STUDIES ON EFFECT OF DIFFERENT ROOTING HORMONES ON STEM CUTTING OF CROTON (*Codiaeum variegatum*)

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B.Sc. (Agriculture)

MASTER OF SCIENCE
IN
HORTICULTURE
(FLORICULTURE AND LANDSCAPE ARCHITECTURE)

DEPARTMENT OF HORTICULTURE
COLLEGE OF AGRICULTURE, PARBHANI
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BY

TANGAWADE ONKAR PANDIT

B.Sc. (Agriculture)

A thesis submitted to
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani
in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE
IN
HORTICULTURE
(FLORICULTURE AND LANDSCAPE ARCHITECTURE)

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2022

DECLARATION BY THE CANDIDATE

I hereby declare that the thesis entitled, **"Studies on effect of different rooting hormones on stem cutting of croton (*Codiaeum variegatum*)"**, submitted by me is based on the actual work carried out by me under the guidance and supervision of **Mr. Rahul Dewaji Baghele.** The extent of information derived from the existing literature have been duly cited and referenced. The exiting research work or its any part is not submitted anywhere else for the award of any degree or diploma.

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19/11/23

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O.Karpandit.

(Tangawade Onkar Pandit)

Place: ***Parbhani***

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ABBREVIATIONS

%	:	Percentage
/	:	Per
@	:	At the rate of
“ ”	:	Inverted comma
°C	:	Degree centigrade
ANOVA	:	Analysis of variance
Av.	:	Average
C.D.	:	Critical difference
cm	:	Centimeter
CRD	:	Completely Randomized Design
Cv.	:	Cultivar
DAP	:	Days After Planting
et al.	:	(*et albeit*) co-workers
etc.	:	and so on; and other people / things
Fig	:	Figure
FYM	:	Farm yard manure
g	:	Gram
ha	:	Hectare
hrs	:	Hours
i.e.,	:	That is
IAA	:	Indole Acetic Acid
IBA	:	Indole-3-Butyric Acid
l	:	Litre

Max	:	Maximum
Mg	:	Milligram
Min.	:	Minimum
N	:	Nitrogen
NAA	:	Naphthalene Acetic Acid
No.	:	Number
P	:	Phosphorus
PGRs	:	Plant Growth Regulators
ppm	:	Parts Per Million
SE (m) ±	:	Standard error of mean
Sr. No.	:	Serial Number
var.	:	Variety
Viz.	:	Videlicet (namely)
wt.	:	Weight

ABSTRACT OF THESIS

THESIS ABSTRACT

1.	Title of thesis	: Studies on effect of different rooting hormones on stem cutting of croton (*Codiaeum variegatum*)
2.	Name of the candidate	: Tangawade Onkar Pandit
3.	Name of the Research Guide	: Baghele Rahul Dewaji
4.	Department	: Horticulture
5.	College / University	: College of Agriculture, V.N.M.K.V, Parbhani.
6.	Degree to be awarded	: M.Sc. (Horticulture)

ABSTRACT

The present investigation on "Studies on effect of different rooting hormones on stem cutting of croton (*Codiaeum variegatum*)'' was carried out at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during the year 2021-22. The experiment was laid out in CRD (Completely Randomized Design) with ten treatment combinations replicated thrice. Each replication consisted of 20 cuttings. Fresh branches were collected from 3-4 years old healthy plant of *Codiaeum variegatum* grown at the college nursery. All the branches were removed from the semi-hardwood branches after which they were cut into 15 cm long segments with 6-8 nodes. A slant cut was given at the base of the cuttings.

IAA, IBA and NAA were used as a rooting hormones. The experiment consists of three different concentrations of IAA (500 ppm, 1000 ppm and 1500 ppm), IBA (500, 1000 ppm and 1500 ppm) along with control. The method adopted for treatment of cuttings with growth regulator solution with the help of quick dip method. In which, the basal end of the prepared cuttings were kept standing in solution of growth regulator to a depth of 2.5-3.0 cm for 2 to 5 minutes. Semi hardwood cuttings of croton were planted in polybags containing one part of red soil, two parts of sand and one part of FYM.

Among the treatments of plant growth regulators, IBA 1000 ppm recorded early sprouting (20.20), early root formation (17.61), maximum success percentage

(78.86%), less mortality percentage (21.14%), maximum number of shoots (3.22), maximum number of roots (14.86, 26.75) at 30 and 60 days after planting respectively, highest length of shoot (4.06 cm), highest length of root (2.22, 4.58 cm) at 30 and 60 days after planting respectively, maximum number of leaves (12.85), highest plant height (21.28 cm), maximum fresh weight of shoot (10.41 g), maximum fresh weight of root (5.95 g), maximum dry weight of shoot (4.48 g), maximum dry weight of root (2.36 g), highest root: shoot ratio (0.68), highest survival percentage (81.66%) and highest B:C ratio (3.80).

On the basis of the result obtained from the investigation, it can be concluded that the croton (*Codiaeum variegatum*) can be propagated through semi hardwood cuttings soaked for quick dip method in the solution of IBA at 1000 ppm and planted in red soil + sand + FYM under shade net house which was the most effective to improving root as well as shoot parameters.

(**Keywords:** Croton, PGRs, IAA, IBA, NAA, ppm, Cuttings, Rooting hormones, *Codiaeum variegatum*)

CHAPTER – I

INTRODUCTION

CHAPTER-I

INTRODUCTION

Codiaeum variegatum, commonly known as croton belongs to the family Euphorbiaceae, is one of the most popular ornamental plants because of it's vivid foliage colors and varied leaf shapes. More than 200 varieties of croton exist on the globe, available in different leaf sizes, shapes and color patterns. It grows naturally in southern Asia, Indonesia and other eastern pacific islands in open forests. Amongst ornamental plants, croton is a stood out species for its blooming foliage. It is a set of semi-hardwood shrubs with latescent, leathery and very attractive leaves (Lorenzi & Souza 2008). It is an evergreen shrub, grows up to 6 m in height but usually maintained at 60-90 cm and grows well in areas having humid climate. Croton with its amazing colors and leathery leaves is regarded as a beautiful foliage plant and sometimes it is called as Joseph's coat or Variegated croton (Nasib *et al*., 2008).

The commercial production of ornamental plants has grown worldwide due to their high potential for income and employment generation and to the environmental benefits and life quality improvements resulting from its products. The agriculture strategy is now much onto the ornamental plants production for local and exportation. Ornamental plants are mainly used to enhance the beauty of a garden or home. Flowering and non- flowering ornamental plants can be used in creating parks, different themed gardens, lawn borders etc. Raising and selling of ornamental plants are a good business. The cut flowers from ornamental plants can fetch you economic benefits as they are used in various floral arrangements. Apart from it's property of increasing the aesthetic value, these also improve the quality of the space by acting as wind barriers, providing shade, cleaning up the pollutants in the air, reducing soil erosion and providing the habitat for animals and birds. The ornamental plants placed indoors provide a good and pleasant ambience and also purifies the air. Attractive looking ornamental plants can influence you psychologically and keeps you happy. You can achieve a calm mind and healthy body by indulging in ornamental plants gardening.

Croton is in demand as a landscape plant because it is an evergreen shrub. The leaves are alternate, non serrated but sometimes lobed. Colour patterns range from multicoloured spots to irregular colour patches or solid coloured leaves with

contrasting veins. Sometimes totally different forms of leaves and colour variations occur on the same plant. Its showy leaves are latex producing, leathery and can have varied colors, shapes and sizes (Lorenzi & Souza 2008). The plant grows in an assortment of shapes and colours. Young leaves are usually green, bronze, yellow or red, later changes to gold, cream, white, scarlet, pink, maroon, purple, black or brown. A wide range of variations in leaf shape and coloration had fascinated breeders, landscapers, horticulturists, and gardeners and a huge number of cultivars have been fixed for commercial production (Chen and Stamps 2006). Croton with their colorful, glossy foliage and variation of leaf types are one of the most popular plants. The plant may change colour as it matures (Ogunwenmo *et al*., 2007). Hence, this species has been selected for the different morphology and color combination of leaves with contrasting veins. Flowers are small, long, axillary, usually unisexual racemes. Fruits are globular capsules and 3-8 mm in diameter.

Crotons are primarily aesthetic in their value. Croton plant brings a burst of color to green landscape (Leonardi *et al*., 2001). Crotons are also well known for their medicinal value. Leaves extracts of croton have many medicinal properties including purgative, sedative antifungal, antiamoebic and anti-cancerous activities (Deshmukh and Borle 1975). The plant is also well reputed for the production of valuable secondary metabolites of alkaloids, terpenes and flavonoids in nature (Puebla *et al*., 2003). According to high decoration values in outdoor and indoor house plants, and the ability of shrubs to thrive well in many regions of the world (Deepa and Shanthi 2013).

Because crotons are in very regular demand, there is the need for fast propagation methods, with low cost and that assures the formation of vigorous, high-quality seedlings. Due to its slow rate of conventional multiplication, the plant is very high in demand. Concrete attention has been paid towards increasing the percentage of cuttings propagation, however, it is one of the difficult-to-root woody plants. Generally, croton can be propagated by shoot tip cuttings, but this process is slow in response and requires large numbers of mother/stock plants. One mother/stock plant may only produce 20 plants each year from shoot tip cuttings (Nasib *et al*., 2008).

Vegetative propagation is the form by which desired individual characteristics are maintained, resulting in a plant that is genetically identical to the original donor plant, thus becoming the preferred method of propagation. Among the vegetative

means, stem cutting is one of the easiest, cheapest and least time consuming methods of plant propagation (Bose *et al*., 1975). The propagation by cuttings favors the quick and massive production of plantlets having tremendous vigor because the plants are on their own roots, making them more resistant to adverse conditions. Methods of vegetative propagation like cutting and layering have proved to be a handy device for the horticulturist and nurserymen for the multiplication of true-to-type plant. However, due to low rate of rooting in cuttings, the vegetative propagation has its own limitations. The process of regeneration is largely controlled by internal and external factors. Cuttings can take root when a number of co-factors are present in addition to auxin. The process of root formation at the base of a cutting may be divided into three stages *viz.,* root initiation, root elongation and root growth and development (Hartmann *et al*., 2002). Success of vegetative propagation mostly depends on the ability of plant to form roots when placed in suitable media and favorable environment conditions for rooting.

Plant growth regulators can accelerate the development and increase the efficiency of adventitious rooting in ornamental plants. Root initiation with the use of growth regulators occupies a significant position in the field of propagation (Mukherjee *et al*., 1976). One of the many approaches has been the application of plant growth regulating chemicals to bring about a change in the growth of roots and shoots of some horticultural crops of ornamental importance. When propagation through stem cutting becomes very difficult, treatments with growth regulators are applied in optimum concentration to promote rooting in stem cutting. Activity of growth regulators depends upon the amount of hormone applied and a particular concentration of growth regulator may be more effective for initiation of root in stem cutting. Thus, optimum concentration of growth regulator needs to be determined for different plant species. Among the growth regulators Indole Butyric Acid (IBA) is the most commonly and widely used to achieve high percentage of rooting success for the ornamental species (Kundu *et al*., 1987). Other exogenous hormones which regulate plant growth are Indole Acetic Acid (IAA), Napthalene Acetic Acid (NAA), 2, 4-Dichloro phenoxy acetic acid (2,4- D), Indole Propionic Acid.

Among the different plant growth regulators, auxin is most effective as a rooting aid. Auxin is used mostly for better rooting in stem cuttings for many plants which increase survival percentage and better rooting. In stem cuttings, Auxins are

important agents for rooting difficult-to-root cuttings of woody plants. Auxin stimulates adventitious root formation in stem cutting. Plant hormones transported to the base of the cutting that acts in the formation of meristematic centers or activates pre-existing meristems that induce root formation (Hartmann *et al*., 2007). IAA, IBA and NAA are used to induce rooting has been practicing since earlier time to ensure success of rooting in cutting and better establishment of plants. In the recent years, synthetic plant growth regulators have received wide spread acceptance and application in the field of horticulture. Among the various uses of growth regulators, the initiation of rooting in the cutting is most useful to the nurserymen. The treated cutting rapidly produce uniform and extensive root system, which when transplanted survives better than untreated cutting. The goal of this study was to look into the effects of rooting ingredients on root ability in order to develop an efficient and reliable methodology for vegetatively propagating croton plants by rooting stem cuttings. Keeping above factors in mind, the present study was intended to be undertaken during kharif 2021 at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

The objectives of this study are as follows :

1. To study the effect of rooting hormones on croton cuttings
2. To find out best concentration of rooting hormone on growth parameters of croton cuttings

CHAPTER –II

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

The present experiment entitled Studies on effect of different rooting hormones on stem cutting of croton (*Codiaeum variegatum*) was conducted at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra) during the year 2021-22.

2.1 Effect of plant growth regulators (PGRs) on rooting of croton cuttings

Nasib *et al.* (2008) studied on In vitro multiplication of croton (*Codiaeum variegatum*). The roots were successfully induced by 2.0 mg/l of IBA. The rooted plants were then effectively acclimatized with the potting mix of 80% sand and 20% farm yard manure.

Baldotto *et al.* (2012) studied that the growth characteristics and the nutritional contents of croton and hibiscus plants during acclimation of seedlings in response to different concentrations of indolebutyric acid (IBA) and humic acid (HA) applied to cuttings for rooting. The experiment was conducted in greenhouse, and the apical stem cuttings were treated with solutions with concentrations of 0, 250, 500, 1000 and 2000 mg L-1of IBA and 0, 10, 20, 30 and 40 mg L-1 of C from HA. At 45 days of rooting in carbonized rice husk, they were individually transferred to plastic bags of 2.0 dm3 containing a mixture of soil: sand: manure (2: 1: 1) as substrate. At 90 days of acclimation, the plants were collected for measurement of growth and nutritional variables. The results showed that the application of the IBA stimulates the absorption of nutrients and growth of croton cuttings and transplanted hibiscus, contributing to formation of vigorous seedlings. A similar response occurred with the application of HA in hibiscus cuttings.

Bharti *et al.* (2013) studied interaction between effect of variety, type of cutting and IBA concentration on rooting in cuttings of croton. Overall performance of hard wood cutting of broad leaf variety treated with 400 ppm IBA was found significantly superior in inducing the highest rooting percentage (82.34%), took lesser time for sprouting (10 days), highest survival percentage (80.04%) and sprouting percentage (88.66) than other treatments. Out of three types of cuttings, semi-hard

wood cuttings and 200 ppm IBA was found better in comparison to 400 ppm IBA with broad leaf for rooting and establishment.

Owusu *et al.* (2020) conducted an experiment on croton at the Multipurpose Crop Nursery at the College of Agriculture Education, Mampong Campus. They revealed that the different growth media and hormones influenced sprouting response of croton at days to 50%, 70%, and 100% sprouting significantly. The study concluded that croton cuttings that were grown on a combination of topsoil and Aloe vera gel resulted in the earliest shoot response and a higher number of roots and leaves followed closely by those of IBA.

Hoda (2021) performed an experiment on croton cutting. Cuttings were treated with four different concentrations of IBA at the rate of 1000, 2000, 3000 and 4000 ppm besides the control. Both 2000 and 3000 ppm IBA significantly improved rooting percentage, survival % of cuttings and produced a significant increase in all vegetative root growth parameters (number of roots, fresh and dry weight of roots and root length). In addition, treated cuttings with 2000ppm also decreased the number of days to root. After 45 days, the rooting percentage gradually increased in comparison to the increase in IBA concentration to over 2000 ppm over the control.

2.2 Effect of plant growth regulators (PGRs) on rooting of other ornamental plants

2.2.1 Rose

Thomson (1983) stated that the best rooting quality was obtained when IBA at 500 or 1,000 mg/litre was applied to *Rosa chinensis* cuttings. However, it slowed the development of new shoots. He also discovered that, in comparison to other growth regulators, IBA enhanced the quantity and length of adventitious roots.

Balakrishnamurthy *et al.* (1986) found that IBA at 1,000 ppm produced maximum number of roots and maximum plant survival in hardwood cuttings of the Edward rose.

Fuchs (1986) discovered that the highest concentration of IBA (1,000 ppm) enhanced the number of roots and root length in rose cuttings of the ‘Kangava’ variety.

Balakrishnamurthy and Rao (1988) revealed that the *R. bourboniana* stem cuttings treated with IBA at 1,000 ppm had improved rooting and survival.

Chu (1990) reported that IBA at 2,000 mg/litre induced the highest number of roots/cutting in comparison to other treatments when applied to the base of budded rootstocks of *R. multiflora*.

