weight is obtained. Oven dried samples were weighed on electronic balance.

3.4 ECONOMICS OF CUTTINGS PRODUCTION

3.4.1 Cost of producing single cutting

The cost of inputs used in the experiment were calculated, and selling price of single cutting was recorded for each individual treatment and expressed in rupees.

3.4.2 Survival rooting percentage

Per cent rooting of cuttings in each individual treatment was recorded and expressed in percentage.

3.4.3 Price of each cutting

The selling price of single cutting was taken based on the commercial nursery price in rupees.

3.4.4 Gross Income for 100 cuttings

The gross income for 100 cuttings was obtained by multiplying survival percentage and price of each cutting and expressed in rupees.

3.4.5 Expenditure for producing 100 cuttings

The expenditure for producing 100 cuttings was obtained by multiplying cost of producing single cutting into 100 and expressed in rupees.

3.4.6 Net income for 100 cuttings

Net income was calculated by subtracting expenditure for producing 100 cuttings from gross income and expressed in rupees.

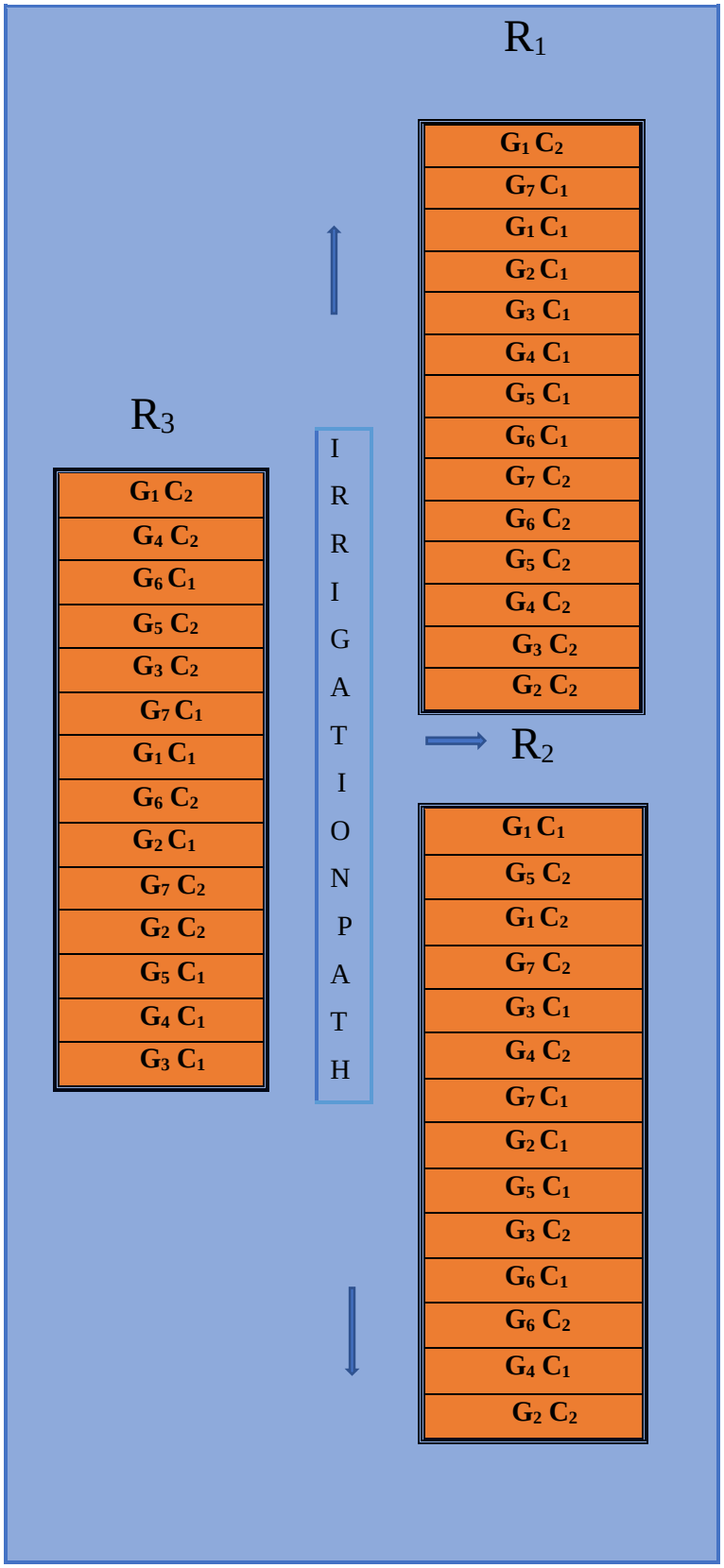
3.4.7 Benefit : Cost ratio

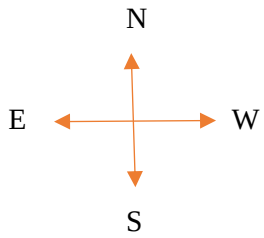
Benefit : Cost ratio was worked out by using formula

$$\text{Benefit : Cost ratio} = \frac{\text{Net income for 100 cuttings}}{\text{Expenditure for producing 100 cuttings}}$$

3.7 Statistical analysis

The data on sprouting, rooting and shooting of bougainvillea recorded during the course of investigation and subjected to statistical analysis as per the method given by Panse and Sukhatme (1967), using the mean values of random plants in each replication from all the treatments, the appropriate standard error of mean SE (m±) and critical difference (CD) were calculated at five per cent significance level.





Factor A:

Plant growth regulators at 7 levels

G_1 - IBA - 1000 ppm

G_2 - IBA - 1500 ppm

G_3 - IBA - 2000 ppm

G_4 -NAA -1000 ppm

G_5 -NAA -1500 ppm

G_6 - NAA -2000 ppm

G_7 - Control

Factor B:

Coconut water at 2 levels

C_1 - Coconut water 50 ml

C_2 - Coconut water 100 ml

Fig 1: Field lay out plan

Chapter - IV

RESULTS AND DISCUSSION

Chapter IV

RESULTS AND DISCUSSION

The results of investigation pertaining to the "Studies on the effect of plant growth regulators and coconut water on rooting of Bougainvillea (*Bougainvillea spectabilis* L.) stem cuttings" are discussed and interpreted in this present chapter. The results obtained with respect to different parameters are as follows:

4.1 Number of days to sprouting

The semi hardwood cuttings responded to growth regulators treated in combination with coconut water to induce sprouting. It was observed that treatment of cuttings showed significant difference in sprouting (Table 4.1.1 and Fig.1).

The results of present study revealed that IBA 2000 ppm induced early sprouting of cutting (6.06) compared to all other treatments significantly which was followed by NAA 2000 ppm (7.59) and IBA 1500 ppm (8.64). Remaining all other treatments recorded intermediate results. However, the maximum number of days (12.45) for sprouting of cuttings was taken by the control.

Between the treatments of coconut water, the number of days to sprouting was found significantly different. Coconut water at 100 ml (9.29) induced early sprouting than 50 ml (9.81).