Ercisli and Guleryuz (1999) found that IBA at 2,000 ppm produced the best rooting in *R. canina* and *R. foetida* as compared to IBA at 1,000, 4,000, and control.

Pivetta *et al.* (1999) revealed that IBA at 1,000 ppm led to higher rooting than control in rose cuttings.

Younis and Riaz (2003) studied the effects of several rooting hormones on the growth and rooting of cut roses. They found that 1000 ppm IBA was beneficial in *Rosa bourboniana* for the more number of sprouted buds (4.0), plant height (57.1 cm), number of branches (3.5 cm), and longest roots (3.9 cm), with fewer mortality (3.9%).

Ulemale *et al.* (2004) conducted study on rooting and cuttings of the rose (*Rosa indica* cv. Odorata) were given IBA and NAA concentrations i.e, 500, 1000, and 1500 ppm alone or in combination. They discovered that, compared to other treatments, IBA at 1000 ppm produced the higher number of primary roots (40.66) and a survival rate of 85%.

Khan *et al.* (2006) investigated how certain auxins affected the growth of Damask rose cuttings in various growing conditions. They noted that cuttings treated with NAA @ 50 mg/l had the highest levels of bud sprouting (78.76%), bud spread (11.32 cm), and shoot length (13.68 cm).

Aklade *et al.* (2010) carried out study of impact of medium and cutting on plant propagation and growth of rose and discovered that cuttings from hardwood placed in coarse sand growth greatest number of roots per rooted cutting (15.02), percentage of sprouted cutting (81.67), dry weight of roots per rooted cutting (560.11 mg), fresh weight of roots per rooted cutting (1680.33 mg), and fresh weight of shoots per rooted cutting (6.41 g) and dry shoot weight per rooted cutting of the rose cv. is (2.14 g), and the rooted cutting survival rate is (38.5) percent of rose cv. Local Red is under control under the polyhouse tent.

Izadi *et al.* (2012) found that the combination of coco peat and perlite was successful for rooted in stem cuttings with a diameter of 10 cm and two leaves treated with 5000 ppm IBA (68.7%) and root number (2.09) with dogrose *(Rosa canina*) cv. Dolcevita.

Susaj *et al.* (2012) found that the highest rooting percentage (91%) achieved by rose cvs. Vayvicend and Christopher Columbus cuttings treated with IBA 500 ppm in a controlled climate.

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

Dawa *et al.* (2013) carried out an experiment to study the effects of two growth regulators, indole butyric acid (IBA) and naphthalene acetic acid (NAA) on rooting of commercial rose cut flower cultivar known as "First Red," and discovered that early root appearance (22.55 day) was stated with maximum rooting (76.67%), highest primary root number (12.57), longest root (5.87 cm), and field survival (73.13%) in cuttings treated with IBA @ 1500 ppm.

Akhtar *et al.* (2015) treated cuttings of *Rosa centifolia* with different concentrations (450 ppm, 700 ppm and 950 ppm) of indole butyric acid (IBA), indole acetic acid (IAA), naphthalene acetic acid (NAA) alone, in combination and with same concentrations of 6-benzylamino purine (BAP). Maximum shoot length, shoot dry weight, number of roots, root length, root dry weight and root fresh weight were produced by 450 ppm IBA followed by 700 ppm and 950 ppm concentrations of IBA. All three concentrations of IBA alone produced better than combination with other growth regulators. Lower concentrations of growth regulators alone and in combination produced superior results as compared with higher concentrations.

Yeshiwas *et al.* (2015) performed an experiment to assess the impact on the growth and development of softwood, semi-hard and hard wood cuttings treated with IBA concentrations of 0, 1000, 1500, 2000, 2500, and 3000 ppm. The majority of the root and shoot parameters, such as root length, number of roots per cutting, fresh and dry weight of root, fresh and dry weight of shoot, leaf number and shoot length, exhibited significantly beneficial impacts on rose cuttings treated with 1000 ppm of IBA.

Krishnamoorthy *et al.* (2017) conducted an experiment with an objective of analyze the reaction of rose cuttings to auxins, such as Indole Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA), at concentrations of 0, 500, 1000, 1500, and 2000

ppm in growth conditions. At IBA 1500 ppm, rose cuttings exhibited maximum bud sprouting (78.8%), days to sprout (6 days), number of leaves per plant (10) and chlorophyll index (39.3 mg/g).

2.2.2 Bougainvillea

Bhattacharjee and Balkrishna (1983) treated the bougainvillaea cv. "Usha" cuttings with IBA at 2,000-6,000 mg/litre and found that 4,000 and 6,000 mg/litre produced the optimum rooted and survival percentages.

Awad *et al.* (1988) utilised cuttings that were 20 cm long, 3, 5, 7 and 12 mm in diameter and dipped in IBA concentrations of 0, 3,000, and 6,000 ppm. The cuttings with the largest diameter (12 mm) and the greatest amount auxin (6,000) had the highest rooting percentage and the most roots per cutting.

Panwar (1988) studied on propagation of several bougainvillaea species. Cuttings of all kinds were subjected to 0, 250, 500, 1,000, and 2,000 ppm of IBA. It was discovered that this level of IBA produced the highest levels of sprouting, roots, length, and leaves per cutting when compared to the other treatments.

Joshi *et al.* (1989) revealed that IBA, NAA, and IAA were applied to hard wood cuttings of five different cultivars of bougainvillaea at concentrations of 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).

Patel (1990) concluded that in stem cuttings of bougainvillaea, IBA at 3,000 mg/litre produced better results than 1,000, 2,000, and 4,000 mg/litre for all rooting parameters.

Baraskar *et al.* (1990) found that bougainvillea varieties Mary Palmer and Mahara were treated by soaking for 10 minutes in the solution of 2500 ppm IBA and 2500 ppm frulic acid. The maximum percentage (100%) of Mahara cuttings and percentage survival in both species were obtained with this treatment.

Singh (1990) found that IBA was superior to NAA in terms of effectiveness, and 3,000 mg/litre of IBA was the optimal concentration for a larger proportion of bougainvillaea cv. 'Thimma' cuttings to survive.

Gupta and Kher (1991) resulted that when quick dip method applied to bougainvillaea cv. “Garment Glory” cuttings, IBA at 4000 ppm produced the highest

rooting (highest number and longest root length) when compared to IBA, IAA, or NAA at 2000, 4000, or 6000 ppm.

Harris and Singh (1991) carried out an experiment on the semi-hardwood cuttings of bougainvillaea cultivars Refulgence, Akola, Magnifica, Formosa, and Shubra. The cuttings were treated with IBA and NAA at 100, 200, and 400 ppm. The highest mean percentage rooting across cultivars and number of roots per cutting (60 and 34% in spring and rainy season, respectively) obtained with 100 ppm IBA, followed by 100 ppm NAA.

Thumar (1991) investigated that the IBA at 5,000 ppm was more efficient in causing roots in bougainvillaea cuttings of the variety “Mary Palmar.”

Patel (1994) found that the best combination for establishing bougainvillaea roots in hardwood cuttings was 2,000 ppm IBA + NAA.

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

Mishra and Sharma (1995) revealed that Dr. R.R. Pal and Mrs. H.C. Buck, two difficult-to-root bougainvillaea cultivars, responded much better to the maximum dosage of 2000 ppm IBA, which greatly improved stem cutting rooting ability.

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

Mukhopadhaya and Bose (1996) investigated that cuttings of bougainvillaea treated with NAA 400 ppm exhibited 12.5% rooting whereas, those treated with control and NAA 100 ppm failed to exhibit rooting.

Sobhana *et al.* (1996) experimented on seven bougainvillaea varieties germination rates. They found that IBA, at 7,500 ppm, had a more rooting potential than NAA, at 7,500 ppm, or when IBA and NAA were combined, at 2,500 ppm each.

Kanamadi *et al.* (1997) found that he bougainvillaea variety "Mahara" showed that the highest percentage of rooting, largest rooting zone, and number of main and secondary roots per cutting when treated with IBA at 10,000 ppm.

Deshmukh and Barad (1999) found that IBA at 6,000 ppm recorded highest rooting rate in hardwood cuttings of several cultivars of bougainvillaea.

Singh *et al.* (1999) recorded that maximum rooting was achieved with 2,500 ppm IBA, followed by 2,000 ppm IBA, in the bougainvillaea cultivars "Lady Mary Baring" and "Rosevilles Delight."

Panwar *et al.* (2001) observed that in hardwood cuttings of bougainvillaea var. 'Mary Palmer,' IBA at 2,000 ppm showed improved results in all growth parameters.

Gupta *et al.* (2002) performed an experiment on the stem cuttings of bougainvillea cv. ‘Los Banos Variegata’. Cuttings were treated with IBA solution each at 0, 250, 500, 750 and 1000 ppm by long dip (24 hours) method and 0, 1000, 2000, 3000, 4000 and 5000 ppm by quick dip (10 seconds) methods. They find that among all the treatments, IBA at 1000 ppm induced maximum rooting (100 %) with maximum number of roots (32.0) and maximum survival percntage (90 %) in the long dip method.

Reddy *et al.* (2002) found that semi hardwood cuttings treated with NAA at 1000 ppm result into maximum rooting percentage (80%) followed by hardwood cuttings treated with IBA at 1000 ppm.

Singh (2002) revealed that when cuttings of bougainvillea cv. Thimma treated by quick (5 seconds) in 2000, 4000, 6000 ppm solutions of NAA and IBA separately or in combinations (1:1) then rooting percentage, number of primary roots and length of the longest primary root were significantly higher in 4000 ppm IBA than control.

Singh and Singh (2003) found that cuttings of bougainvillea cv. 'Cherry Blossom' treated with IBA 1,500 ppm produced maximum number of roots (6.67).

Adiga *et al.* (2004) observed that when bougainvillaea hardwood cuttings were treated with NAA 1000 ppm, Vernonia showed the greatest mean rooting percentage (85.42%), while Hibiscus showed the largest average number of roots as a result of NAA 1000 ppm treatment. In contrast, the cutting of *Jasminum multiflorum* that had been treated with IBA 500 ppm had the maximum rooting (94.43%).

Sultana (2006) observed the rooting performance of three ornamentals stem cuttings of bougainvillea, nerium and *jasminum sp.* which are influenced by growth regulators. Different concentration of growth regulators IBA, NAA had significant effects on the rooting performance of the ornamental plants. Bougainvillea showed maximum percentage of success (95.60) when treated with IBA 400 ppm and nerium

showed minimum percentage of success (44.33). Further, The longest root (23.53 cm) was produced at 400 ppm IBA in bougainvillea while nerium produced the shortest one (6.53 cm).

Kishan and Raju (2008) found that cuttings of the Bougainvillea cv. Sonnet produced the highest rooting percentage (90.8%), most primary roots (9.25), and longest primary roots when treated with IBA at 1000 mg/l (17.33 cm).

Parmar *et al.* (2010) conducted an experiment in which cuttings of *Bougainvillea peruviana* were treated with various concentrations of IBA and NAA, and it was discovered that IBA @ 4000 ppm proved superior in terms of the percentage of rooted cuttings that had roots, the survival percentage of cutting, and the number of days for sprouting.

Patel (2011) revealed that the IBA at 4000 mg/l produced the highest rooting percentage (95.00), number of days required for sprouting (8.50 day), number of roots per rooted cutting (24.45), length of root (14.23 cm), number of shoots per rooted cutting (5.11), length of shoot (12.29 cm), number of leaves per shoot (11.74), and survival percentage of rooted cutting in hardwood cuttings of Bougainvillea cv. Touch Glory (64.00).

Asl *et al.* (2012) studied the impact of IBA treatment for seven seconds on the capacity of bougainvillaea semi-hardwood cuttings to root, and discovered that IBA 2000 ppm produced the most roots (8.67 roots per plant) and the longest roots (151.42 mm).

Babashpour *et al.* (2012) found that the bougainvillaea cutting treated with 2000 ppm IBA and perlite as a rooting medium produced the maximum number of roots (8.67), the longest roots (15.42 cm) and the greatest rooting percentage (76.19%).

Singh (2012) tested that the impact of different IBA concentrations on hardwood cuttings of various bougainvillaea varieties, including Thimma, Louise Wathen, Mrs. Butt, and Shubra, and found that IBA concentration and variety had a major effect on cutting germination, rooting, callus formation, and establishment. Lousie Wathen cuttings Applying 1000 ppm IBA improved the sprouting (85.39%), rooting (75.46%), callusing (80.78%) and establishment (100%).

Memon *et al.* (2013) evaluated that the different concentrations of NAA had a significant effect on the sprouting and rooting of bougainvillaea stem cuttings,

whereas varieties had no significant impact on these aspects other from the number of sprouts per cutting and the percentage of sprouting and rooting. 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), and length of leaves were obtained when cuttings were treated with NAA 6000 ppm (6.007 cm).

Mehraj *et al.* (2013) carried out an experiment on stem cuttings of *Bougainvillea spectabilis* that were given the following treatments: T_0: control; T_1: IBA in dust form; T_2: IBA -500 ppm; T_3: IBA-1000 ppm; T_4: IBA-2000 ppm; on sprouting and rooted. IBA 1000 ppm was found to be the most effective treatment in terms of days to first rooting (4.0), days to first sprout bud initiation (5.3), leaves per cutting (35.2), sprout length (15.0 cm), branches per cutting (4.7), roots per cutting (64.2), and longest root length (33.2 cm), as well as rooting percentage (100%) and cutting survival percentage (100%).

Sahariya *et al.* (2013) studied that the effect of IBA (0, 1000, 1500, 2000 ppm) on the sprouting of Bougainvillea var. Thimma cuttings in open field and poly house condition. IBA was shown to be more favourable under polyhouse conditions than in open field conditions, however benefits were more obvious under polyhouse conditions when IBA concentration increased from 1500 to 2000 ppm. 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 months (14.73 cm), number of roots per cutting (30), length of roots (12.85 cm), and dry weight of roots obtained after treatment with IBA 2000 ppm (0.43 g).

Singh *et al.* (2013) studied that the effect of various IBA concentrations on the rooting potential of *Bougainvillea glabra* var. Torch Glory during the winter season and discovered that IBA 2000, 2500, and 3000 ppm recorded the highest levels of rooting and sprouting (100%) in cuttings while IBA 3000 ppm produced the highest length of sprout per cutting (18.87 cm) and maximum number of roots per cutting (21.22) in the month of February. With IBA 5000 ppm in February sample, the greatest length of root per cutting was measured at 15.32 cm.

Seyedi *et al.* (2014) studied on *Bougainvillea glabra* cuttings treated with IBA 4000 mg/l exhibited the highest rooting compared to other treatments when researchers studied the impact of stem type and various amounts of IBA on the plant's

ability to root. Semi-hardwood cuttings were discovered to be the best for rooting Bougainvillea glabra since the quantity, length, and fresh weight of the roots were altered at a greater amount of auxin treatment.

Ibironke (2016) performed an experiment on bougainvillaea in which IBA, Tetracycline, and coconut water were used to stimulate the rooting of six different species of bougainvillaea. The findings demonstrated that, in comparison to the other hormone employed, Indole-3-Butyric Acid and coconut water had a substantial impact on root emergence and root development in Bougainvillea species.

2.2.3 Hibiscus

Mukhopadhyay and Gain (1982) found that IBA 1,000 ppm significantly increased number of roots per cutting and number of rooted cuttings in *Hibiscu tiliaceus.*

Bhattacharjee and Balakrishnan (1986) treated the cuttings of *Hibiscus rosa-sinensis* with IBA at 2,000-6,000 mg/l. Best rooting was found in cuttings treated with IBA 2,000 mg/l.

Varalakshmi (1986) studied the effect of IBA on four varieties of *Hibiscus rosa-sinensis* by quick dip and prolong dip method and discovered that quick dip method resulted in maximum percent of rooted cuttings than the prolonged dip method. Cuttings treated in 6,000 ppm IBA yielded maximum percent of rooted cuttings (51.88) among the various concentrations used in quick dip method. Cuttings treated in 250 ppm IBA produced significantly higher percentage of rooted cuttings (41.25) in prolonged dip method.

Gupta (1989) found that the hardwood cuttings of hibiscus treated with IBA at 4,000 ppm resulted in increased rooting percent (80) and survival percent (95.81).

Shiva and Nair (2009) evaluated the effect of rooting hormones on root and shoot characters of hibiscus and found maximum number of roots per cutting (27), longest root (25 cm) and maximum leaf size (7 cm) in cuttings treated with IBA @ 1000 mg/l.

Shadparvar *et al.* (2011) studied the effect of IBA and soil mixture on hibiscus using IBA @ 0, 1000, 2000, and 4000 mg/1 in peat-perlite and sand-perlite and bed and found that the IBA @ 4000 mg/1 and peat-perlite was best treatment for

increasing percentage of rooting and other affecting factors on the quality of cutting in hibiscus.

Torkashvand and Shadparvar (2011) revealed that significantly maximum rooting percentage, root length, root diameter, number of buds, number of root was found with treatment 4000 mg/l IBA and coco peat + perlite as substrate in *Hibiscus rosa-sinensis*.

Bhandari (2014) found that hardwood cutting of hibiscus treated with Indole Butyric Acid (IBA) @ 750 mg/l was most effective with respect to rooting percentage, number of days to sprout, number of shoots, number of roots, number of leaves, fresh and dry weight of roots and survival percentage of cuttings in hibiscus.

2.2.4 *Jasminum* spp.

Gowda *et al.* (1989) found that hardwood cuttings of *J. sambac* treated with 5000 ppm IBA gave higher percentage of rooting with more number of roots and longer roots per cutting.

Sreelatha *et al.* (1991) noticed that cuttings of *J. auriculatum* treated with 3,000 ppm NAA or 4,000 ppm IBA found maximum rooting percentage, whereas cuttings of *J. grandiflorum* treated with 2000 ppm IBA found maximum rooting percentage.

Sari and Qrunflesh (1995) noticed that the rooting percentage was greater in softwood cutting of *Jasminum grandiforum* when treated with NAA at 500 mg/liter.

Basavarajeshwari and Kanamadi (1998) treated the hardwood cuttings of *Jasminum grandiflorum*, *J. sambac* and *J. auriculatum* with IBA at 2000, 4000 and 6000 ppm concentrations. They found that maximum rooting percentage in IBA at 4000 ppm within all the three species.

Patel (2001) revealed that 4,000 ppm IBA was found best for obtaining good rooting in cuttings, length and thickness of the longest root, number of main roots, sprouting and number of shoots per rooted cuttings as well as fresh and dry weight of roots and survival percentage of rooted cutting among different levels of IBA (1,000, 2,000, 3,000, 4,000 and 5,000 ppm), in hardwood cutting of *Jasminum sambac* cv. 'Double Mogra'.

Singh (2001) studied the rooting and survival of *Jasminum sambac* cv. Double Mogra stem cuttings. The cuttings were treated with IAA and IBA at 1000, 2000 and

3000 ppm and NAA at 500, 1000 and 1500 ppm. He found the highest rooting percentage, root number and root length in treatment 2000 ppm IBA.

Hirapara *et al.* (2007) recorded that the effect of NAA (2000, 3000, 4000 ppm) and IBA (2000, 3000, 4000 ppm) on vegetative propagation of *Jasminum arborescens* L. cv. Paras, through semi-hard wood cutting and reported that the higher survival percentage, rooting percent and length of longest root per cutting were recorded with IBA of 4000 ppm.

Netam (2018) treated cuttings of *Jasminum sambac* L. Aiton with IBA (500, 1000, 1500 and 2000 ppm). The maximum survival percentage (88.33%) of rooted cuttings, less days to sprouting per cuttings (8.25), maximum number of buds per cutting (2.75), number of leaves per rooted cutting (10.58) and length of shoot per rooted cutting (3.30 cm) were recorded maximum with treatment of IBA at 1500 ppm. While the maximum number of main roots per rooted cutting (9.33) and length of root per rooted cutting (5.10 cm) was also recorded at 1500 ppm IBA.

2.2.5 Poinsettia

Singh and Singh (2005) observed that the cuttings of poinsettia treated with 3000 ppm IBA have obtained the significantly maximum number of primary and secondary roots per cutting, longest root, diameter of root, maximum fresh weight of roots per cutting, highest number of leaves per cutting, maximum length and diameter of sprout.

Ramtin *et al.* (2011) resulted that the combined treatment with lower cutting of poinsettia and hormone density of 1000 mg/l IBA increased rooting, which resulted maximum length of root (53.24 mm), number of cyathium (70.19), number of bracts (25.63), number of buds (215.65) and number of leaves (34.50).

2.2.6 Ixora

Gupta and Kher (1989) treated the cuttings of ixora with IBA at 1,000 to 5,000 mg/l and they found that maximum rooting percentage (86.7%), maximum number of primary roots (24.6) as well as highest survival percentage (96.1%) of cuttings with IBA at 2,000 mg/l.

Shirol *et al.* (1992) treated the stem cuttings of *Ixora singaporensis* with IBA or NAA each at 2000, 3000 and 4000 ppm alone or in combination. They observed that 2000 ppm IBA concentration gave the maximum rooting percentage.

Bhattacharjee and Balakrishna (1992) found that the stem cuttings of *Hamelia patens* and *Ixora singaporensis* treated with IBA 4000 ppm stimulated maximum rooting, survival percentage and large number of roots.

Dave *et al.* (1993) studied on the ixora stem cuttings treated with IBA, NAA and IAA at 1,000, 2,000 and 3,000 mg/lit each by quick dip method. They observed that among all treatments, IBA at 2,000 mg/lit was the most effective in inducing rooting as compared to IAA and NAA.

Mallareddy and Vittal (1993) conducted an experiment to study the efficacy of cool-humid chamber on rooting of *Ixora singaporensis* by employing four concentrations of IBA viz., 0, 1,000, 2,000 and 3,000 mg/litre. IBA 3,000 mg/litre gave significantly higher survival percentage (88.89), rooting percentage (100) and maximum number of roots (40.31) among all the concentrations but it was at par with 2,000 mg/litre except in case of number of roots per cutting.

Thakor (1994) revealed that the hardwood cuttings of ixora treated with 3,000 ppm IBA + NAA mixture was the most effective for rooting.

Patel and Dave (1996) found that the cuttings of ixora treated with IBA at 2,000 ppm promoted the highest rooting (62.63%) followed by IAA, 3,000 ppm (58.13%) and NAA 1,000 ppm (56.75%).

Thakor *et al.* (1996) revealed that hardwood cuttings of ixora treated with 3,000 ppm of IBA + NAA solution was found most effective for stimulated rooting.

2.2.7 Carnation

Gowda *et al.* (2017) studied the effect of IBA on rooting of different carnation genotypes. IBA showed significant difference for rooting percent, days to root initiation, number of roots per cutting, root length, fresh weight of roots and dry weight of roots.

Prince and Beniwal (2017) studied an influence of Indole-3-Butyric Acid on rooting efficiency in different carnation genotypes under protected condition. As compared to 200 ppm concentration, 500 ppm IBA resulted in the maximum percentage of rooting.

2.2.8 Marigold

Bhatt and Chouhan (2012) studied effect of different rooting hormones and their different combination on rooting of African Marigold (*Tagetes erecta* L.) and results found that maximum number of roots per cutting after 20 and 30 days was 40.53 and 58.79, respectively under the treatment at IBA + NAA 150ppm. The length of stem per cutting was maximum (6.1 and 15.33 cm) under IBA + NAA 150ppm after 20 and 30 days, respectively. The length of root per cutting was recorded maximum (4.6 cm) under NAA 200ppm after 20 days and (5.51 cm) under IBA + NAA 150ppm after 30 days.

Sharma (2014) conducted experiment to observe the effect of rooting hormone IBA on propagation of marigold and concentrations 0, 100, 200, 300, 400, 500 ppm were treated to well-prepared marigold cuttings and reported that the root length (9.14 cm) and root spread (4.53 cm) was highest in 200 ppm of IBA. Whereas, the maximum number of roots (44.43), higher fresh weight (0.71 gm) and dry weight (0.079 gm) of roots found in 400 ppm of IBA.

Majumder *et al.* (2014) revealed that in shoot tip culture of Marigold cv. Pusa Narangi Gainda half-strength MS medium supplemented with 1.0 mg/l NAA and 1.0 mg/l IBA was found to be efficient for rooting (87.33%). While MS medium supplemented with low auxin (0.2 mg/l NAA) was found to be highest shoot multiplication (10.15 shoots/explant).

CHAPTER – III

MATERIAL AND METHODS

CHAPTER-III

MATERIALS AND METHODS

The present investigation on "Studies on effect of different rooting hormones on stem cutting of croton (*Codiaeum variegatum*)'' was carried out at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, during the year 2021-22. 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 the shade net house. Geographically, Parbhani is situated between 190 27' North latitude and 760 78' East longitudes at an altitude of 408.50 meters above the mean sea level. The climate of Marathwada region on annual basis is classified as semi-arid type. Parbhani is grouped under assured rainfall zone. The region experiences hot dry summer (March - May), cold dry winter (October - February) and wet humidity with medium rainfall in monsoon season (June - September). But due to vagaries of monsoon the crop production is always at a risk. Mean rainfall received in experimental year was 283.25 mm, distributed in 51 rainy days. The maximum temperature range during experiment season from 16.5 to 33.8℃ (2021) whereas mean minimum temperature varied in between 11.3 to 23.1℃ (2021). Relative humidity range observed 22 to 100 percent during the period of experiment.

3.2 Preparation of media

The media was prepared in the ratio of 1:2:1 of red soil, sand and FYM respectively. The sand was taken as a major part has low water retention but excellent aeration. The media was prepared by mixing the one part of red soil and one part of FYM and two parts of sand and the media was filled in nine inches polybags. The media was treated with 50 g Carbendazim (50% w/p) and Chloropyriphos 100 ml (20 EC) for prevention against soil borne fungal diseases and termites, respectively.

3.3 Experimental details

The experiment was laid out in CRD (Completely Randomized Design) with Ten treatment combinations replicated thrice.

1.	Name of the Crop	:	Croton
2.	Botanical name	:	*Codiaeum variegatum*
3.	Number of treatments	:	10
4.	Number of cuttings pertreatments	:	20
5.	Number of replications	:	03
6.	Location	:	Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.
7.	Experimental design	:	Completely Randomized Design
8.	Date of planting	:	August 2021
9.	Method of planting	:	Polybag

Table 3.1: The details of treatments

Treatments	Name of Treatment	Plant Growth Regulators	Concentration (ppm)
T_1	IAA	Indole-3-acetic acid	500
T_2	IAA	Indole-3-acetic acid	1000
T_3	IAA	Indole-3-acetic acid	1500
T_4	IBA	Indole-3- butyric acid	500
T_5	IBA	Indole-3- butyric acid	1000
T_6	IBA	Indole-3- butyric acid	1500
T_7	NAA	Naphthalene acetic acid	500
T_8	NAA	Naphthalene acetic acid	1000
T_9	NAA	Naphthalene acetic acid	1500
T_{10}	Control (Distilled water)	-	-

3.4 Methodology

Treatments were evaluated in a completely randomized design (CRD) with three replications, each replication consisted of 20 cuttings. Semi-hardwood croton cuttings used in this study. Red soil + Sand + FYM in the ratio of 1:2:1 was used as a rooting media. Auxins are widely used for promoting rooting of hardwood cuttings (Hartman

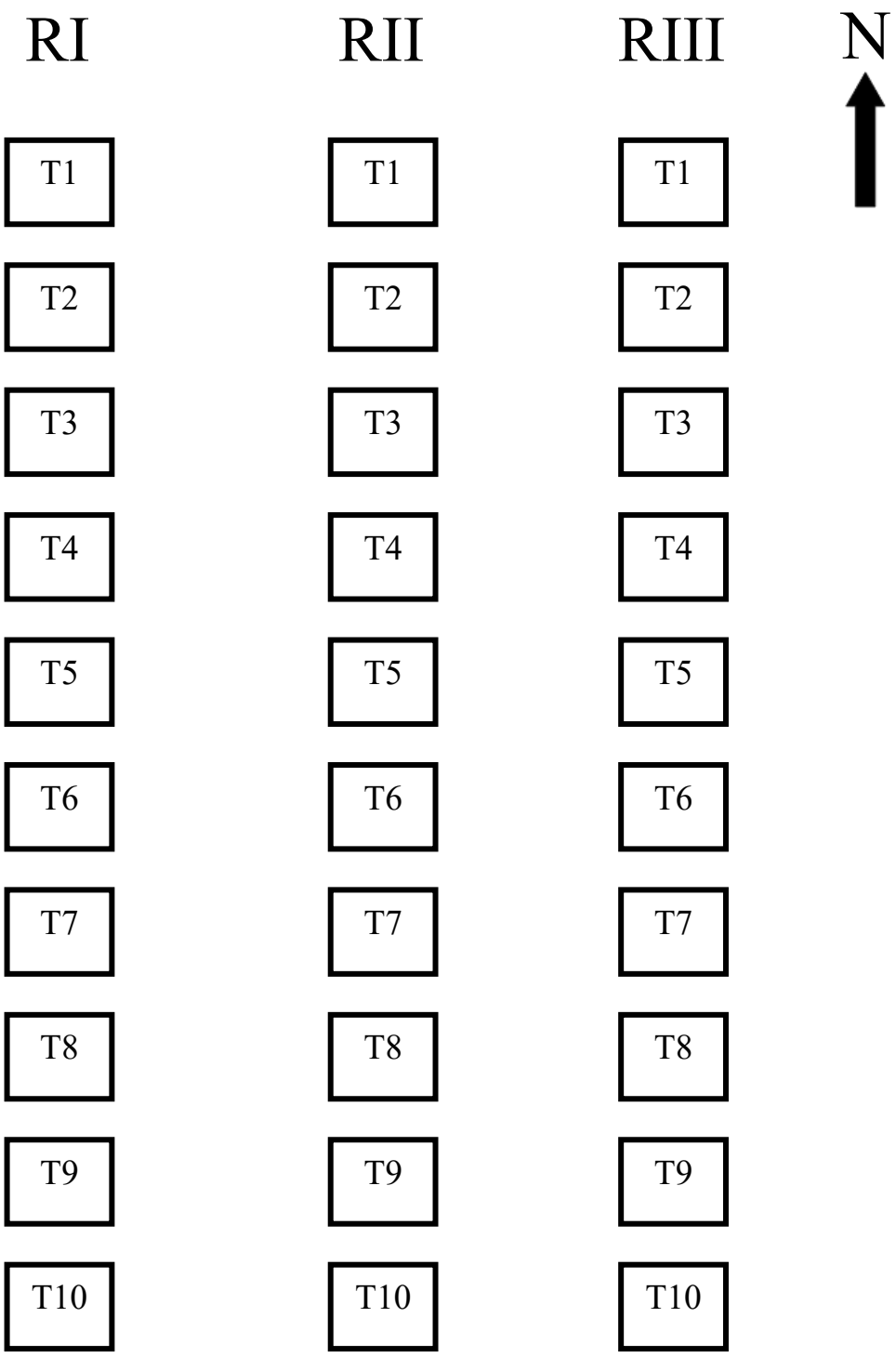

Fig 3.1: Plan of layout

Plate 1: General view of the experiment.

et al., 2002) IAA, IBA and NAA are used as rooting hormones. The formulations of auxins were prepared by dissolving the pure compound in 95% ethanol and adding distilled water. Control treatment was maintained without combination of auxins. Cutting of 6 - 8 buds were prepared after discarding the non-hardened upper parts. In order to reduce the transpiration, all leaves are removed from the cuttings. The basal end of cuttings was dipped briefly in a fungicide solution @ 0.1% of Captan prior to imposing rooting hormone treatments.

3.5 Plant growth regulators (PGRs) used in experimentation

Table 3.2: Plant growth regulators used in experimentation

Sr. No.	Growth regulator (Auxins)	Molecular formula	Molecular weight (g/mol)	Nature of solubility
1	Indole-3-acetic acid (IAA)	$C_{10}H_9NO_2$	175.18	Alcohol (Polar solvents)
2	Indole-3-butyric acid (IBA)	$C_{12}H_{13}NO_2$	203.24	Alcohol (Polar solvents)
3	1-Naphthelene acetic acid (NAA)	$C_{12}H_{10}O_2$	186.21	Alcohol (Polar solvents)

3.6 Preparation of treatment solutions

3.6.1 Preparation of IAA solutions

To prepare 500 ppm of Indole Acetic Acid solution 500 mg of IAA was dissolved in 10 ml of ethanol taking in a volumetric flask and then the volume was made to one litreby adding required amount of distilled water followed by frequent stirring. A 1000 ppm IAA solution was prepared by dissolving 1 g of IAA powder in 10 ml of ethanol taking in a volumetric flask and then the volume was made to one litre by adding sufficient distilled water with frequent stirring. Similarly, 1500 ppm of IAA solution was made by dissolving 1500 mg of IAA in 10 ml of ethanol taking in a volumetric flask and then the volume was made to one litre by adding required quantities of distilled water with frequent stirring.