The interaction effect of plant growth regulators and coconut water was also found significant. Among the combination of treatments, IBA 2000 ppm and coconut water 100 ml (5.50) recorded significantly less number of days to sprouting, which was followed by IBA 2000 ppm with 50 ml coconut water (6.63). Whereas, IBA 2000 ppm with 50 ml coconut water was on par with NAA 2000 ppm and 100 ml coconut water (7.42). However, coconut

Table 4.1.1 Effect of plant growth regulators and coconut water on number of days taken to sprouting in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C_1)	Coconut water 100 ml (C_2)	Mean
G_1 IBA 1000 ppm	10.87	10.42	10.65
G_2 IBA 1500 ppm	8.87	8.41	8.64
G_3 IBA 2000 ppm	6.63	5.50	6.06
G_4 NAA 1000 ppm	12.31	11.43	11.87
G_5 NAA 1500 ppm	9.71	9.51	9.61
G_6 NAA 2000 ppm	7.76	7.42	7.59
G_7 Control (Coconut water)	12.54	12.36	12.45
Mean	9.81	9.29	
	SEm±	**CD at 5 %**	
G	0.24	0.71	
C	0.13	0.38	
G X C	0.34	0.98	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

Fig.2 Effect of plant growth regulators and coconut water on number of days taken to sprouting of bougainvillea cuttings

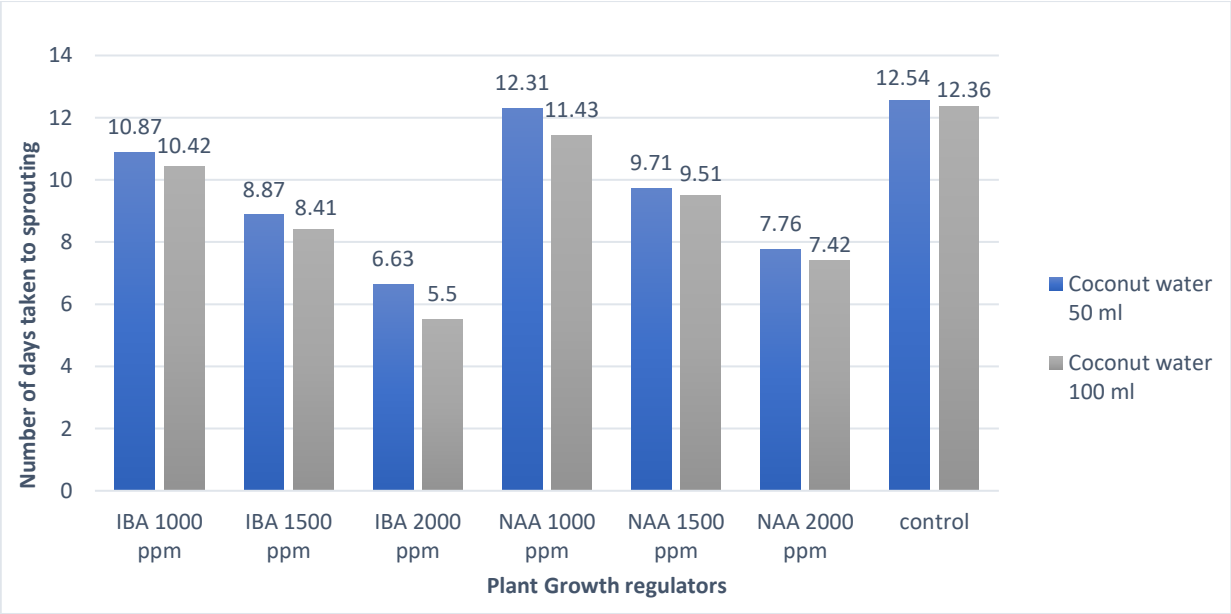


Plate 4: Sprouting observed in the cutting treated with IBA 2000 ppm + coconut water 100 ml.

water 50 ml treatment recorded maximum (12.54) number of days to sprouting followed by coconut water 100 ml (12.36). (Plate 4)

The number of days taken to sprouting was observed early with IBA and coconut water treated cuttings and it may be due to auxin and its appropriate concentration which enhanced the formation of callus tissue and differentiation of vascular tissue (Mitra and Bose, 1954). Coconut water also has synergistic effect as it also able to encourage callus induction and serves as a buffer or a buffer solution (Waeniwati, 2012). Further, the earliness in sprouting may be due to utilization of stored carbohydrates, nitrogen and other factors present in cutting with aid of growth regulators and coconut water. (Chandramouli, 2001)

These findings were agreement with Kumari *et al.* (2013) in *Jatropha curcas,* Dhua *et al.* (1983) in guava cuttings and Ogunwa (2011) in cuttings of *Bougainvillea spectabilis.*

4.2 Number of days to root formation

The data pertaining to number of days to root formation as influenced by the plant growth regulators and coconut water on Bougainvillea cuttings is presented in Table 4.1.2 and Fig. 2.

It clearly indicates that, the plant growth regulators differed significantly for root formation in bougainvillea cuttings, the treatment IBA 2000 ppm recorded minimum (7.54) number of days to root formation and significantly followed by NAA 2000 ppm (8.30) and IBA 1500 ppm (9.21). Significantly maximum number of days (12.11) was registered in control to induce root formation. Remaining all other treatments showed intermediate results.

Table 4.1.2 Effect of plant growth regulators and coconut water on number of days of taken to root formation in Bougainvillea cuttings.

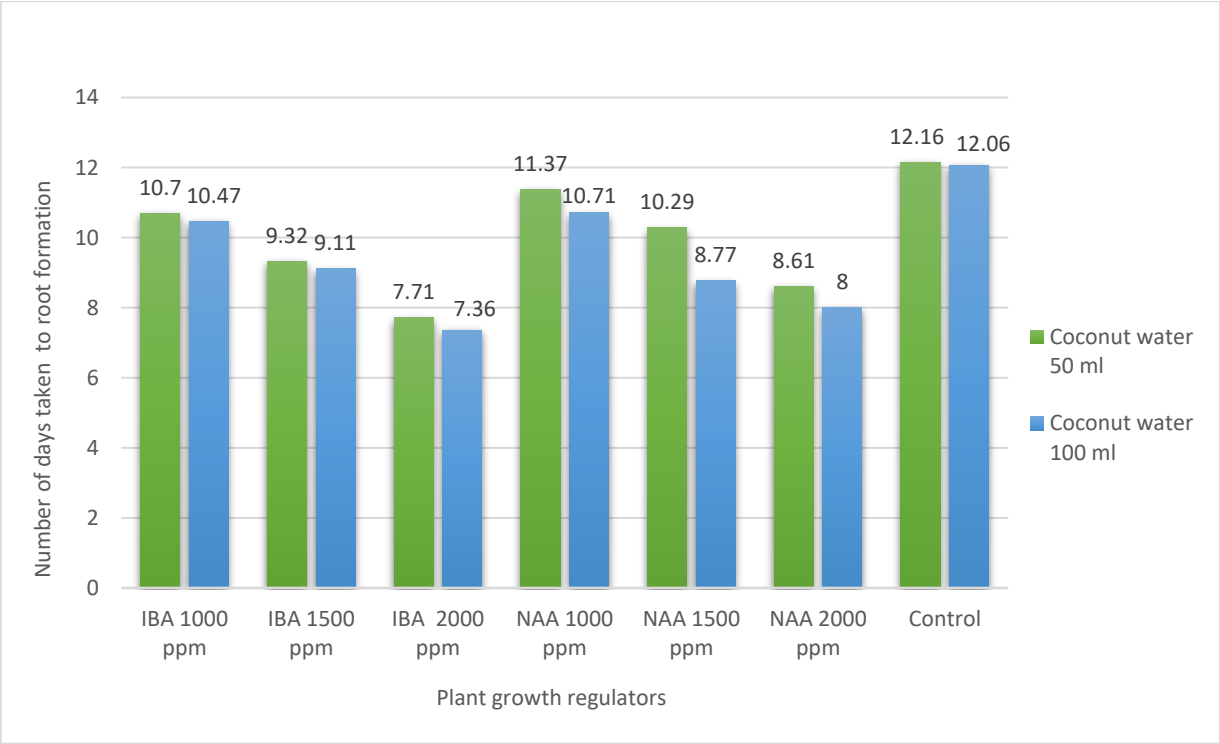
Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	10.70	10.47	10.58
G_2 IBA 1500 ppm	9.32	9.11	9.21
G_3 IBA 2000 ppm	7.71	7.36	7.54
G_4 NAA 1000 ppm	11.37	10.71	11.04
G_5 NAA 1500 ppm	10.29	8.77	9.53
G_6 NAA 2000 ppm	8.61	8.00	8.30
G_7 Control (Coconut water)	12.16	12.06	12.11
Mean	10.02	9.49	
	SEm ±	**CD at 5 %**	
G	0.17	0.50	
C	0.09	0.26	
G X C	0.20	0.70	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

Fig. 3 Effect of plant growth regulators and coconut water on number of days taken to root formation of bougainvillea cuttings



The two concentrations of coconut water also differed significantly in inducing root formation. Early root formation (9.49) was recorded in coconut water 100 ml compared to 50 ml (10.02).