3.6.2 Preparation of IBA solutions

To prepare 500 ppm of Indole Butyric Acid solution 500 mg of IBA was dissolved in 10 ml of ethanol taking in a volumetric flask and then the volume was made to one litre by adding required amount of distilled water followed by frequent stirring. A 1000 ppm IBA solution was prepared by dissolving 1 g of IBA powder in 10 ml of ethanol taking in a volumetric flask and then the volume was made to one litre by adding sufficient distilled water with frequent stirring. Similarly, 1500 ppm of IBA solution was made by dissolving 1500 mg of IBA in 10 ml of ethanol taking in a volumetric flask and then the volume was made to one litre by adding required quantities of distilled water with frequent stirring.

3.6.3 Preparation of NAA solutions

To prepare 500 ppm of NAA, solution 500 mg of NAA was dissolved in 10 ml of ethanol taking in a volumetric flask and then the volume was raised to one litre by adding distilled water with frequent stirring. 1 g of NAA powder was dissolved in 10 ml of ethanol taking in a volumetric flask and then the volume was made to one litre by adding sufficient amount of distilled water with frequent stirring to prepare 1000 ppm of NAA solutions. Similarly, 1500 ppm of NAA solution was prepared when 1500 mg of NAA powder was dissolved in 10 ml of ethanol taking in a volumetric flask and then the volume was made to 1 litre by adding required amount of distilled water with frequent stirring.

3.7 Preparation of cuttings

Fresh branches were collected from 3-4 years old healthy plants of *Codiaeum variegatum* from the college nursery. All the branches were removed from the semi-hardwood branches after which they were cut into 15 cm long segments with 6-8 nodes. A slant cut was given at the base of the cuttings.

3.7.1 Treatment of cuttings

Different concentrations of IAA, IBA, NAA were used for treatment by dipping basal end of cuttings in jars containing 100 ml growth regulator solution.

3.7.2 Treatment application and planting of cuttings

The method adopted for treatment of cuttings with growth regulator solution

Plate 2: Dipping the cuttings of Croton in treatment solutions.

with the help of quick dip method. In which, the basal end of the prepared cuttings were kept standing in solution of growth regulator to a depth of 2.5-3.0 cm for 2 to 5 minutes. twenty cuttings for each treatment were treated with the growth regulators and repeated thrice in Completely Randomized Design. The treated cuttings were planted in polybags under shade net house as per treatment. The planting was done in slightly slanting position.

3.7.3 After care

The polythene bags were kept moist by watering regularly with rose-can at an interval of 2-3 days. The weeds were timely removed manually from the polythene bags.

3.8 Details of observations recorded

Five randomly chosen cuttings in each replication of all treatments were labeled 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.

3.8.1 Number of days taken for 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.

3.8.2 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.

3.8.3 Success percentage

The percentage of rooted cuttings were calculated by dividing the number of rooted cuttings with the total number of cuttings planted and multiplied with hundred.

3.8.4 Mortality percentage

Mortality percentage of cuttings was recorded in each treatment one month after propagation in polythene bags by counting the total number of dead cuttings out of total cuttings planted in polythene bags.

3.8.5 Number of shoots per cutting

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

3.8.6 Length of the shoot per cutting (cm)

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

3.8.7 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.

3.8.8 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.

3.8.9 Number of leaves per cutting

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

3.8.10 Plant height (cm)

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

3.8.11 Survival percentage of the cuttings

The number of living plant was transplanted in polythene bags and after three weeks of transplanting of rooted cuttings the survival percentage of rooted cuttings was worked out under different treatment.

3.8.12 Fresh weight of shoot per cutting (g)

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

3.8.13 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.

3.8.14 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.

3.8.15 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.

3.8.16 Root: shoot ratio

Root: shoot ratio was worked out by using formula

$$\text{Root: shoot ratio} = \frac{\text{Dry weight of root}}{\text{Dry weight of root}}$$

3.9 Economics of cuttings production

3.9.1 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.

3.9.2 Success percentage

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

3.9.3 Price of each cutting

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

3.9.4 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.

3.9.5 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.

3.9.6 Net income for 100 cuttings

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

3.9.7 B:C ratio

Benefit : cost ratio was worked out by using formula

$$\text{Benefit : cost ratio} = \frac{\text{Gross return from 100 cuttings}}{\text{Expenditure for producing 100 cuttings}}$$

3.10 Statistical analysis

The data on sprouting, rooting and shooting of croton 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.

CHAPTER – IV

RESULTS AND DISCUSSION

CHAPTER –IV

RESULTS AND DISCUSSION

The present investigation entitled "Studies on effect of different rooting hormones on stem cutting of croton (*Codiaeum variegatum*)." was conducted at the Department of Horticulture, Vasantrao Naik Krishi Vidyapeeth, Parbhani during 2021-22. This chapter deals with the results obtained for various characters of shoot and root growth of croton as influenced by different concentrations of IAA, IBA and NAA. The data has been presented in tabular form and also supported by graphical representation, wherever necessary along with statistical interpretation. Data recorded on various aspects during the course of investigation revealed interesting facts.

4.1 Number of days taken for sprouting

The semi hardwood cuttings responded to growth regulators to induce sprouting. It was found that treatment of cuttings resulted significant difference in sprouting. The results pertaining to number of days taken to sprouting have been presented in Table 4.1 and depicted graphically in Fig. 4.1.

The results of present study revealed that treatment T_5 *i.e.* IBA 1000 ppm induced early sprouting of cutting (20.20) compared to all other treatments significantly which was at par with treatment T_6 *i.e.* IBA 1500 ppm (20.37) and treatment T_9 *i.e.* NAA 1500 ppm (21.32). Remaining all other treatments recorded intermediate results. However, the maximum number of days (24.34) for sprouting of cuttings was taken by the control.

Cuttings treated with IBA showed less number of days taken to sprouting and it could be attributed to auxin and its appropriate concentration which promoted the formation of callus tissue and differentiation of vascular tissue (Mitra and Bose 1957). These results are probably due to the application of IBA at suitable concentrations, that increased IBA oxidase activity and promoted earlier roots formation (Carpenter and Cornell 1992). IBA is the best root promoter due to its fast auxin activity and an enzymatic system of fairly slow destruction. Auxin treatment may have increased rooting in treated cuttings by supplementing the endogenous auxin concentration at the base of the cuttings, which expedited root initiation and development of root primordial (Hartmann *et al.* 2002) Additionally, the early sprouting may be caused by

due to utilization of stored carbohydrates, nitrogen and other elements present in cutting with the help of growth regulators (Chandramouli 2001).

Above results are in conformity with the Hoda (2021) in croton cuttings treated with 2000 ppm IBA recorded the shortest days to sprouting. Dhua *et al.* (1982) in guava cuttings, Kumari *et al.* (2013) in *Jatropha curcas*.

Table 4.1: Effect of plant growth regulators on number of days taken for sprouting in croton cuttings

Treatment No.	Name of Treatment	Number of days taken for sprouting
T_1	IAA 500 ppm	23.10
T_2	IAA 1000 ppm	22.39
T_3	IAA 1500 ppm	21.51
T_4	IBA 500 ppm	22.08
T_5	IBA 1000 ppm	20.20
T_6	IBA 1500 ppm	20.37
T_7	NAA 500 ppm	22.59
T_8	NAA 1000 ppm	21.75
T_9	NAA 1500 ppm	21.32
T_{10}	Control	24.34
S.E(m).±		**0.40**
C.D. @ 5%		**1.27**

4.2 Number of days taken to root formation

The data related to number of days to root formation as influenced by the plant growth regulators on croton cutting is presented in Table 4.2 and depicted graphically in Fig. 4.2

It clearly indicates that, for root formation in croton cuttings the plant growth regulators differed significantly, the treatment T_5 IBA 1000 ppm recorded minimum (17.61) number of days to root formation and significantly at par with treatment T_6 *i.e.* IBA 1500 ppm (18.43) and treatment T_9 *i.e.* NAA 1500 ppm (18.52). To induce root formation there was significantly maximum number of days (22.07) was registered in control. Remaining all other treatments showed intermediate results.

Plate 3: Sprouting observed in the cutting treated with IBA 1000 ppm .

The number of days to root formation was found earlier in cuttings treated with IBA and it may be due to IBA stimulates initiation of cambial activity, root initials and triggers early formation of root primordia. Additionally, early rooting in cuttings treated with IBA may be aided by the fact that they are more persistent and do not translocate from the site of treatment.

Table 4.2: Effect of plant growth regulators on number of days taken to root formation in croton cuttings

Treatment No.	Name of Treatment	Number of days taken to root formation
T_1	IAA 500 ppm	20.86
T_2	IAA 1000 ppm	19.93
T_3	IAA 1500 ppm	19.40
T_4	IBA 500 ppm	19.29
T_5	IBA 1000 ppm	17.61
T_6	IBA 1500 ppm	18.43
T_7	NAA 500 ppm	19.26
T_8	NAA 1000 ppm	18.75
T_9	NAA 1500 ppm	18.52
T_{10}	Control	22.07
S.E(m).±		**0.79**
C.D. @ 5%		**2.35**

Rooting of cuttings revealed the presence of auxin which produced in buds or young leaves and carried to the base of the cutting and stimulated the formation of callus and emergence of roots (Shadparvar *et al.* 2011). Auxin may promote high metabolic activity and maximum utilisation of sugar and starch after stem hydrolysis, hence it becomes clear to inderstand why roots develop more quickly and rooting is improved. Among the various auxins superior effect of IBA was noticed because of its higher chemical stability and slow mobility in the plant system.

These findings were agreement with the eralier research of Stefancic *et al.* (2005) who resulted that Early adventitious root formation is impacted by IBA treatment. The considerable influence of the IBA on the rooting and root growth has been experimentally substantiated by several workers like Hirapara *et al.* (2007) and

Patel (2001) in Jasmine, Shirol *et al.* (1992) and Sochacki and Chmiel (1994) in *Poinsettia pulcherrima*, Torkashvand and Shadparvar (2011) in Hibiscus, Patel (2011) and Sahariya *et al.* (2013) in Bougainvillea.

4.3 Success percentage

The results pertaining to success percentage have been presented in Table 4.3 and depicted graphically in Fig. 4.3.

Treatments of plant growth regulators exhibited significant difference in success percentage of cuttings. The maximum success percentage was observed in treatment T_5 *i.e.* IBA 1000 ppm (78.86) followed by treatments T_6 *i.e.* IBA 1500 ppm (76.17) and treatment T_9 *i.e.* NAA 1500 ppm (74.12) and minimum was observed in control (61.58).

Table 4.3: Effect of plant growth regulators on success percentage of croton cuttings

Treatment No.	Name of Treatment	Success percentage
T_1	IAA 500 ppm	63.49 **(52.82)***
T_2	IAA 1000 ppm	65.61 **(54.09)**
T_3	IAA 1500 ppm	68.91 **(56.11)**
T_4	IBA 500 ppm	73.47 **(58.99)**
T_5	IBA 1000 ppm	78.86 **(62.62)**
T_6	IBA 1500 ppm	76.17 **(60.78)**
T_7	NAA 500 ppm	69.24 **(56.31)**
T_8	NAA 1000 ppm	72.78 **(58.55)**
T_9	NAA 1500 ppm	74.12 **(59.42)**
T_{10}	Control	61.58 **(51.69)**
S.E(m).±		**1.69**
C.D. @ 5%		**5.04**

* Figures in parentheses are arcsine transformed value

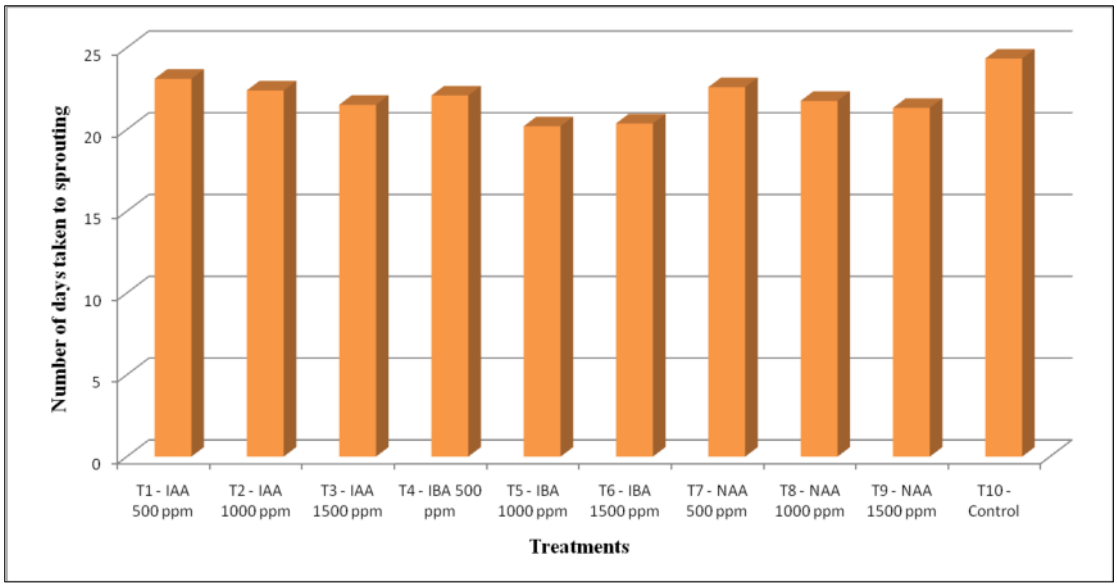

Fig. 4.1: Effect of plant growth regulators on number of days taken for sprouting in croton cuttings.

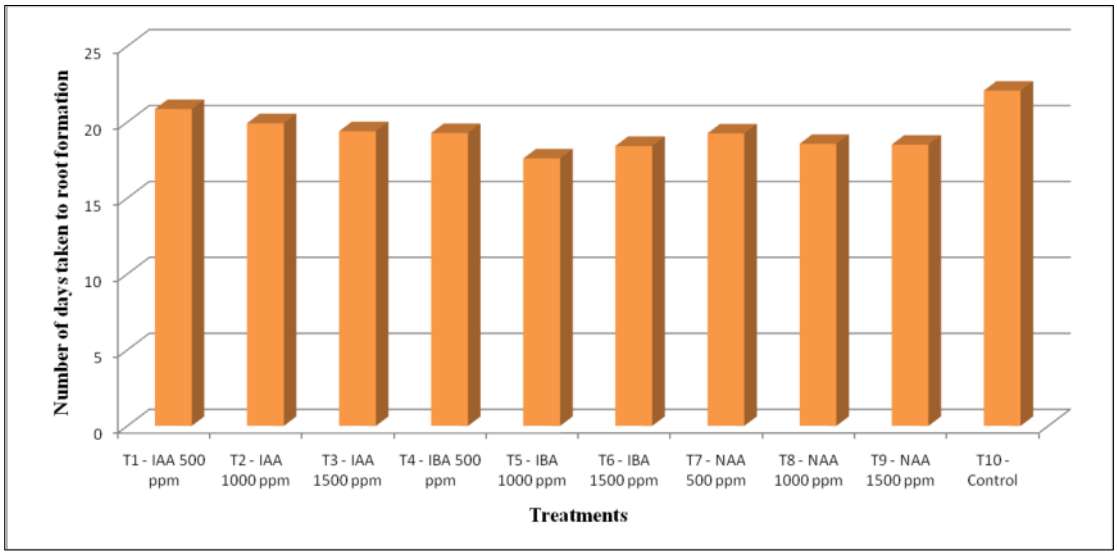

Fig. 4.2: Effect of plant growth regulators on number of days taken to root formation in croton cuttings

This might be due to the fact that auxin is known to induce stimulus for regeneration of roots by promotion of hydrolysis, mobilization and utilization of nutritional reserves in the region of root and shoot formation (Nanda 1975). The specific concentration of IBA induced maximum number of roots with considerable length and hence formed well developed root system for better establishment of rooted cuttings (Singh and Singh 2005) in Croton.

This result is in close approximately with the findings of Sultana (2006) in nerium, bougainvillea and Jasminum and Hemlata *et al*. (2013) in croton.

4.4 Mortality percentage

The results pertaining to mortality percentage have been presented in Table 4.4 and depicted graphically in Fig. 4.4.

Treatments of plant growth regulators exhibited significant difference in mortality percentage of cuttings. The minimum mortality percentage was observed in treatment T_5 *i.e.* IBA 1000 ppm (21.14) followed by treatments T_6 *i.e.* IBA 1500 ppm (23.83) and treatment T_9 *i.e.* NAA 1500 ppm (25.88) and maximum was observed in control (38.42).

This might be due to stronger framework of root system lead to less number of failure cuttings.

Our findings with respect to mortality percentage of croton cuttings after treatment with rooting hormones at different concentration are in closely conformity with the earlier findings as reported by (Preece 2003) who found that cuttings treated with moderate concentrations of IBA hormone (400 ppm to 500ppm) and high concentrations of NAA hormone resulted in low mortality percentage which made them to perform better even after transplanting as compared to other concentrations and control, and also resulted in better number of rooted cuttings.

This reason might be due to the fact that applied auxin is capable of stimulating adventitious rooting although promoting rooting on stem terminal cuttings depends on adequate absorption by plant tissue however, the absorption of auxin solutions at the base of terminal stem cuttings can be influenced by the concentration and treatment duration such as at high concentrations it can inhibit subsequent bud break and results to an increase in the amount of callus and retard elongation of young shoots (Loach 1988).

Several studies have also shown that exogenous application of auxin i.e. IBA

and NAA resulted in reduction of mortality percentage as reported in several studies such as Nisio (1998) and Qin and Luo (2007) in chrysanthemum.

Table 4.4: Effect of plant growth regulators on mortality percentage of croton cuttings

Treatment No.	Name of Treatment	Mortality percentage
T_1	IAA 500 ppm	36.51 **(37.17)***
T_2	IAA 1000 ppm	34.39 **(35.90)**
T_3	IAA 1500 ppm	31.09 **(33.88)**
T_4	IBA 500 ppm	26.53 **(31.00)**
T_5	IBA 1000 ppm	21.14 **(27.37)**
T_6	IBA 1500 ppm	23.83 **(29.21)**
T_7	NAA 500 ppm	30.76 **(33.68)**
T_8	NAA 1000 ppm	27.22 **(31.44)**
T_9	NAA 1500 ppm	25.88 **(30.57)**
T_{10}	Control	38.42 **(38.30)**
S.E(m).±		**1.50**
C.D. @ 5%		**4.78**

* Figures in parentheses are arcsine transformed value

4.5 Number of shoots per cutting

The results pertaining to number of shoots per cutting have been presented in Table 4.5 and depicted graphically in Fig. 4.5

Plant growth regulators treatments exhibited significant difference on number of shoots per cuttings in Croton. The results of present study revealed that treatment T_5 *i.e.* IBA 1000 ppm induced maximum number of shoots per cuttings (3.22) compared to all other treatments significantly which was at par with treatment T_6 *i.e.* IBA 1500 ppm (2.78) and treatment T_9 *i.e.* NAA 1500 ppm (2.67). All other remaining treatments recorded intermediate results. However, the minimum number of shoots (1.24) observed in control.

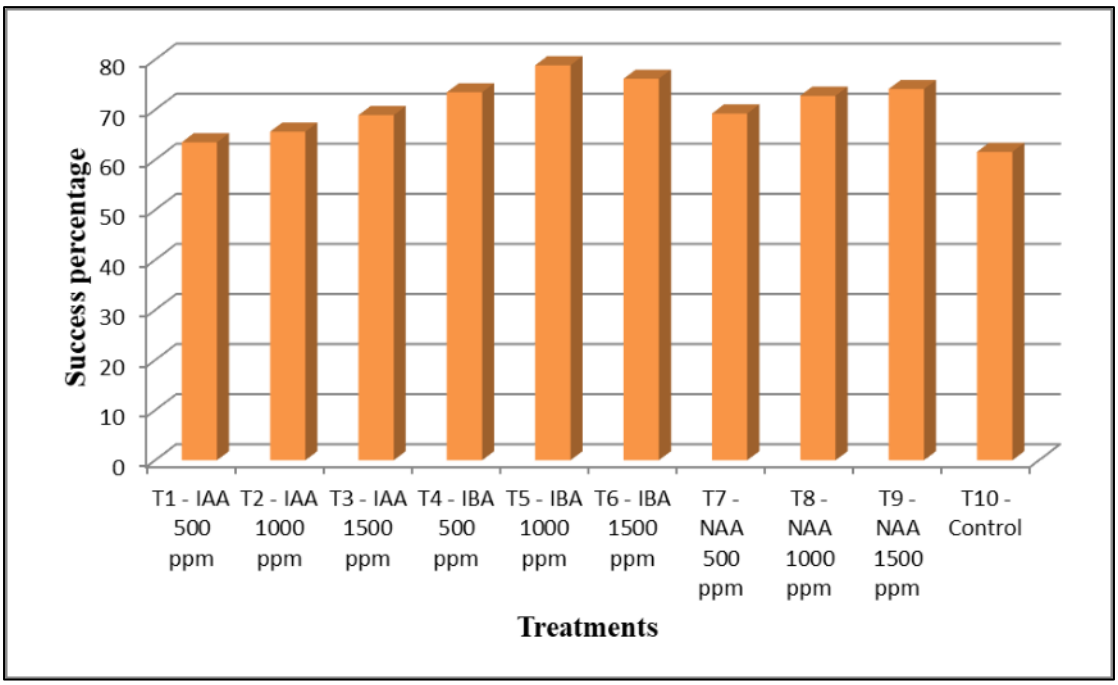

Table 4.3: Effect of plant growth regulators on success percentage of croton cuttings

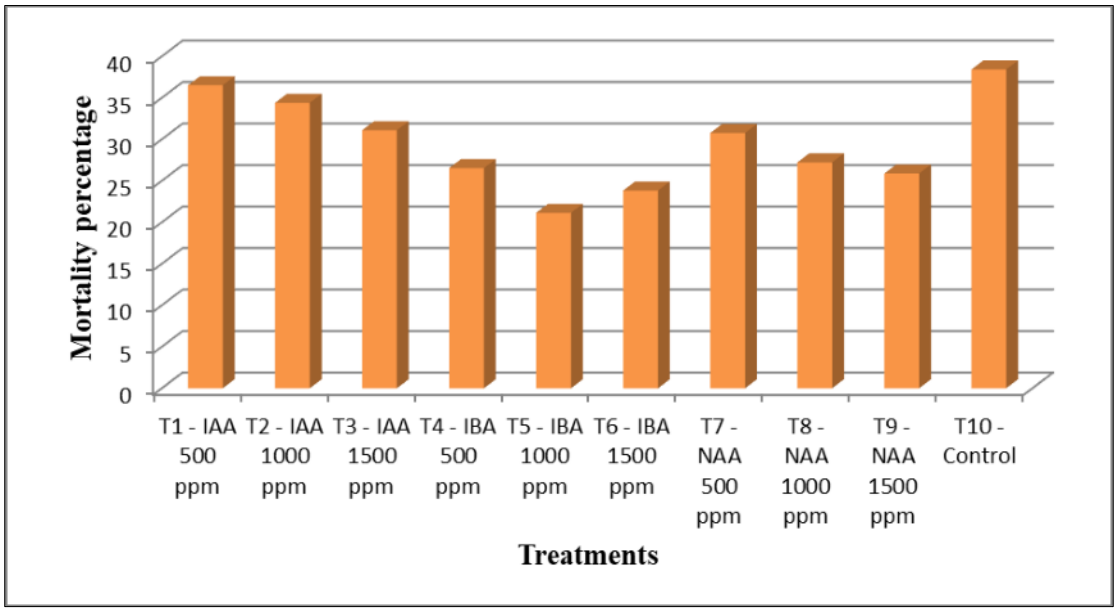

Table 4.4: Effect of plant growth regulators on mortality percentage of croton cuttings

The cuttings treated with IBA produced the maximum number of shoots per cutting, which may have been a result of the vigorous root system which enhanced nutrient uptake under the combined influence of IBA. Growth regulators helped to mobilise the stored food material that was present in the cutting. This may have accelerated sprouting by generating a sink at the base of cuttings and improving photosynthesis, which would have improved the use of carbohydrates (Singh *et al.* 2013).

These findings were agreement with the earlier research of Alshammary *et al.* (2013) in *Bougainvillea peruviana* cv. Shubra and *Hamelia patens* and Panwar (1988) and Patel (1990) in stem cuttings of bougainvillea.

These findings were agreement with the earlier research of Stefancic *et al.* (2005) who resulted that early adventitious root formation is impacted by IBA treatment. The considerable influence of the IBA on the rooting and root growth has been experimentally substantiated by several workers like Hirapara *et al.* (2007) and

Table 4.5: Effect of plant growth regulators on number of shoots per cutting

Treatment No.	Name of Treatment	Number of shoots per cutting
T_1	IAA 500 ppm	1.94
T_2	IAA 1000 ppm	2.06
T_3	IAA 1500 ppm	2.20
T_4	IBA 500 ppm	2.59
T_5	IBA 1000 ppm	3.22
T_6	IBA 1500 ppm	2.78
T_7	NAA 500 ppm	2.00
T_8	NAA 1000 ppm	2.31
T_9	NAA 1500 ppm	2.67
T_{10}	Control	1.24
S.E(m).±		**0.19**
C.D. @ 5%		**0.59**

Patel (2001) in Jasmine, Shirol *et al.* (1992) and Sochacki and Chmiel (1994) in *Poinsettia pulcherrima*, Torkashvand and Shadparvar (2011) in hibiscus, Patel (2011) and Sahariya *et al.* (2013) in Bougainvillea.

4.6 Length of the shoot per cutting (cm)

Shoot length is one of the main characters representing vegetative growth of plant. The length of the longest shoot was recorded at 60 days after planting of cuttings. The effect of different treatments on length of shoot is presented in Table 4.6 and depicted graphically in Fig. 4.6.

The treatment of the cuttings of croton with plant growth regulators had significantly influenced the length of the shoot per cutting. In different levels of growth regulators, treatment T_5 *i.e.* IBA 1000 ppm recorded the highest shoot length (4.06 cm) as compared to rest of the treatments. Which was statistically at par with treatment T_6 *i.e.,* 1500 ppm IBA (3.57). All other remaining treatments recorded intermediate results. The minimum length (0.89 cm) of the shoot was noticed in treatment T_{10} (control). The inhibitory or toxic effects of IBA at greater levels could account for the shorter length of the longest shoot at higher concentrations.

Table 4.6: Effect of plant growth regulators on length of shoot per cutting (cm)

Treatment No.	Name of Treatment	Length of shoot per cutting (cm)
T_1	IAA 500 ppm	1.38
T_2	IAA 1000 ppm	1.99
T_3	IAA 1500 ppm	2.30
T_4	IBA 500 ppm	3.23
T_5	IBA 1000 ppm	4.06
T_6	IBA 1500 ppm	3.57
T_7	NAA 500 ppm	1.76
T_8	NAA 1000 ppm	2.18
T_9	NAA 1500 ppm	3.39
T_{10}	Control	0.89
S.E(m).±		**0.17**
C.D. @ 5%		**0.51**

Better vegetative development with IBA 1000 ppm treated cuttings may be attributed to the greatest number of roots, which likely absorb more nutrients and water from the soil and enhanced photosynthesis, which ultimately led to more growth. (Singh and Singh 2005). Additionally, auxin may influence the cell wall,

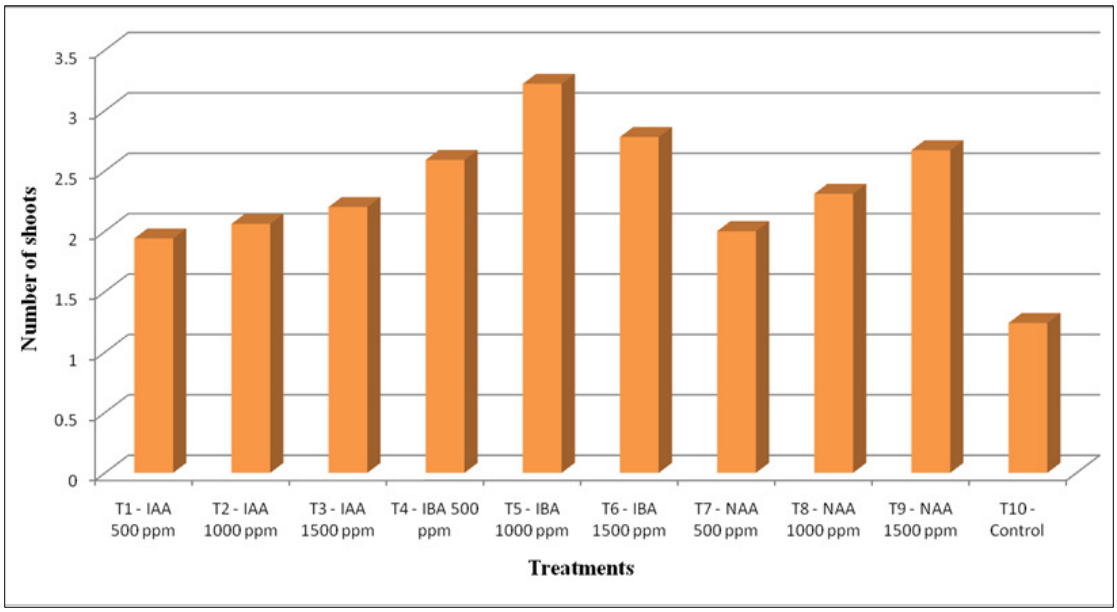

Fig. 4.5: Effect of plant growth regulators on number of shoots per cutting

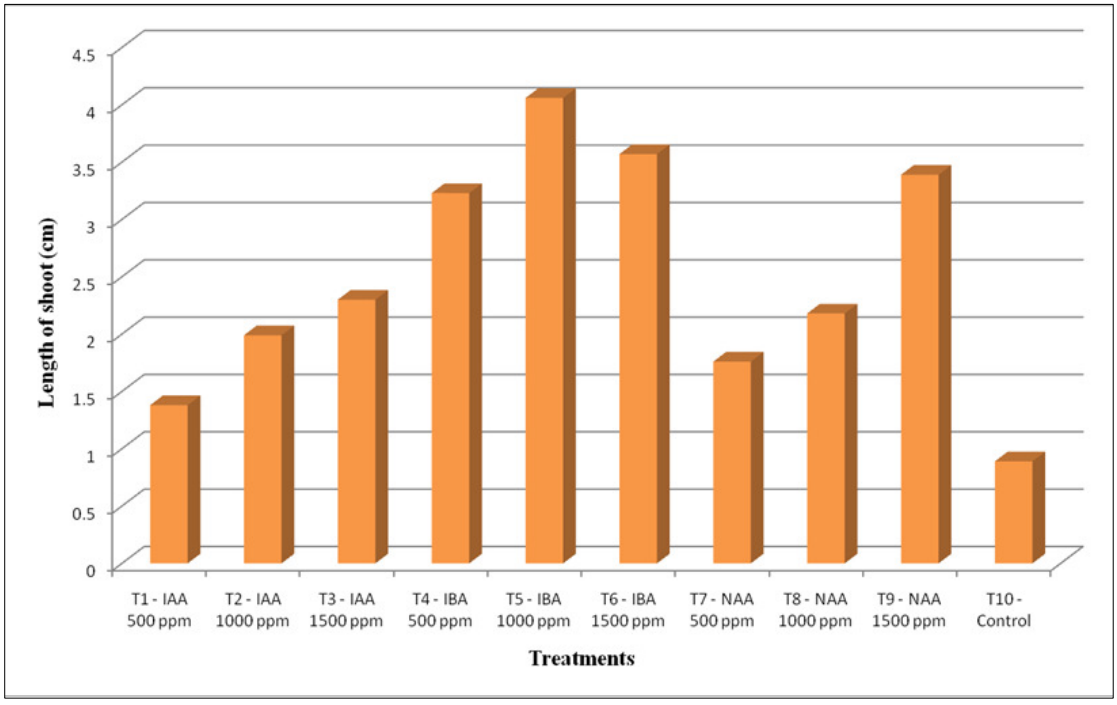

Fig 4.6: Effect of plant growth regulators on length of shoot per cutting (cm)

turgor, osmotic pressure, and water permeability, which results in cell expansion and accelerated vegetative growth and it results into the rise in the shoot length (Taiz and Zeiger 2006).

Auxin increased protein synthesis, cell development, and cell division, which may have led to an increase in vegetative growth (Evans 1973). The shoot length increases with the auxin concentration (Awad *et al.* 1988).

Above results were supported by the earlier research of Nasib *et al.* (2008) in crotons and Akhtar *et al.* (2015) in *Rosa centifolia,* Sharma *et al.* (2014) in Jasmine and Chovatia *et al.* (1995) in cutting of Bougainvillea cv. "Mary Palmer".

4.7 Number of roots per cutting

The results pertaining to number of roots per cutting of croton have been presented in Table 4.7 and depicted graphically in Fig. 4.7.