The interaction effect of plant growth regulators and coconut water was also found significant. Among all the combinational treatments IBA 2000 ppm with coconut water 100 ml induced early root formation (7.36) compared to all others, which was on par with IBA 2000 ppm with coconut water 50 ml (7.71) and NAA 2000 ppm with coconut water 100 ml (8.00). The root formation was very late (12.16) days in coconut water 50 ml which was on par with coconut water 100 ml (12.06) alone treatment.

The number days to root formation was observed earlier in cuttings treated with IBA and coconut water and it may be due to IBA stimulates initiation of cambial activity, root initials and triggers early root primordia formation. Further, early rooting in IBA treated cutting may be it is more persistant and do not translocate from the place of application might helped in early rooting.

Coconut water also influence synergistically on root formation as it contains auxins and gibberellins together stimulate the cambial activity and causing formation of large xylem and phloem (Davies 2004, Buchanan *et al.* and Tucker and Roberts, 2000). The synergistic effect of OBA and coconut water stimulated early root formation.

The results were supported by the previous research of Mateja Stefancic *et al.* (2015) who observed that IBA treatment has an influence on early development of adventitious roots. Komamine *et al.* (1990) and Agele *et al.* (2010) reported that coconut water promotes root formation and shoot emergence in stem cuttings of various species.

4.3 Number of shoots per cutting

The influence of plant growth regulators and coconut water on number of shoots of Bougainvillea cuttings is indicated in table 4.1.3

Plant growth regulators treatments exhibited significant difference on number of shoots per cuttings in Bougainvillea. The maximum (4.72) number of shoots per cuttings was registered in IBA 2000 ppm, which was followed by the NAA 2000 ppm (4.46) without any significant difference. The minimum (2.45) of number of shoots per cuttings was recorded in control where coconut water alone was treated.

Number of shoots per cutting was found non-significant due to two levels of coconut water. More number of cuttings (3.84) was observed in coconut water 100 ml compared to 50 ml (3.55) treated cuttings.

The interaction of plant growth regulators and coconut water on number of shoots per cuttings was found significant. The maximum (4.81) was noticed in IBA 2000 ppm with coconut water 100 ml, the lowest (2.30) number of shoots per cuttings was registered in coconut water 50 ml alone which was on par with coconut water (2.61) 100 ml, NAA 1000 ppm with coconut water 50 ml (2.84) and IBA 1000 ppm with coconut water 50 ml (3.37). Remaining all other combinations are no par to each other.

The number of shoots per cutting were maximum with treatments IBA and coconut water and it might be due to the vigorous root system which increased nutrient uptake under the combined influence of IBA. While coconut water increased the availability of the nutrients as it is a natural reservoir of nutrients.

It was reported earlier that dip treatment increased number of shoots by Alshammary *et al.* (2013) who reported in *Bougainvillea peruviana*

Table 4.1.3 Effect of plant growth regulators and coconut water on number of shoots per cutting in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	3.37	3.44	3.40
G_2 IBA 1500 ppm	3.83	4.26	4.05
G_3 IBA 2000 ppm	4.63	4.81	4.72
G_4 NAA 1000 ppm	2.84	3.44	3.14
G_5 NAA 1500 ppm	3.53	3.74	3.63
G_6 NAA 2000 ppm	4.32	4.60	4.46
G_7 Control (Coconut water)	2.30	2.61	2.45
Mean	3.55	3.84	
	SEm ±	**CD at 5 %**	
G	0.34	1.01	
C	0.18	NS	
G X C	0.49	1.42	

G = Plant growth regulators

C = Coconut water ;

GXC = Interaction of plant growth regulators and coconut water.

cv.Shubra and *Hamelia patens* that IBA 2000 ppm resulted in higher number of branches per cutting.

4.4 Number of roots per cutting

The plant growth regulators and coconut water influenced on number of roots per cuttings of bougainvillea cuttings is indicated in Table 4.1.4 and Fig. 3.

Treatments of plant growth regulators revealed significant difference on number of roots per cuttings in Bougainvillea. The maximum (16.91) number of roots per cuttings was recorded in IBA 2000 ppm, which was followed by the NAA 2000 ppm (14.80) without any significant difference. The minimum (6.28) of number of roots per cuttings was recorded in control where coconut water alone was treated.

While in terms of coconut water, non-significant difference was observed in number of roots per cutting. Compared to 50 ml coconut water (10.70) higher number of roots were observed in 100 ml coconut water (11.71).

The interaction of plant growth regulators and coconut water on number of shoots per cuttings was found significant. The higher number of roots were observed in IBA 2000 ppm with 100 ml coconut water (17.82) compared to all other treatment combinations. The lowest was noticed in control (5.87) which was alone treated with 50 ml coconut water and it was on par with 100 ml coconut water (6.69) alone treated, 1000 ppm NAA with 50 ml coconut water (7.06), 1000 ppm NAA (8.17) with 100 ml coconut water and IBA 1000 ppm with 50 ml coconut water (8.62). All other combinations were not on par with each other. (Plate 5 a & b).

Table 4.1.4 Effect of plant growth regulators and coconut water on number of roots per cutting in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	8.62	9.43	9.02
G_2 IBA 1500 ppm	12.75	13.54	13.14
G_3 IBA 2000 ppm	16.00	17.82	16.91
G_4 NAA 1000 ppm	7.06	8.17	7.62
G_5 NAA 1500 ppm	10.25	11.04	10.64
G_6 NAA 2000 ppm	14.34	15.27	14.80
G_7 Control (Coconut water)	5.87	6.69	6.28
Mean	10.70	11.71	
	SEm ±	**CD at 5 %**	
G	0.37	1.10	
C	0.20	NS	
G X C	0.53	1.53	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

Fig. 4 Effect of plant growth regulators and coconut water on number of roots per cutting in bougainvillea