The result revealed that number of roots per cutting was significantly influenced due to different levels of plant growth regulators. Indole Butyric Acid significantly increased the number of roots per cutting. The treatment T_5 (1000 ppm IBA) recorded the highest number of roots per cutting (14.86) at 30 DAP which was at par with treatment T_6 *i.e.* 1500 ppm IBA (14.53) and treatment T_9 *i.e.* NAA 1500 ppm (14.17). In case of 60 DAP, the treatment T_5 (1000 ppm IBA) recorded maximum number of roots per cutting (26.75), which was at par with treatment T_4 *i.e.* 500 ppm IBA (24.31), T_6 *i.e.* 1500 ppm IBA (25.46) and treatment T_9 *i.e.* NAA 1500 ppm (24.12). However, the minimum number of roots per cutting (7.13 and 11.73) was recorded in the treatment T_{10} (control) at 30 and 60 DAP, respectively.

IBA at 1000 ppm concentration increased the number of roots. There is a decrease in number of roots with the increasing concentration of IBA above 1000 ppm. Reason for this may be due to the fact that auxin helps in rooting behavior only up to particular limit. If higher concentrations that go above the acceptable limits could result in poor or unfavourable circumstances and toxicity of the exogenously applied chemicals (Hartmann and Kester 2002). Initiation of rooting primordia may not be possible with the endogenous auxins that reach the cambial zone. Roots began to grow earlier and in greater numbers when IBA was applied externally at the recommended doses.

The action of auxin may have triggered the hydrolysis and transfer of carbohydrates and nitrogenous substances at the base of cuttings, which may have

contributed to the maximum number of roots per cutting with treatment of IBA (Hartmann *et al.* 2007). Furthermore, proper absorption by plant tissues at the right concentration is necessary to promote roots on Croton stem cuttings when IBA is applied exogenously.

Above results are in conformity with the Hoda (2021) in croton cuttings treated with 2000 ppm IBA recorded the maximum number of roots per cutting. Gupta and Kher (1989) observed the favourable response of IBA in ixora cuttings in which IBA might have helped in increasing the cell multiplication leading to increased number of roots in ixora cuttings.

Table 4.7: Effect of plant growth regulators on number of roots per croton cutting

Treatment No.	Name of Treatment	Number of roots per croton cutting	
		30 DAP	**60 DAP**
T_1	IAA 500 ppm	10.40	17.86
T_2	IAA 1000 ppm	12.00	20.93
T_3	IAA 1500 ppm	13.81	21.54
T_4	IBA 500 ppm	13.38	24.31
T_5	IBA 1000 ppm	14.86	26.75
T_6	IBA 1500 ppm	14.53	25.46
T_7	NAA 500 ppm	12.14	21.60
T_8	NAA 1000 ppm	12.42	23.97
T_9	NAA 1500 ppm	14.17	24.12
T_{10}	Control	7.13	11.73
S.E(m).±		**0.37**	**0.87**
C.D. @ 5%		**1.17**	**2.64**

Above results are in conformity with the Yeshiwas *et al.* (2015) in rose with 1000 ppm increased the number of roots. Netam (2018) in *Jasminum sambac* L. Aiton stem cuttings, maximum number of main roots per rooted cutting (9.33) recorded at 1500 ppm IBA. Gowda *et al.* (2017) in carnation increased the number of roots at IBA 200.

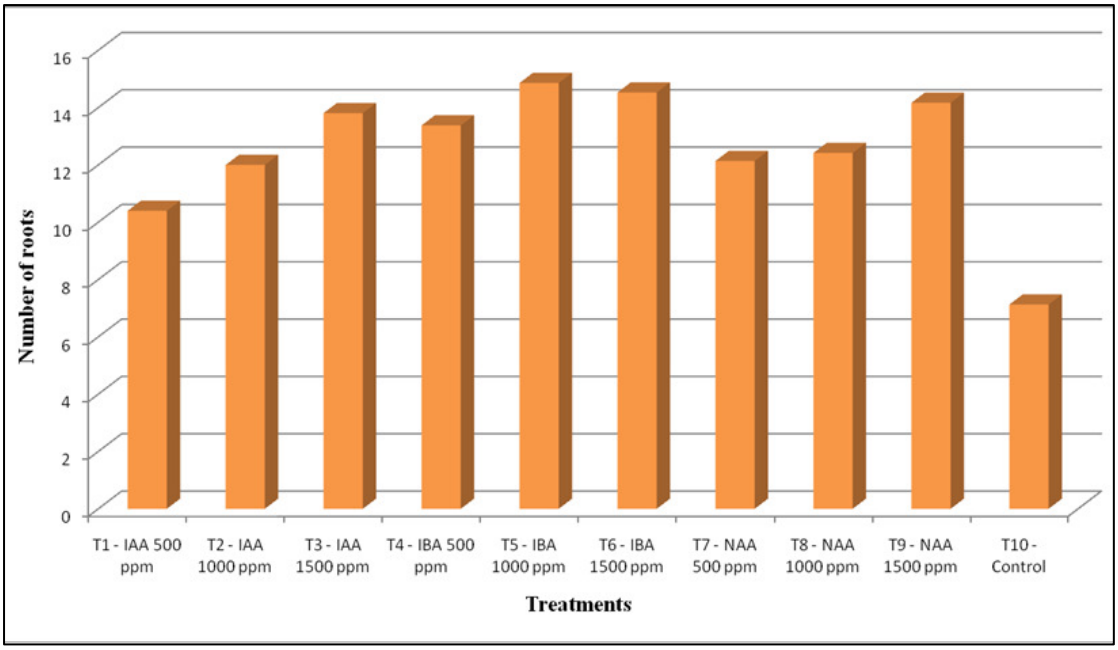

Fig. 4.7.1: Effect of plant growth regulators on number of roots per croton cutting (30 DAP)

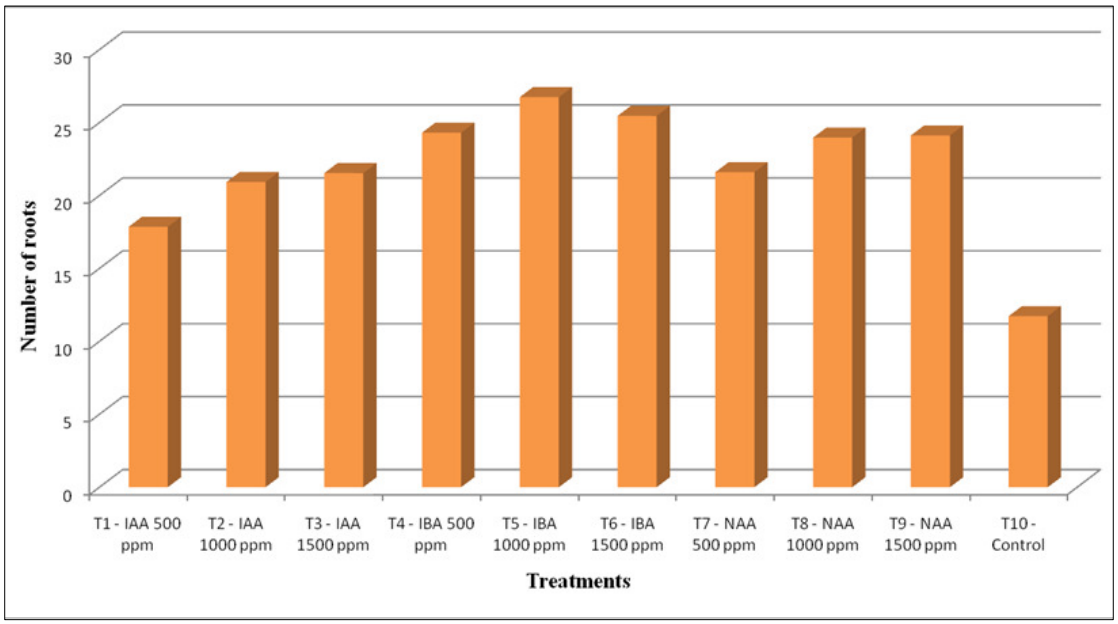

Fig. 4.7.2: Effect of plant growth regulators on number of roots per croton cutting (60 DAP)

Plate 4: Effect of IBA 1000 ppm on number of roots per cutting.

4.8 Length of the root per cutting (cm)

The results pertaining to length of roots per cutting of croton have been presented in Table 4.8 and depicted graphically in Fig. 4.8.

The result revealed that length of roots per cutting was significantly influenced due to different levels of plant growth regulators. Indole Butyric Acid significantly increased the length of roots per cutting. The treatment T_5 *i.e.* IBA 1000 ppm recorded the longest length of roots per cutting (2.22) at 30 DAP which was at par with treatment T_6 *i.e.* 1500 ppm IBA (2.08) and treatment T_9 *i.e.* NAA 1500 ppm (2.04). In case of 60 DAP, the treatment T_5 *i.e.* IBA 1000 ppm recorded the longest length of roots per cutting (4.58), which was at par with treatments T_6 *i.e.* 1500 ppm IBA (4.17) and treatment T_9 *i.e.* NAA 1500 ppm (3.90). However, the minimum length of roots per cutting (0.84 and 1.94) was recorded in the treatment T_{10} (control) at 30 and 60 DAP, respectively.

The growth of roots in plants is controlled by growth substances and a crucial role in this process is being played by auxins hence an external application of synthetic auxins may enhance the effect of endogenous auxins or directly triggered rhizogenesis (Kralik and Sebahenek 1980).

The increased length of roots in cuttings of Croton treated with auxins (IBA 1000 ppm) may be due to the contraction of metabolites at the site of application, which results to the cell expansion, improved hydrolysis of carbohydrates, synthesis of new proteins and cell division driven by auxins (Strydem and Hartmann 1960) and also this outcome could be attributed to auxin which plays a vital role in the process of cell elongation. Furthermore, it was observed that all treated cuttings had higher root length as compared to untreated cuttings.

Similar to our research findings the significant increase in average root length after application of rooting hormones such as IBA and NAA have also been reported earlier by Janakiram *et al.* 2006.

The results obtained are in conformity with the Mehraj *et al.* (2013) in *Bougainvillea spectabilis* stem cuttings with IBA 1000 ppm increased root length. Siddiqui and Hussain (2007) in *Ficus hawaii* cuttings with 4000 ppm IBA increased root length.

Table 4.8: Effect of plant growth regulators on length of root per croton cutting

Treatment No.	Name of Treatment	Length of roots per croton cutting	
		30 DAP	60 DAP
T_1	IAA 500 ppm	1.17	2.63
T_2	IAA 1000 ppm	1.64	3.28
T_3	IAA 1500 ppm	1.97	3.55
T_4	IBA 500 ppm	1.76	3.44
T_5	IBA 1000 ppm	2.22	4.58
T_6	IBA 1500 ppm	2.08	4.17
T_7	NAA 500 ppm	1.87	2.85
T_8	NAA 1000 ppm	1.98	3.76
T_9	NAA 1500 ppm	2.04	3.90
T_{10}	Control	0.84	1.94
S.E(m).±		**0.07**	**0.23**
C.D. @ 5%		**0.21**	**0.70**

Similar, results were also observed by Panwar *et al.* (2001) and Patel (1990) in stem cuttings of bougainvillea and Singh *et al.* (1993) in fig, who found that exogenous application of auxins resulted in increased root length.

4.9 Number of leaves per cutting

In terms of number of leaves per cutting of croton, the results have been presented in Table 4.9 and depicted graphically in Fig. 4.9.

Treatments of plant growth regulators were found significantly different in number of leaves per cutting. The results of present study revealed that IBA 1000 ppm induced maximum number of leaves (12.85) compared to all other treatments significantly, which was followed by treatment T_6 *i.e.* IBA 1500 ppm (11.27) and NAA 1500 ppm (10.55). All other remaining treatments recorded intermediate results. However, the minimum number of leaves (3.24) found in control.

One of the primary symbols for plant vegetative growth is the leaf. Increase in number of leaves might be attributed to early initiation of roots induced by the growth regulators and an increased root number, root length and vigorous growth that might have enabled cuttings to absorb more water and nutrients from rooting media, leading

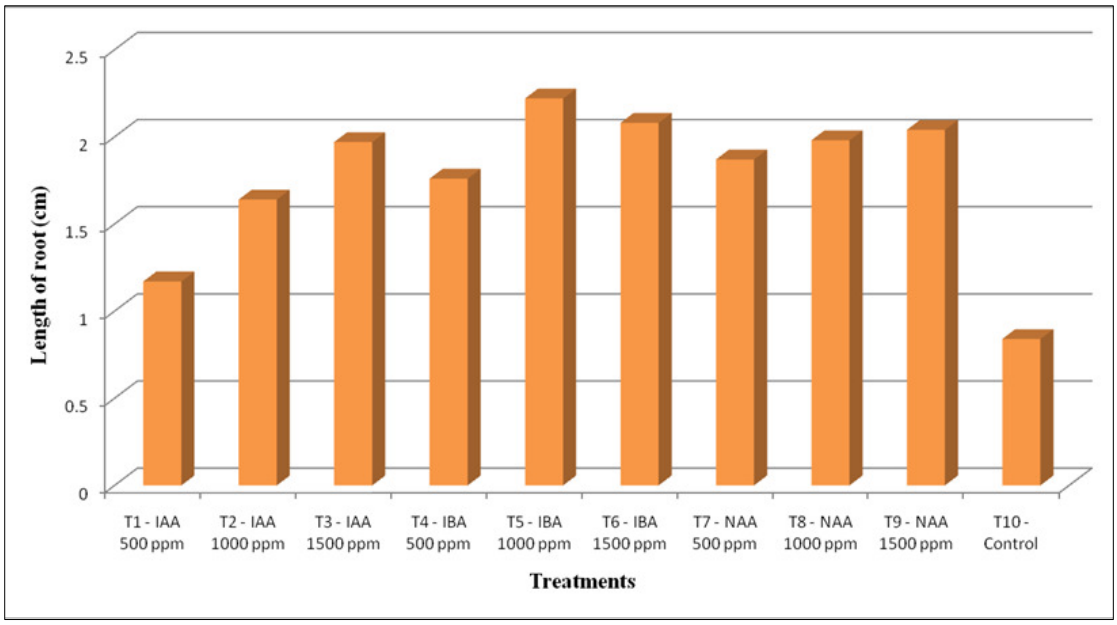

Fig. 4.8.1: Effect of plant growth regulators on length of root per croton cutting (30 DAP)

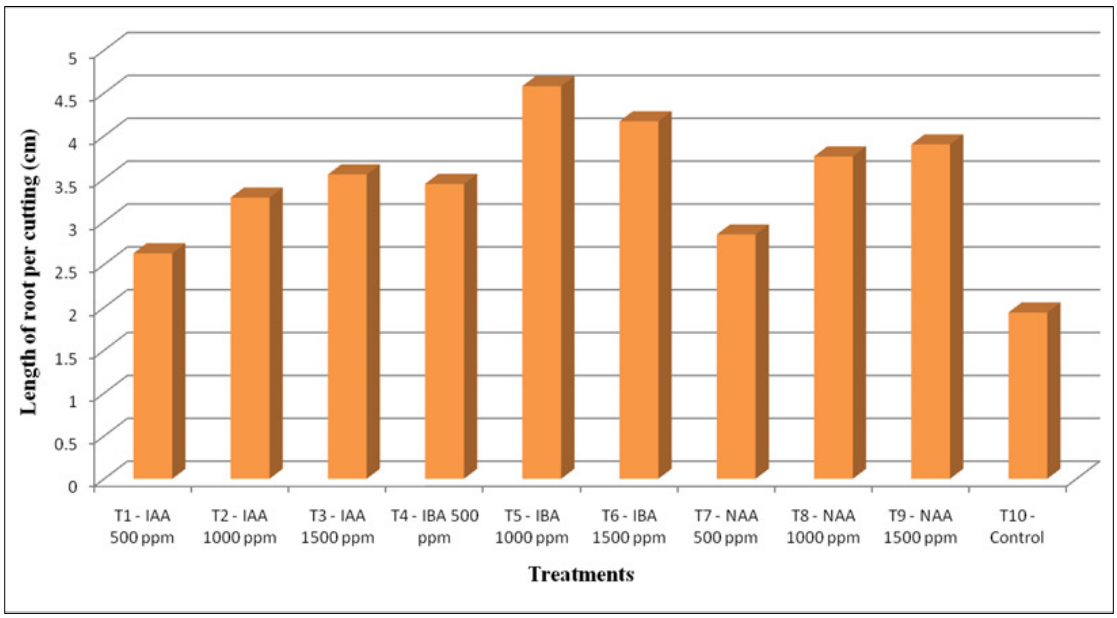

Fig. 4.8.2: Effect of plant growth regulators on length of root per croton cutting (60 DAP)

Plate 5: Effect of IBA 1000 ppm on length of roots per cutting

to better growth and production of new leaves as reported by Stancato *et al.* (2003) in *Rhipsalis grandiflora*.