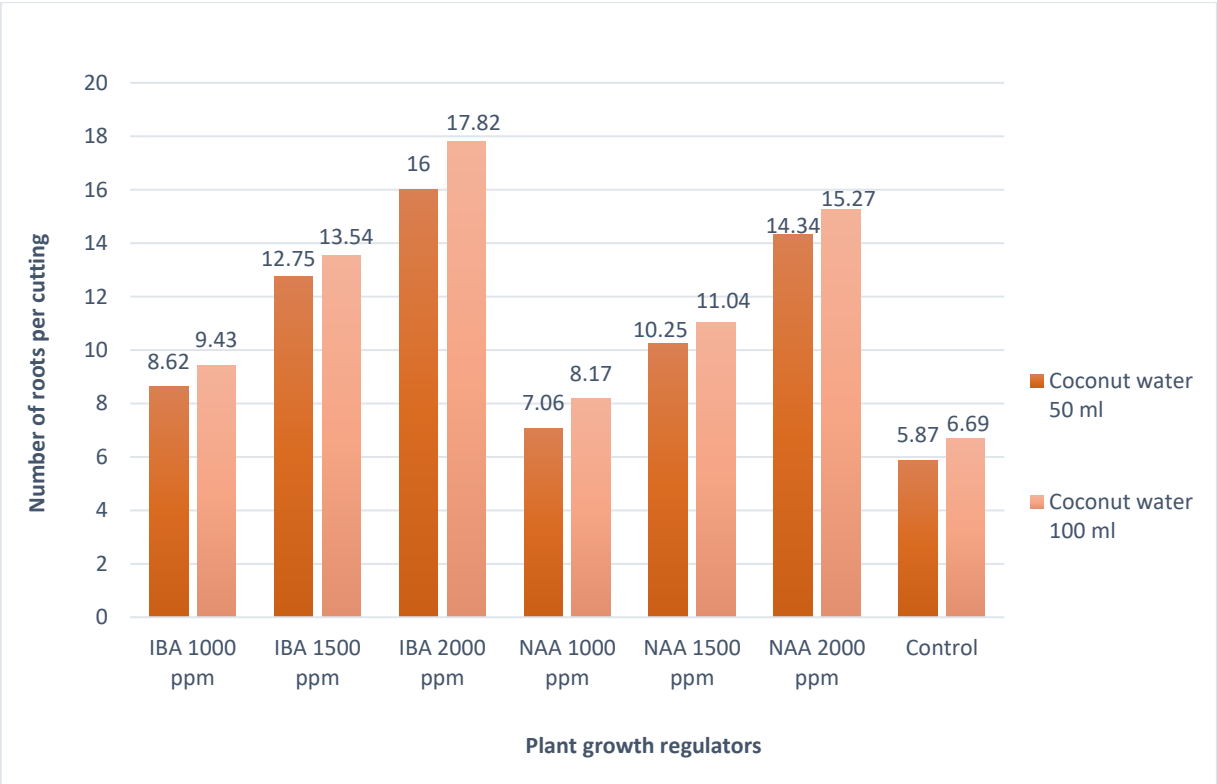


Plate 5 (a): More number if roots in IBA 2000 ppm with coconut water 100 ml treated cuttings

Plate 5 (b): Less number of roots treated with coconut water 50 ml

The number of roots per cutting were maximum with treatments IBA and coconut water might be due to the action of auxin which might have caused hydrolysis and translocation of carbohydrates and nitrogenous substances at the base of cuttings (Hartmann *et al*. 2007), and similar synergistic action of coconut water which also enhanced the hydrolysis and translocation of carbohydrates resulting more number of roots per cutting. Further, the effectiveness of exogenous application of IBA and coconut water in promoting rooting on Bougainvillea stem cuttings is dependent on adequate absorption by plant tissues at appropriate concentration.

These results were supported by the studies done by Panwar *et al.* (1994) in Bougainvillea cv. Alok and Ogunwa (2011) in *Bougainvillea spectabilis*.

4.5 Length of the shoot per cutting (cm)

The treatment of the cuttings with plant growth regulators and coconut water had significant difference in length of the shoot per cutting as per the recorded observations presented in the Table 4.1.5

A significant difference was observed in the treatments of plant growth regulators in length of the shoot per cutting. The maximum length of the shoot was observed in IBA 2000 ppm (22.75) followed by NAA 2000 ppm (21.45). The minimum length of the shoot was noticed in control (7.93) where coconut water alone treated.

Length of the shoot was differed significantly in terms of cuttings treated with coconut water. The maximum length of shoot per cutting was observed in 100 ml coconut water (15.87) and minimum in 50 ml (14.22).

The interaction effect of plant growth regulators and coconut water was also differed significantly. The maximum length of the shoot was

Table 4.1.5 Effect of plant growth regulators coconut water on length of the shoot per cutting (cm) in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	11.36	14.50	12.93
G_2 IBA 1500 ppm	17.73	19.46	18.60
G_3 IBA 2000 ppm	21.76	23.73	22.75
G_4 NAA 1000 ppm	10.56	12.56	11.56
G_5 NAA 1500 ppm	14.40	16.53	15.46
G_6 NAA 2000 ppm	20.36	22.53	21.45
G_7 Control (Coconut water)	7.43	8.43	7.93
Mean	14.22	15.87	
	SEm±	**CD at 5 %**	
G	0.13	0.38	
C	0.07	0.20	
G X C	0.18	0.54	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

noticed in IBA 2000 ppm with 100 ml coconut water (23.73 cm) and minimum in control (7.43) with 50 ml of coconut water alone which was on par with 100 ml coconut water treated alone (8.43). While remaining treatment combinations were not on par with each other. (Plate 6).

Better vegetative growth with IBA 2000 ppm and 100 ml coconut water treated cuttings might be due to maximum number of roots which probably drive more nutrients and water from the soil and enhanced photosynthesis which ultimately resulted in more growth. (Singh and Singh, 2005). Further, the increase in length of the shoot may be due to auxin affect the cell wall, turgor and osmotic pressure and water permeability, which causes cell enlargement resulted in enhanced vegetative growth (Taiz and Zeiger 2006). Moreover, coconut water contains urea diphenyl which has activities of cytokinins thereby increases growth and differentiation of cells affecting cell division leading to longer shoot.

The present results are in accordance with Akhtar *et al.* (2015) in *Rosa centifolia* and Asma *et al.* (2008) in crotons.

4.6 Length of the root per cutting (cm)

As per the recorded observations, the treatment of the cuttings with growth regulator and coconut water had significant difference in length of the root per cutting presented in the Table 4.1.6 and Fig.4.

Treatments of plant growth regulators was found significantly different in length of the root per cutting. The longest root was observed in IBA 2000 ppm (33.86) followed by NAA 2000 ppm (30.49) and shortest in control (13.59) which was alone treated with coconut water.

The coconut water was also exhibited significant difference on the length of the root per cutting. Between the two concentrations the root length

Table 4.1.6 Effect of plant growth regulators and coconut water on length of root per cutting (cm) in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	20.80	21.95	21.37
G_2 IBA 1500 ppm	27.23	28.52	27.88
G_3 IBA 2000 ppm	32.96	34.76	33.86
G_4 NAA 1000 ppm	15.95	19.55	17.75
G_5 NAA 1500 ppm	23.59	25.02	24.30
G_6 NAA 2000 ppm	29.83	31.16	30.49
G_7 Control (Coconut water)	13.04	14.15	13.59
Mean	23.34	25.02	
	SEm ±	**CD at 5 %**	
G	0.20	0.59	
C	0.10	0.31	
G X C	0.28	0.83	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

Fig.5 Effect of plant growth regulators and coconut water on length of the root per cutting in bougainvillea

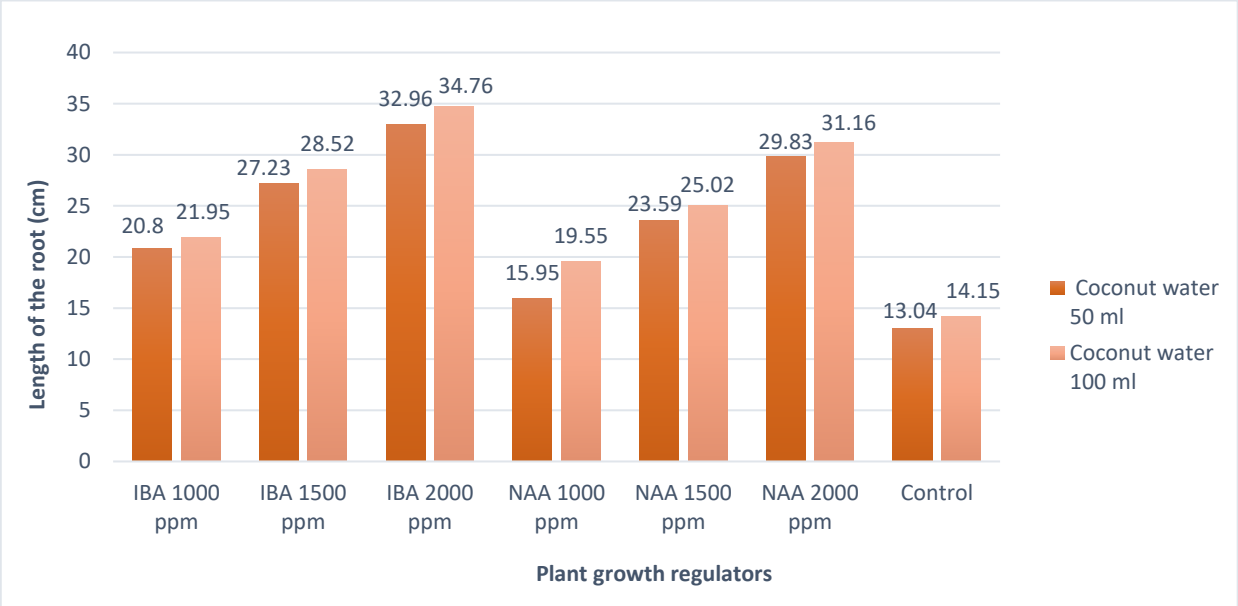


Plate 6 : The longest shoot length in stem cuttings treated with IBA 2000 ppm plus coconut water 100 ml.