Similar trends were noted by Patel (2001) in jasmine and Shiva and Nair (2009) in hibiscus and attributed it to the stimulation of shoot growth, which may have increased the number of nodes and in response it caused the growth of additional leaves.

Table 4.9: Effect of plant growth regulators on number of leaves per croton cutting

Treatment No.	Name of Treatment	Number of leaves per croton cutting
T_1	IAA 500 ppm	5.06
T_2	IAA 1000 ppm	7.53
T_3	IAA 1500 ppm	8.60
T_4	IBA 500 ppm	9.19
T_5	IBA 1000 ppm	12.85
T_6	IBA 1500 ppm	11.27
T_7	NAA 500 ppm	6.66
T_8	NAA 1000 ppm	8.70
T_9	NAA 1500 ppm	10.55
T_{10}	Control	3.24
S.E(m).±		**0.52**
C.D. @ 5%		**1.56**

This type of response might be achieved due to response different levels of plant growth regulators, which might have helped in early differentiation of leaves. Similar trend was also observed by Brahmbhatt (2000) in stem cuttings of *Lagerstroemia indica* L. and Singh *et al.* (1986) in lagerstroemia and calliandra cuttings.

Above results are in conformity with the Baldotto *et al.* (2012) in croton cuttings treated with 1000 ppm IBA recorded the maximum number of leaves. These observations in the present study are supported by the findings of Gandotra *et al.* (1975) who recorded higher number of leaves per cutting with the application of higher concentration of IBA (6000 ppm) in bougainvillea.

These results are also in close agreement with the findings of Ingle and Venugopal (2009) in Stevia, Singh *et al.* (2014) on Mulberry and Ibironke (2016) on bougainvillea.

4.10 Plant height (cm)

One of the primary symbols for plant vegetative growth is the plant height The results pertaining to plant height have been presented in Table 4.10 and depicted graphically in Fig. 4.10.

Plant growth regulators treatments exhibited significant difference on plant height in croton. The maximum height (21.28 cm) was registered in IBA 1000 ppm, which was at par with treatments T_6 *i.e.* 1500 ppm IBA (20.41) and treatment T_9 *i.e.* NAA 1500 ppm (19.77). All other remaining treatments recorded intermediate results. The minimum height (16.22 cm) was recorded in control.

Table 4.10: Effect of plant growth regulators on plant height (cm)

Treatment No.	Name of Treatment	Plant height (cm)
T_1	IAA 500 ppm	16.38
T_2	IAA 1000 ppm	16.77
T_3	IAA 1500 ppm	17.20
T_4	IBA 500 ppm	19.26
T_5	IBA 1000 ppm	21.28
T_6	IBA 1500 ppm	20.41
T_7	NAA 500 ppm	17.91
T_8	NAA 1000 ppm	18.20
T_9	NAA 1500 ppm	19.77
T_{10}	Control	16.22
S.E(m).±		**1.01**
C.D. @ 5%		**2.9**

The appropriate growth regulator and its concentration increase the cell division, cell elongation and early differentiation of callus tissue toward the root formation and resulted in better growth of cutting during vegetative propagation, hence auxin enhanced protein synthesis which might have resulted in enhanced high vegetative growth (Evans 1973).

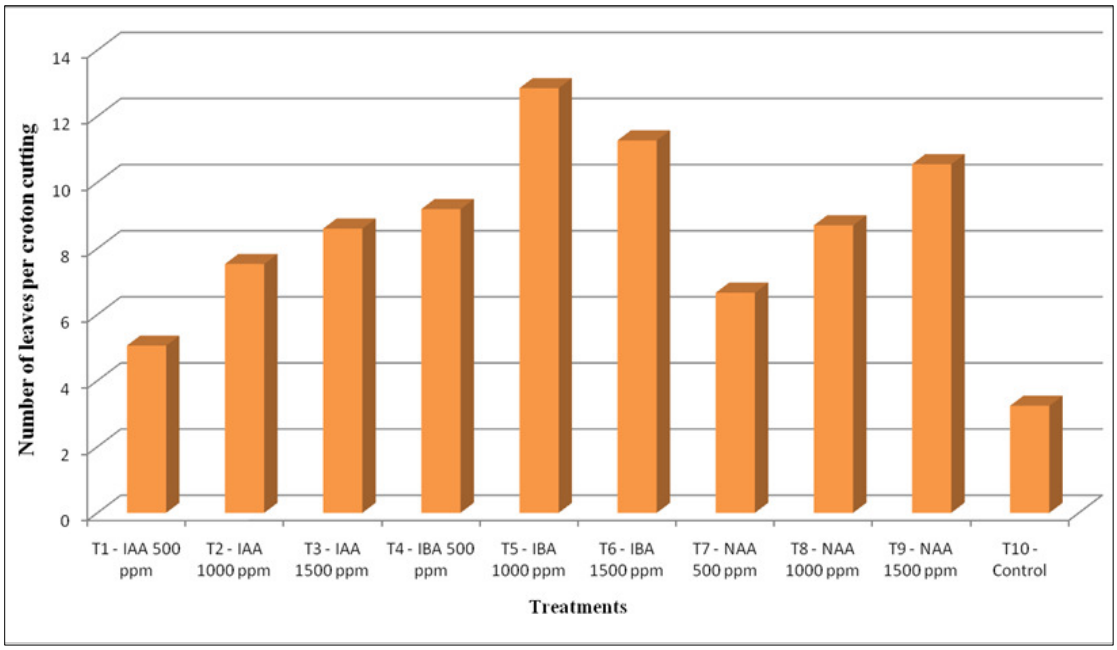

Fig. 4.9: Effect of plant growth regulators on number of leaves per croton cutting.

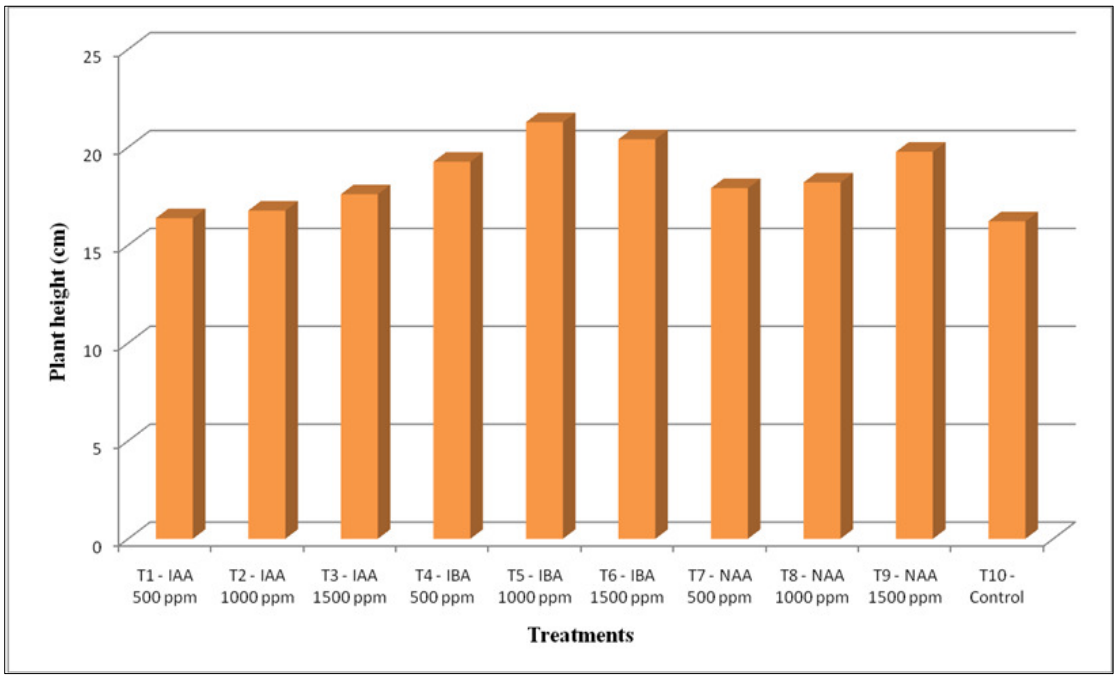

Fig. 4.10: Effect of plant growth regulators on plant height (cm)

Better vegetative development with IBA 1000 ppm treated cuttings may be attributed to the greatest number of roots, which likely absorb more nutrients and water from the soil and enhanced photosynthesis, which ultimately led to more growth. (Singh and Singh 2005). Additionally, auxin may influence the cell wall, turgor, osmotic pressure, and water permeability, which results in cell expansion and accelerated vegetative growth and it results into the rise in the plant height (Taiz and Zeiger 2006).

The present findings with respect to plant height of cuttings of Croton after treatment with rooting hormone with different concentrations are in confirmation with the earlier findings that explains significant increase in plant height (Ullah *et al.* 2013).

Above results are in conformity with the Baldotto *et al.* (2012) in croton cuttings treated with 1000 ppm IBA recorded the maximum height.

4.11 Fresh weight of shoot per cutting (g)

The results pertaining to fresh weight of shoot per cutting have been presented in Table 4.11 and depicted graphically in Fig. 4.11.

Treatments of plant growth regulators showed significant difference pertaining to fresh weight of shoot per cutting. Significantly, maximum fresh weight was noticed in treatment T_5 *i.e.* IBA 1000 ppm (6.41) which was at par with treatment T_6 *i.e.* 1500 ppm IBA (6.04) and treatment T_9 *i.e.* NAA 1500 ppm (5.79) and minimum fresh weight was observed in control (2.35).

Generally, ability of plant of accumulation of fresh matter depends upon its vegetative growth parameter such as plant height, spread or average number of branches and it is also directly influenced by auxin resulted from the hydrolysis of starch or increased photosynthesis which raises the concentration of sugar (Thimman 1972). The Higher rate photosynthesis may also also due to increased uptake of nutrition and enhanced protein synthesis due to the presence of high cytokinins. In the present study, IBA exhibited auxin and cytokinin like activity and increased fresh weight of cuttings.

Superiority of IBA was also reported by Singh and Singh (2005) in poinsettia. The increased length of shoots and more number of leaves lead to higher biomass accumulation, which indirectly gave higher fresh and dry weight in cuttings treated with IBA 1000 ppm.

Table 4.11: Effect of plant growth regulators on fresh weight of shoot per croton cutting

Treatment No.	Name of Treatment	Fresh weight of shoot per cutting (g)
T_1	IAA 500 ppm	3.05
T_2	IAA 1000 ppm	4.89
T_3	IAA 1500 ppm	5.54
T_4	IBA 500 ppm	3.79
T_5	IBA 1000 ppm	6.41
T_6	IBA 1500 ppm	6.04
T_7	NAA 500 ppm	3.31
T_8	NAA 1000 ppm	5.15
T_9	NAA 1500 ppm	5.79
T_{10}	Control	2.35
S.E(m).±		**0.28**
C.D. @ 5%		**0.85**

These results are also in close agreement with the findings observed by Chaitanya (2015) in Jasmine and Girisha *et al.* (2012) in daisy. Deshmukh and Barad (2006) revealed that IBA at 6000 ppm was found significantly superior for fresh weight of shoots of *Bougainvillea buttiana* cv. Mahara.

4.12 Dry weight of shoot per cutting (g)

The results pertaining to dry weight of shoot per cutting have been presented in Table 4.12 and depicted graphically in Fig. 4.12.

As per the data obtained it found that, plant growth regulator treatments exhibited significant difference. The highest dry weight oh shoot was observed in treatment T_5 *i.e.* IBA 1000 ppm (3.48) significantly which was at par with treatment T_6 *i.e.* 1500 ppm IBA (3.09) and treatment T_9 *i.e.* NAA 1500 ppm (3.27) and lowest dry weight of shoot was observed in control (0.84).

The impacts of plant growth regulators may be responsible for the rise in dry weight, this may be due to favourable environmental conditions for higher photosynthates accumulation in shoots. Additionally, mobilization of reserve food resources and hormonal balance in the stem are largely responsible for the growth of

plant, which indirectly effects on dry matter production (Singh *et al.* 2013).

Table 4.12: Effect of plant growth regulators on dry weight of shoot per croton cutting

Treatment No.	Name of Treatment	Dry weight of shoot per cutting (g)
T_1	IAA 500 ppm	1.30
T_2	IAA 1000 ppm	1.97
T_3	IAA 1500 ppm	2.97
T_4	IBA 500 ppm	1.86
T_5	IBA 1000 ppm	3.48
T_6	IBA 1500 ppm	3.09
T_7	NAA 500 ppm	1.64
T_8	NAA 1000 ppm	2.17
T_9	NAA 1500 ppm	3.27
T_{10}	Control	0.84
S.E(m).±		**0.13**
C.D. @ 5%		**0.40**

Above findings were supported by the prior study of Deshmukh and Barad (2006) in *Bougainvillea buttiana* cv. Mahara that IBA at 6000 ppm was found significantly superior for inhancing the fresh weight and dry weight of shoots and Umesha (2017) in chrysanthemum.

Singh and Singh (2005) also noted the superiority of IBA in poinsettia. Increased shoot length and leaves in cuttings treated with IBA 4000 ppm led to a higher biomass accumulation, which indirectly increased dry weight of shoot.

The early sprouting and good length of the shoots may have contributed to the increase in dry weight of the shoots after IBA application.

Above results are in conformity with the Baldotto *et al.* (2012) in croton cuttings treated with 1000 ppm IBA recorded the highest dry weight of shoot. This result is also supported by Patil *et al.* (1998) in their experiment on jasmine. Deshmukh and Barad (2006) reported that IBA at 6000 ppm was found significantly superior for dry weight of shoots of *Bougainvillea buttiana* cv. Mahara.

4.13 Fresh weight of root per cutting (g)

The results pertaining to fresh weight of root per cutting have been presented in Table 4.13 and depicted graphically in Fig. 4.13.

As per the data obtained it found that, plant growth regulator treatments exhibited significant difference. The highest fresh weight of root was observed in treatment T_5 *i.e.* IBA 1500 ppm (5.95) significantly followed by treatment T_6 *i.e.* IBA 1500 ppm (5.14) and treatment T_9 *i.e.* NAA 1500 ppm (4.97). Lowest fresh weight of root was observed in control (2.20).

By increasing the IBA concentration beyond tolerable level there is a decrease in fresh weight. Individual root differentiation and growth tended to decline as they received overloaded auxins beyond the external supply that required reinforcing the endogenous (Caser 2008).

4.13: Effect of plant growth regulators on fresh weight of root per croton cutting

Treatment No.	Name of Treatment	Fresh weight of root per cutting (g)
T_1	IAA 500 ppm	2.66
T_2	IAA 1000 ppm	3.89
T_3	IAA 1500 ppm	4.78
T_4	IBA 500 ppm	3.72
T_5	IBA 1000 ppm	5.95
T_6	IBA 1500 ppm	5.14
T_7	NAA 500 ppm	3.46
T_8	NAA 1000 ppm	4.18
T_9	NAA 1500 ppm	4.97
T_{10}	Control	2.20
S.E(m).±		**0.25**
C.D. @ 5%		**0.75**

The fresh weight of roots is strongly related to the number and size of root, as higher concentration of IAA, IBA and NAA recording higher number of primary and secondary roots as well as due to auxin treatment which might have also resulted in elongation of these roots through cell division hence the fresh weight was also more. This may be caused by increased enzymatic activity and faster hormone transfer during cell division and elongation (Debnath and Maiti 1990).