Plate 7 : The longest root length in stem cuttings treated with IBA 2000 ppm plus coconut water 100 ml.

in 100 ml coconut water (25.02) was found longer than the 50 ml coconut water (23.34).

The interaction of plant growth regulators and coconut water was also differed significantly. Among all the treatment combinations, longest root was found in IBA 2000 ppm with 100 ml coconut water (34.76) and minimum length of root was observed in control (13.04) which alone was treated with 50 ml coconut water and it was on par with 100 ml coconut water treated alone and NAA 1000 ppm with 50 ml coconut water (15.95). (Plate 7).

The increased length of roots in cuttings treated with auxins (IBA 2000 ppm) may be due to the accumulation of metabolites at the site of application, lead to the cell enlargement, enhanced hydrolysis of carbohydrates, synthesis of new proteins and cell division induced by auxins. (Strydem and Hartmann, 1960). Further, auxins and cytokinins present in the coconut water stimulated the formation of masses of undifferentiated cells (callus) and also increased the carbohydrate metabolism and metabolite translocation (Brintha Karunarathna and Kumuthini, 2016). Where their synergistic effect induced better root characters at appropriate concentrations.

4.7 Number of leaves per cutting

In terms of number of leaves, the treatment of the cuttings with growth regulator and coconut water had significant difference according to the recorded observations as pertaining to number of leaves presented in the Table 4.1.7. and Fig.5.

Treatments of plant growth regulators was found significantly different in number of leaves per cutting. The maximum number of leaves

Table 4.1.7 Effect of plant growth regulators and coconut water in number of leaves per cutting in Bougainvillea cuttings.

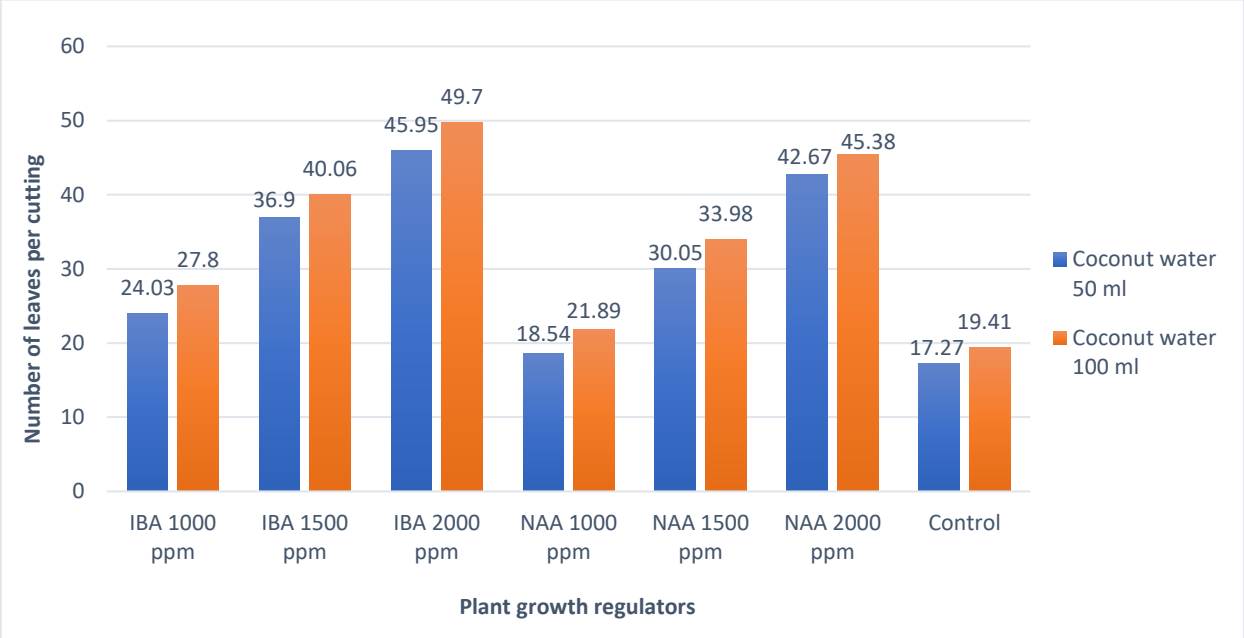
Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	24.03	27.80	25.91
G_2 IBA 1500 ppm	36.90	40.06	38.48
G_3 IBA 2000 ppm	45.95	49.70	47.82
G_4 NAA 1000 ppm	18.54	21.89	20.21
G_5 NAA 1500 ppm	30.05	33.98	32.01
G_6 NAA 2000 ppm	42.67	45.38	44.02
G_7 Control (Coconut water)	17.27	19.41	18.34
Mean	30.77	34.03	
	SEm±	**CD at 5 %**	
G	0.20	0.58	
C	0.28	0.31	
G X C	0.40	0.20	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

Fig.6 Effect of plant growth regulators and coconut water on number of leaves per cutting in bougainvillea



per cutting was observed in IBA 2000 ppm (47.82) and minimum in control (18.34) which was treated alone with coconut water.

Number of leaves was found significant in cuttings treated with two concentrations of coconut water. The maximum number of leaves was observed in 100 ml coconut water (34.03) and minimum was noticed in 50 ml coconut water (30.77).

The interaction of plant growth regulators and coconut water was found significantly different. The higher number of leaves was observed in IBA 2000 ppm with 100 ml coconut water (49.70) and minimum was observed in control (17.27) which was alone treated with 50 ml coconut water. All other combinations were on par with each other.

Increase in number of leaves may be due to vigorous growth and early initiation of root induced by the growth regulator which absorbed more nutrients and thereby producing more leaves as reported by Stancato *et al*. (2003).

The results were supported by the recent studies done by Singh *et al.* (2014) recorded in Mulberry and Okunlola (2016) reported in *Bougainvillea species* cuttings treated with coconut water.

4.8 Leaf Area (cm^2)

The treatment of the cuttings with growth regulator and coconut water showed significant difference in leaf area as per the recorded data presented in the Table 4.1.8

According to the data, the treatments of plant growth regulators was found significantly different. The maximum leaf area was observed in IBA 2000 ppm (17.96) and minimum leaf area was observed in control (5.63).

Table 4.1.8 Effect of plant growth regulators and coconut water on leaf area (cm^2) in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	8.96	10.14	9.55
G_2 IBA 1500 ppm	13.08	14.30	13.69
G_3 IBA 2000 ppm	17.35	18.57	17.96
G_4 NAA 1000 ppm	7.28	8.31	7.80
G_5 NAA 1500 ppm	11.09	12.22	11.65
G_6 NAA 2000 ppm	15.16	16.35	15.75
G_7 Control (Coconut water)	5.01	6.24	5.63
Mean	11.13	12.30	
	SEm ±	**CD at 5 %**	
G	0.37	1.08	
C	0.19	0.57	
G X C	0.52	1.51	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

Treatments of coconut water was also found significantly different. The maximum leaf area was observed in 100 ml coconut water (12.30) and minimum was observed in 50 ml coconut water (11.13).

The interaction effect of plant growth regulators and coconut water was found significant. The maximum leaf area was observed in IBA 2000 ppm with 100 ml coconut water (18.57) and minimum leaf area was noticed in control (5.01) which was alone treated with 50 ml coconut water and it was on par with 100 ml coconut water treated alone (6.24), NAA 1000 ppm with 50 ml coconut water (7.28) and NAA 1000 ppm with 100 ml coconut water (8.31). Remaining combinations were not on par with each other.

The reason behind this may be that uptake of nitrates depends on the number of roots and further more depends on the energy supplied by the plants themselves. Therefore, the plants need to improve the photosynthetic rate and produce more photosynthates. Plants struggle to achieve this goal by expanding their leaves and hence more leaf area was observed in cuttings treated with exact concentration of IBA and coconut water.

With use of coconut water subsequently increase in plant size and wider leaf, and may be due to the increased speed of nutrition and amino asides transportation as it create an active attraction point companied with an increase in enzymes activity that regulate protein production in plant cell (Bangerth and Gruber, 2000; El-shraiy and Amal, 2010).

Similarly, results were confirmed by the previous work of Ismail and Asghar (2007) in *Ficus hawaii* treated with IBA 4000 ppm.

4.9 Fresh weight of the shoot per cutting (g)

The cuttings treated with plant growth regulator and coconut water had significant difference in fresh weight of shoot per cutting in accordance with recorded observations presented in the Table 4.1.9.

Treatments of plant growth regulators showed significant difference pertaining to fresh weight of shoot per cutting. Significantly, maximum fresh weight was noticed in IBA 2000 ppm (27.04) followed by NAA 2000 ppm (23.46) and minimum fresh weight was observed in control (9.39) treated with coconut water alone.

While in terms of coconut water, significant difference was observed between the concentrations. The fresh weight of shoot was noticed more in 100 ml coconut water (18.43) compared to 50 ml coconut water (17.15).

The interaction of plant growth regulators and coconut water was also found significantly different. The maximum weight was noticed in IBA 2000 ppm with 100 ml coconut water (28.13) and minimum was observed in control (8.84) treated with 50 ml coconut water alone which was on par with 100 ml coconut water treated alone (9.95) and NAA 1000 ppm with 50 ml (10.82).

Generally, fresh matter accumulation of plant depends upon the vegetative growth parameter viz. plant height, spread or average number of branches and it is directly influenced by auxin resulted from increased photosynthesis or the hydrolysis of starch resulting in increase in concentration of sugar (Thimman,1972). Increased rate photosynthesis might be also due to increased uptake of nutrition and enhanced protein synthesis due to the presence of high cytokinins. In the present study, IBA and coconut water at higher concentration exhibited auxin and cytokinin like activity and increased fresh weight of cuttings.

Table 4.1.9 Effect of plant growth regulators and coconut water on fresh weight of shoot per cutting (g) in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	14.27	15.16	14.72
G_2 IBA 1500 ppm	20.31	21.55	20.93
G_3 IBA 2000 ppm	25.95	28.13	27.04
G_4 NAA 1000 ppm	10.82	12.05	11.43
G_5 NAA 1500 ppm	16.94	18.16	17.55
G_6 NAA 2000 ppm	22.92	24.00	23.46
G_7 Control (Coconut water)	8.84	9.95	9.39
Mean	17.15	18.43	
	SEm ±	**CD at 5 %**	
G	0.19	0.55	
C	0.10	0.29	
G X C	0.26	0.78	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

4.10 Dry weight of shoot per cutting (g)

The cuttings treated with growth regulator and coconut water had significant difference in dry weight of shoot per cutting as evident from the data presented in the Table 4.1.10.

As per the data obtained, plant growth regulator treatments exhibited was found significant difference. The highest dry weight was observed in IBA 2000 ppm (12.33) significantly followed by NAA 2000 ppm (11.44) and lowest was observed in control (4.76) which was treated with coconut water alone.

Treatments of coconut water was also found significant, the highest dry weight was observed in 100 ml (8.64) and the lowest was observed in control with 50 ml coconut water (8.07).

The interaction of plant growth regulators and coconut water was found significantly different in dry weight of shoot per cutting. The maximum dry weight was observed in IBA 2000 ppm with 100 ml coconut water (12.63) and minimum was observed in control (4.61) which was treated with 50 ml coconut water alone and it was on par with 100 ml coconut water treated alone (4.91), NAA 1000 ppm with 50 ml (5.21) and NAA 1000 ppm with 100 ml coconut water (5.49).

The increase in dry weight may be ascribed to effects of plant growth regulators, higher rate of supply of photosynthates from source to sink which subsequently might have resulted in higher fresh matter and dry matter accumulation (Singh *et al*, 2004) in higher concentration of IBA and with 100 ml of coconut water.

Above results were supported by the earlier research of Deshmukh and Barad (2006) in *Bougainvillea buttiana* cv. Mahara that IBA at 6000

Table 4.1.10 Effect of plant growth regulators and coconut water on dry weight of shoot per cutting (g) in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	6.86	7.90	7.38
G_2 IBA 1500 ppm	9.03	9.55	9.29
G_3 IBA 2000 ppm	12.03	12.63	12.33
G_4 NAA 1000 ppm	5.21	5.49	5.35
G_5 NAA 1500 ppm	7.62	8.34	7.92
G_6 NAA 2000 ppm	11.19	11.69	11.44
G_7 Control (Coconut water)	4.61	4.91	4.76
Mean	8.07	8.64	
	SEm±	**CD at 5 %**	
G	0.21	0.62	
C	0.11	0.33	
G X C	0.30	0.88	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

ppm was found significantly superior for increasing fresh weight and dry weight of shoots and Umesha (2017) in chrysanthemum.

4.11 Fresh weight of roots per cutting (g)

It is clear from the data presented in the Table 4.1.11, that the cuttings treated with growth regulator and coconut water had significant difference in fresh weight of root per cutting.

The maximum fresh weight was observed in IBA 2000 ppm (27.54) significantly followed by NAA 2000 ppm (25.38) and minimum fresh weight was noticed in control (9.81) which was treated with coconut water alone.

The fresh weight of roots treated with coconut water was found significantly different. The fresh weight was noticed more in 100 ml coconut water (19.70) than 50 ml coconut water (18.17).

The interaction of plant growth regulators and coconut water was found significantly different in fresh weight of root per cutting. Among all the combinations, more fresh weight was found in IBA 2000 ppm with 100 ml coconut water (28.41) and minimum was recorded in control (8.82) which was treated with 50 ml coconut water alone.

The fresh weight of roots is directly associated to the number and size of root, as higher concentration of IBA and NAA with 100 ml coconut water recorded more number of roots and length of roots and the fresh weight was also more. The reason for this may be due the more rapid translocation of hormone along the way of cell division and elongation and enhanced enzymatic activity (Debnath and Maiti, 1990). The presence of gibberellin, cytokinin and auxin in coconut water medium and allows the translocation of glucose and amides from the storage area to the growth area. (Dewa Nyoman Oka, 2014).

Table 4.1.11 Effect of plant growth regulators and coconut water on fresh weight of root per cutting (g) in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	14.83	16.75	15.79
G_2 IBA 1500 ppm	21.14	22.81	21.98
G_3 IBA 2000 ppm	26.67	28.41	27.54
G_4 NAA 1000 ppm	12.34	13.68	13.01
G_5 NAA 1500 ppm	18.24	19.85	19.04
G_6 NAA 2000 ppm	25.14	25.61	25.38
G_7 Control (Coconut water)	8.82	10.81	9.81
Mean	18.17	19.70	
	SEm ±	**CD at 5 %**	
G	0.20	0.59	
C	0.10	0.31	
G X C	0.28	0.81	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

The results were in conformity with the findings of Singh *et al.* (2015) in phalsa.

4.12 Dry weight of root per cutting (g)

The cuttings treated with growth regulator and coconut water had significant difference in dry weight of root per cutting based on the recorded observations presented in the Table 4.1.12.

The treatments of plant growth regulators revealed significant difference in dry weight of root per cutting. The maximum dry weight was found in IBA 2000 ppm (13.77) followed by NAA 2000 ppm (12.41) and least was found in control (4.32) which was treated alone with coconut water.

The two concentrations of coconut water also differed significantly in dry weight of root per cutting. More dry weight was observed in 100 ml coconut water (9.16) compared to 50 ml coconut water (8.48).

The interaction of plant growth regulators and coconut water was also found significant. The maximum dry weight was observed in IBA 2000 ppm with 100 ml coconut water (14.11) followed by NAA 2000 ppm with 100 ml coconut water (13.43) and minimum in control treated with 50 ml coconut water (3.86) and it was on par with 100 ml coconut water treated alone (4.77), NAA 1000 ppm with 50 ml coconut water (5.19) and NAA 1000 ppm with 100 ml coconut water (5.61).

Plant growth regulators with coconut water induced higher number of roots, cell elongation of roots with cell division and consequently accounting for higher fresh weight and thus dry weight of roots.

The results are in agreement with the previous research of Tadele Yeshiwas *et al.* (2015) observed that dry weight (0.21) of rose cuttings were recorded highest from cuttings treated with 1000 ppm of IBA.

Table 4.1.12 Effect of plant growth regulators and coconut water on dry weight of root per cutting (g) in Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	6.84	7.42	7.13
G_2 IBA 1500 ppm	9.72	10.42	10.07
G_3 IBA 2000 ppm	13.43	14.11	13.77
G_4 NAA 1000 ppm	5.19	5.61	5.40
G_5 NAA 1500 ppm	8.33	8.96	8.64
G_6 NAA 2000 ppm	11.98	12.85	12.41
G_7 Control (Coconut water)	3.86	4.77	4.32
Mean	8.48	9.16	
	SEm ±	**CD at 5%**	
G	0.21	0.61	
C	0.11	0.32	
G X C	0.29	0.86	

G = Plant growth regulators

C = Coconut water

GXC = Interaction of plant growth regulators and coconut water.

4.13 Survival percentage of cuttings (Percent success)

The data pertaining to the survival percentage of cuttings treated with growth regulator and coconut water is presented in the Table 4.1.13.

Treatments of plant growth regulators exhibited significant difference in survival percentage of cuttings. The maximum survival percentage was observed in IBA 2000 ppm (93.71) followed by NAA 2000 ppm (89.81) and minimum was observed in control (68.86) treated with 50 ml coconut water alone.

A significant difference was observed between the concentrations of coconut water. Higher survival percentage was observed in 100 ml (82.52) than 50 ml coconut water (80.60).

The interaction of plant growth regulators and coconut water was found significantly different. Higher survival percentage (94.95) was noticed in IBA 2000 ppm with 100 ml coconut water which was significantly followed by NAA 2000 ppm with 100 ml coconut water (90.67) and least was observed in control treated with 50 ml coconut water alone (68.05) which was on par with 100 ml coconut water treated alone (69.68).

The increased survival percentage might be due to the better root growth and shoot growth which was augmented due to absorption and translocation of nutrients by IBA and NAA. (Singh, 2012) and a synergistic effect of enhanced transportation and availability of the nutrients by coconut water at higher concentrations.

The results were in confirmation with the previous work of Shalini Kaushik (2017), who reported that the maximum survival percentages (88.33 %) of rooted cutting with 300 ppm of IBA. Further, Khatun *et al.* (2018) reported adding coconut water as an organic addition in pots increased survival rate in carnation.

Table 4.1.13 Effect of plant growth regulators and coconut water on survival percentage of the Bougainvillea cuttings.

Plant growth regulators (G)	Coconut water 50 ml (C1)	Coconut water 100 ml (C2)	Mean
G_1 IBA 1000 ppm	76.67	78.48	77.57
G_2 IBA 1500 ppm	84.58	87.04	85.81
G_3 IBA 2000 ppm	92.48	94.95	93.71
G_4 NAA 1000 ppm	72.38	73.98	73.18
G_5 NAA 1500 ppm	81.06	82.87	81.96
G_6 NAA 2000 ppm	88.96	90.67	89.81
G_7 Control (Coconut water)	68.05	69.68	68.86
Mean	80.60	82.52	

G = Plant growth regulators

C = Coconut water

Fig.7 Effect of plant growth regulators and coconut water on survival percentage of Bougainvillea cuttings

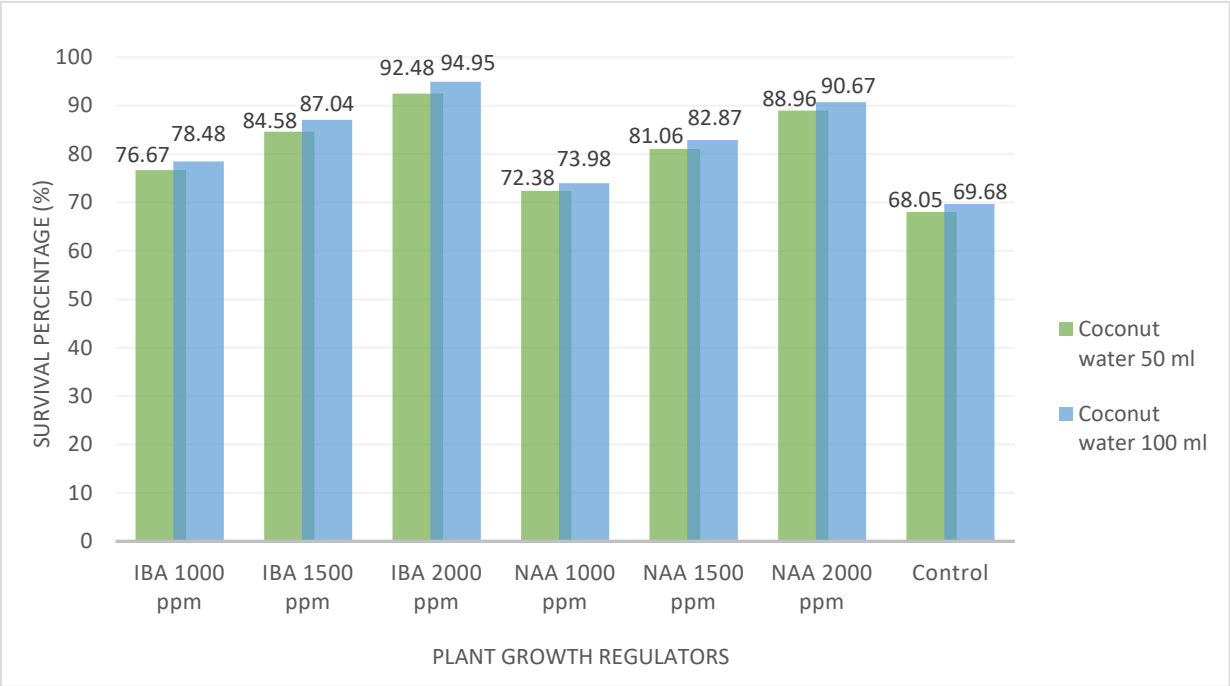


Plate 8 : Healthy flush obtained in the treatments IBA 2000 ppm and NAA 2000 ppm with 100 ml of coconut water.

4.14 Benefit: cost ratio

The benefit cost ratio differed due to the treatments of rooting hormones (auxins) and coconut water as indicated in Table 4.1.14.

The highest benefit cost ratio was obtained in NAA 2000 ppm in combination with 100 ml treated cuttings which was followed by IBA 2000 ppm with 50 ml coconut water (2.52).

Even though the percentage of survival was recorded highest (94.95) in IBA 2000 ppm with 100 ml coconut water compared to NAA 2000 ppm with 100 ml coconut water (90.67) the benefit cost ratio was more in NAA due to the less cost than IBA, but with regard to the quality of the cuttings in respect of rooting parameters and survival percentage, the treatment IBA 2000 ppm with 100 ml coconut water was found to be the best treatment.

From the economic analysis, it can be concluded that coconut water alone recorded lowest B:C ratio (1.70 and 1.75) in both the concentrations of 50 ml and 100 ml. Hence, coconut water when used with IBA and NAA at higher concentrations showed synergistic effect in increasing survival percentage and B:C ratio.

4.1.14 Benefit : cost ratio

Treatments	Cost of producing single cutting (Rs) (a)	Survival percentage (%) (b)	Price of each rooted cutting (Rs) (c)	Gross Income for 100 cuttings (b) x (c) =(d)	Expenditure for producing 100 cuttings (a) x 100 = (e)	Net income for 100 cuttings (d) - (e) = (f)	B: C (f) / (e)
G_1C_1	3.115	76.67	12	920.04	311.50	608.54	1.95
G_2C_1	3.165	84.58	12	1014.96	316.50	698.46	2.20
G_3C_1	3.215	92.48	12	1109.76	321.50	788.26	2.45
G_4C_1	3.018	72.38	12	868.56	301.80	566.76	1.87
G_5C_1	3.027	81.06	12	972.72	302.70	670.02	2.21
G_6C_1	3.031	88.96	12	1067.52	303.10	764.42	2.52
G_7C_1	3.015	68.05	12	816.60	301.50	515.10	1.70
G_1C_2	3.130	78.48	12	941.76	313.00	628.76	2.00
G_2C_2	3.180	87.04	12	1044.48	318.00	726.48	2.28
G_3C_2	3.230	94.95	12	1139.40	323.00	816.40	2.52
G_4C_2	3.038	73.98	12	887.76	303.80	583.96	1.92
G_5C_2	3.042	82.87	12	994.44	304.20	690.24	2.26
G_6C_2	3.046	90.67	12	1088.04	304.60	783.44	2.57
G_7C_2	3.030	69.68	12	836.16	303.00	533.16	1.75

G_1 = IBA 1000 ppm ; G_2 = IBA 1500 ppm ; G_3 = IBA 2000 ppm ; G_4 = NAA 1000 ppm ; G_5 = NAA 1500 ppm ; G_6 = NAA 2000 ppm ; G_7 = Control

C_1 = Coconut water 50 ml ; C_2 = Coconut water 100 ml

Chapter - V

SUMMARY AND CONCLUSION

Chapter V

SUMMARY AND CONCLUSION

The present investigation entitled "Studies on the effect of plant growth regulators and coconut water on rooting of Bougainvillea (*Bougainvillea spectabilis* L.) stem cuttings." was conducted at College of Horticulture, Mojerla, during the year 2017-18.

The study consisted of three different concentrations of IBA (1000 ppm, 1500 ppm 2000 ppm) and NAA (1000 ppm, 1500 ppm, 2000 ppm) in combination with two levels of coconut water (50 ml and 100 ml). Experiment was laid out in Factorial Completely Randomised Design with three replications and fourteen treatments. Semi hard wood cuttings with 4-5 buds of 7.5 mm thickness and 15 cm length were taken and treated with plant growth regulators and coconut water in different concentration. The treated cuttings were planted in poly bags for recording observations. The observation of rooted cuttings vegetative parameters like, number of days taken to sprouting, number of days to root formation, number of shoots per cutting, number of roots per cutting, number of leaves, leaf area, length of shoot per cutting (cm), length of root per cutting (cm), fresh and dry weight of shoot (g), fresh and dry weight of roots (g), survival percentage (%) of cuttings, were recorded. The salient findings of the experiment based on the results are summarized below.

5.1 Number of days taken to sprouting was found earlier with 2000 ppm IBA with 100 ml coconut water (5.50). The significant difference was observed between coconut water of 100 ml and 50 ml. The number of days taken for sprouting was observed more (12.54) in control. Number of days to root formation was found earlier (7.36) in IBA 2000 ppm with

100 ml coconut water. The maximum days (12.06) taken to root formation was found be in control. The number of shoots per cutting was observed maximum (4.81) in IBA 2000 ppm with 100 ml coconut water and least (2.30) was observed in control. An application of 2000 ppm IBA with 100 ml coconut water (17.82) proved remarkably better than all other treatments for enhancing number of roots per cutting and least (5.87) was in control treated with 50 ml coconut water alone.

5.2 Number of leaves per cutting were found maximum (49.70) with the application of IBA 2000 ppm with 100 ml coconut water which was at par with IBA 2000 ppm with 50 ml coconut water (45.95) and NAA 2000 ppm with 100 ml coconut water (45.38). The minimum number of leaves per cutting (17.27) were found in control with 50 ml coconut water. Leaf area was also observed maximum (18.57) in IBA 2000 ppm with 100 ml coconut water and least (5.01) was recorded in control treated with 50 ml coconut water alone.

5.3 The length of shoot was found maximum (23.73 cm) in IBA 2000 ppm with 100 ml coconut water. The shoot length was minimum (7.43 cm) in control with 50 ml coconut water. The maximum length of roots per cutting (34.76 cm) was recorded in 2000 ppm IBA with 100 ml of coconut water and shorter roots (13.04 cm) were observed in control treated with 50 ml coconut water alone.

5.4 Fresh and dry weight of shoot per cutting were observed maximum with the treatment of IBA 2000 ppm with 100 ml coconut water, which was followed by NAA 2000 ppm. The fresh weight and dry weight of root was recorded significantly higher under 2000 ppm of IBA with 100 ml coconut water which was significantly followed by NAA 2000 ppm.

5.5 The maximum survival percentages (94.95 %) of rooted cuttings were recorded in treatment under IBA 2000 ppm plus 100 ml coconut water

and the lowest survival percentage (68.06 %) of rooted cutting was recorded in control with 50 ml coconut water alone treatment.

5.6 Even though, the survival percentage is more (94.95 %) in IBA 2000 ppm plus coconut water 100 ml, the highest benefit cost ratio (2.57) was recorded in NAA 2000 ppm with 100 ml coconut water with survival percentage of 90.67. Based on the benefit cost ratio NAA 2000 ppm with coconut water 100 ml (2.57) and IBA 2000 ppm with coconut water 100 ml (2.52) are the best treatments for propagation of Bougainvillea through cuttings which were significantly followed by IBA 2000 ppm with 50 ml coconut water (92.48 %) and NAA 2000 ppm with coconut water 100 ml (90.67).

5.7 CONCLUSION:

Based on the results obtained from the investigation entitled "Studies on the effect of plant growth regulators and coconut water on stem cuttings of Bougainvillea (*Bougainvillea spectabilis)* the following conclusion can be made :

1. The study suggested that semi hard wood cuttings of *B. spectabilis* when dipped for two hours in IBA 2000 ppm in combination with 100 ml of coconut water is the best treatment for all the parameters from earlier sprouting of the cutting, root formation, longer shoot and root ,more number of shoots, roots and leaves, increased fresh weight and dry weight of shoots and roots, more importantly for maximum survival percentage (94.95 %) with B:C ratio 2.52. However, based on benefit cost ratio (2.57) NAA 2000 ppm with coconut water 100 ml is best as the cost of NAA is less than IBA on economic point of view.
2. The coconut water when used in combination with growth regulator worked well and gave economic results in propagating bougainvillea, which showed synergistic effect both with IBA and NAA at higher concentrations.

5.7 FUTURE LINE OF WORK

Based on the experience gained and results obtained, following suggestions are made for future line of work

1. Experiment should be repeated using different dipping durations with same or further higher concentrations of plant growth regulators.
2. Wider experiments must be done on using coconut water as a growth promotor in inducing rooting in other ornamental plants.

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APPENDICES

APPENDIX I

Monthly meteorological data during crop growth period from November 2017 to February 2018.

Month	Temperature (˚C)		Rainfall (mm)	Relative humidity (%)	
	Maximum	Minimum		Maximum	Minimum
November	33.41	18.19	-	107.17	36.08
December	31.84	15.64	-	78.64	30.90
January	32.44	16.18	-	73.57	30.08
February	34.53	17.34	-	67.89	23.14