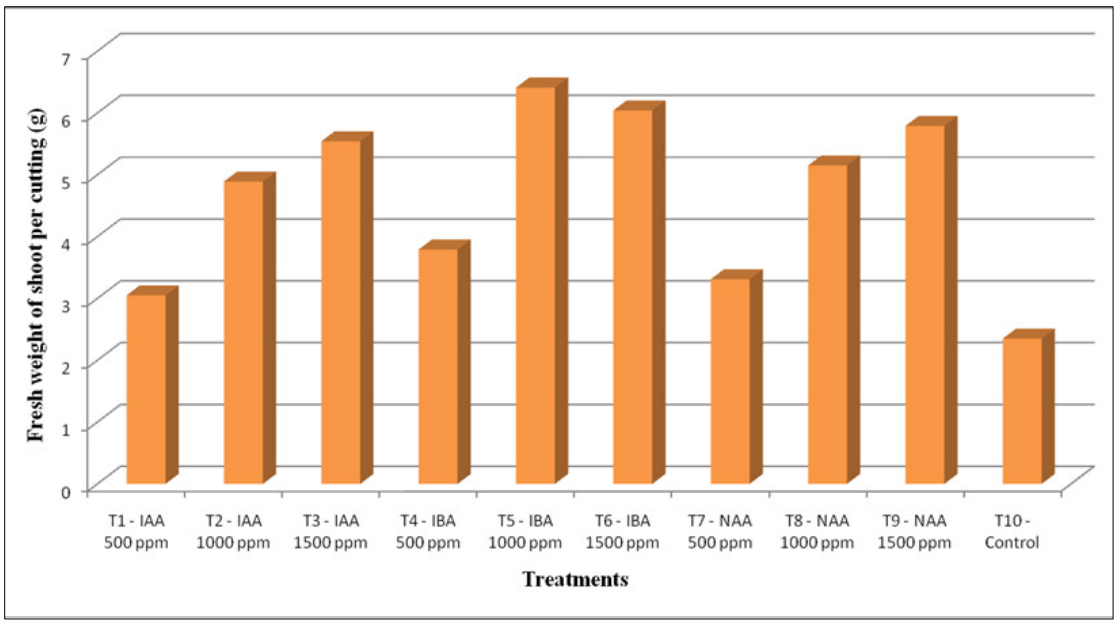

Fig 4.11: Effect of plant growth regulators on fresh weight of shoot per croton cutting (g)

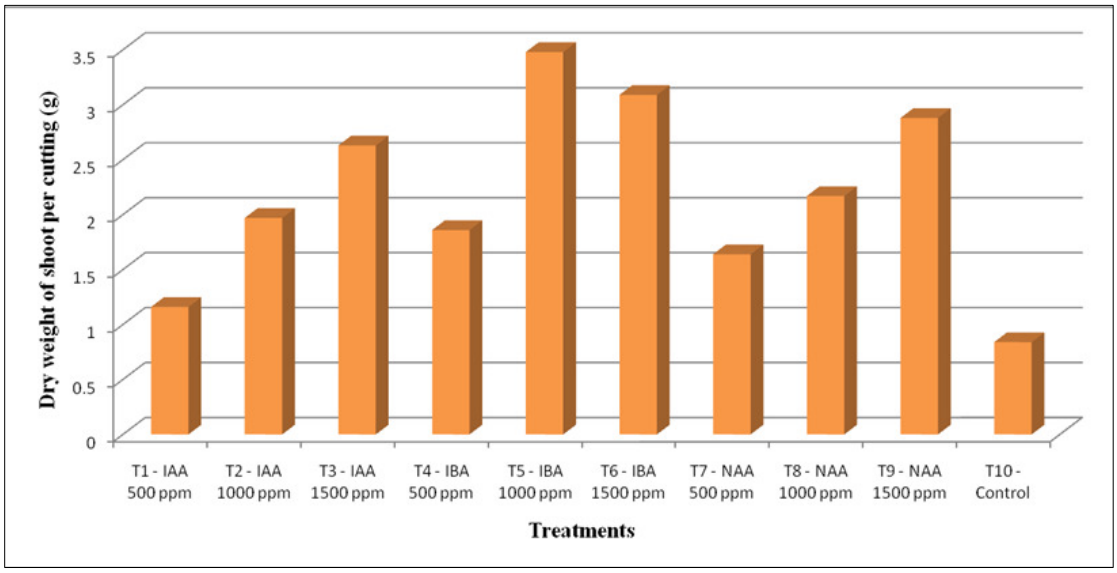

Fig 4.12: Effect of plant growth regulators on dry weight of shoot per croton cutting (g)

The results of the present study are in conformity with findings of Gandotra *et al.* (1975) who reported the best results with hardwood cuttings of bougainvillea were obtained with 6000 ppm IBA as compared to 6000 – 10000 ppm NAA or IAA.

4.14 Dry weight of root per cutting (g)

The results pertaining to dry weight of root per cutting have been presented in Table 4.14 and depicted graphically in Fig. 4.14.

As per the data obtained it found that, plant growth regulator treatments exhibited significant difference. The highest dry weight oh root was observed in the treatment T_5 *i.e.* IBA 1000 ppm (2.36) significantly followed by treatment T_6 IBA 1500 ppm (2.08) and treatment T_9 *i.e.* NAA 1500 ppm (2.05) and lowest dry weight of root was observed in control (0.32).

Plant growth regulators increased the number of roots, caused cell division to lengthen the cells of root and as a result, increased the fresh weight and subsequently the dry weight of the roots. Stimulation of rooting process with auxin, carbohydrate transportation from leaf to root increases, therefore, it causes increasing of the dry weight of root (Hartmann *et al.* 2002).

Table 4.14: Effect of plant growth regulators on dry weight of root per croton cutting

Treatment No.	Name of Treatment	Dry weight of root per cutting (g)
T_1	IAA 500 ppm	0.73
T_2	IAA 1000 ppm	1.15
T_3	IAA 1500 ppm	1.82
T_4	IBA 500 ppm	1.18
T_5	IBA 1000 ppm	2.36
T_6	IBA 1500 ppm	2.08
T_7	NAA 500 ppm	0.98
T_8	NAA 1000 ppm	1.32
T_9	NAA 1500 ppm	2.05
T_{10}	Control	0.32
S.E(m).±		**0.09**
C.D. @ 5%		**0.26**

The results are in agreement with the previous research of Yeshiwas *et al.* (2015) observed that dry weight (0.21) of rose cuttings were recorded highest from cuttings treated with 1000 ppm of IBA and Baldotto *et al.* (2012) in croton cuttings treated with 1000 ppm IBA recorded the highest dry weight of root.

4.15 Root : shoot ratio

The results pertaining to root : shoot ratio have been presented in Table 4.15 and depicted graphically in Fig. 4.15.

Treatments of plant growth regulators exhibited significant difference in root: shoot ratio of cuttings. The maximum root : shoot ratio was observed in treatment T_5 *i.e.* IBA 1000 ppm (0.67) followed by treatments T_6 *i.e.* IBA 1500 ppm (0.66) and treatment T_4 *i.e.* IBA 500 ppm (0.63) and minimum was observed in control (0.38).

The increase in the production of the leaves and leaf area ultimately increased photosynthesis, relative growth rate and growth of lateral branching of shoot which were increased dry biomass of shoot and root: shoot ratio.

The results are in agreement with the previous research of Malaviya *et al.* (2022) observed that root: shoot ratio (0.43) of croton cuttings were recorded highest from cuttings treated with 300 ppm of IBA.

Table 4.15: Effect of plant growth regulators on root : shoot ratio of croton cuttings

Treatment No.	Name of Treatment	Root : shoot ratio
T_1	IAA 500 ppm	0.56
T_2	IAA 1000 ppm	0.58
T_3	IAA 1500 ppm	0.61
T_4	IBA 500 ppm	0.63
T_5	IBA 1000 ppm	0.67
T_6	IBA 1500 ppm	0.66
T_7	NAA 500 ppm	0.59
T_8	NAA 1000 ppm	0.60
T_9	NAA 1500 ppm	0.62
T_{10}	Control	0.38
S.E(m).±		0.006
C.D. @ 5%		0.02

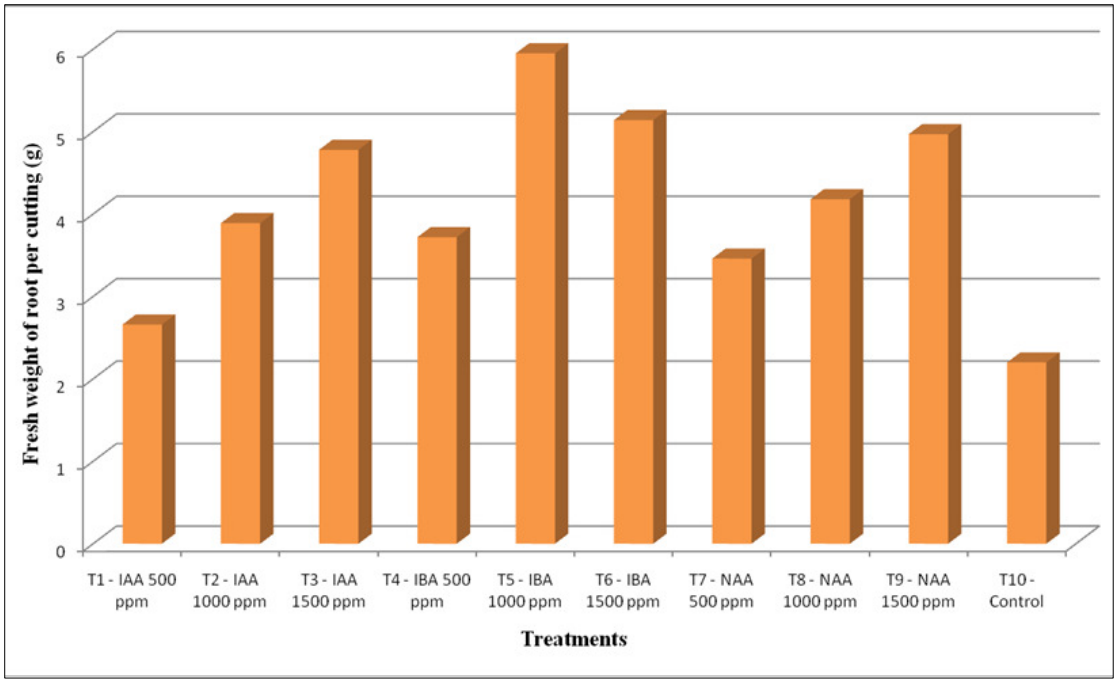

Fig. 4.13: Effect of plant growth regulators on fresh weight of root per croton cutting (g)

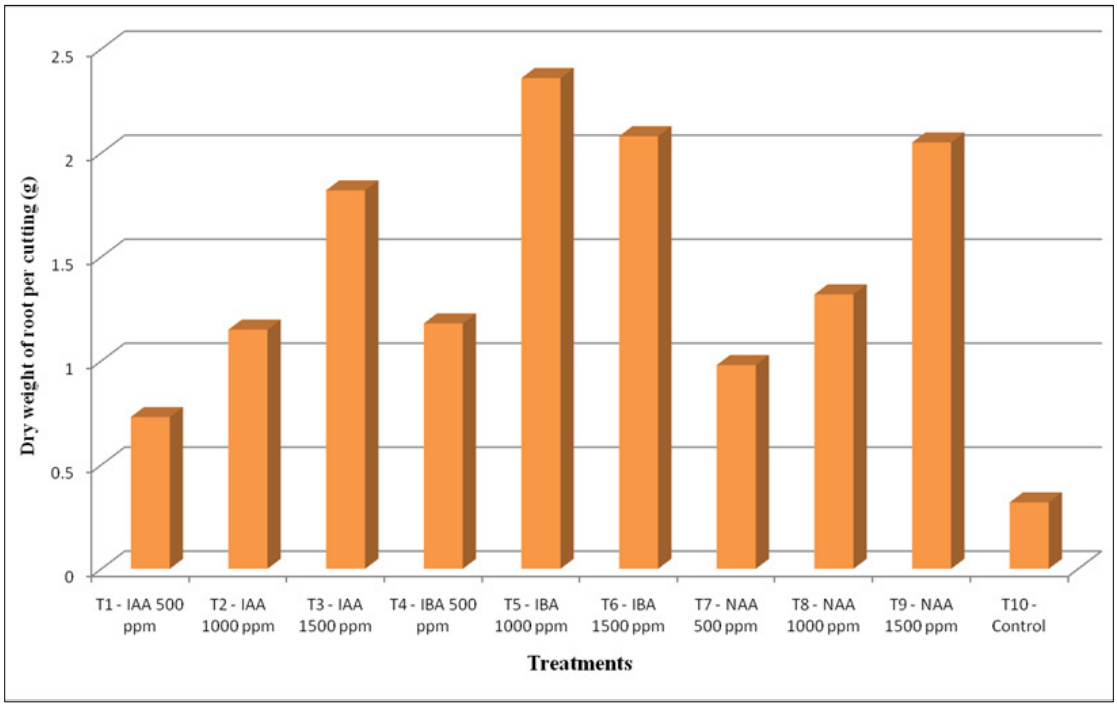

Fig. 4.14: Effect of plant growth regulators on dry weight of root per croton cutting (g)

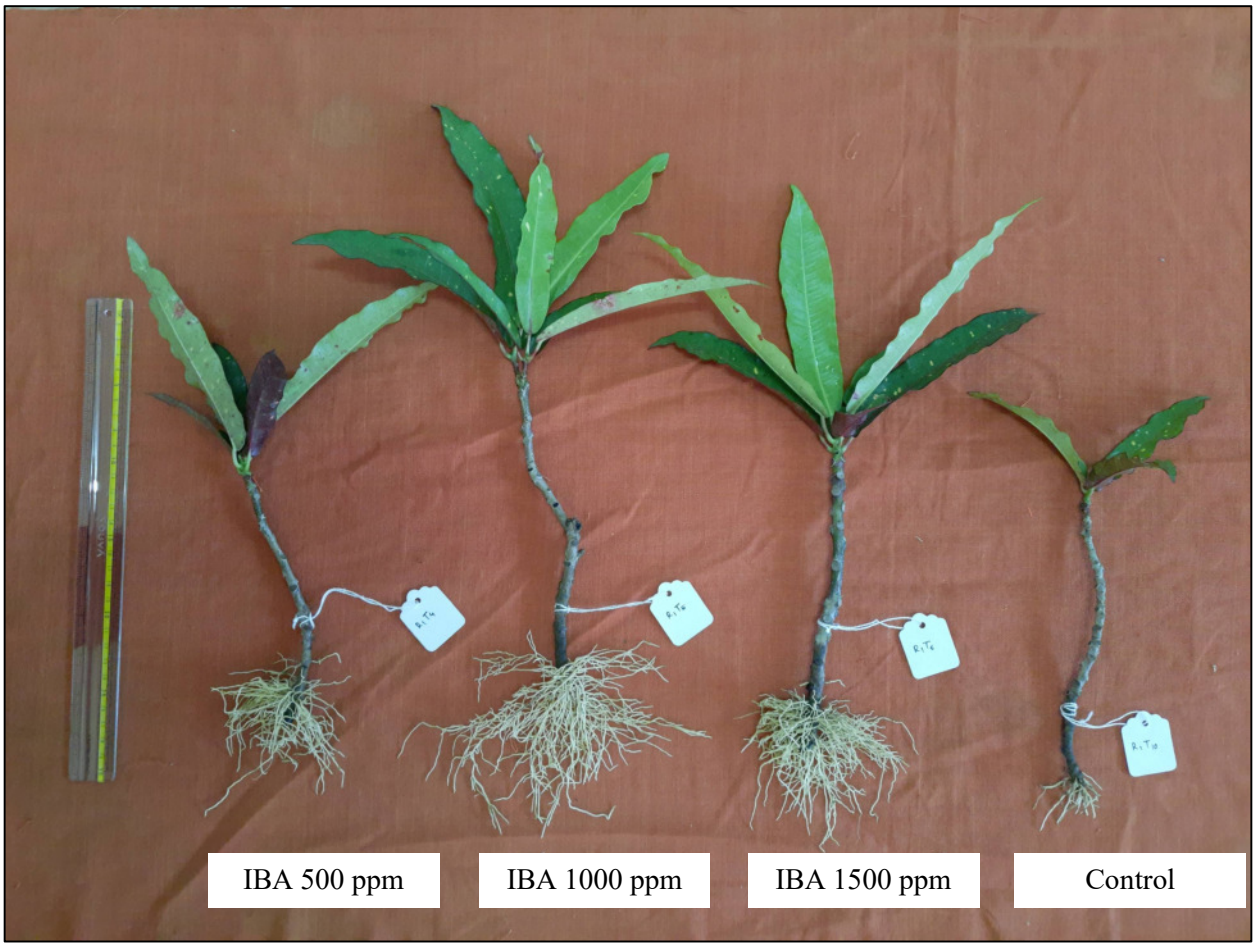

Plate 6: Effect of different concentrations of IBA on root and shoot parameters.

4.16 Survival percentage

The results pertaining to survival percentage have been presented in Table 4.16 and depicted graphically in Fig. 4.16.

Treatments of plant growth regulators exhibited significant difference in survival percentage of cuttings. The maximum survival percentage was observed in treatment T_5 *i.e.* IBA 1000 ppm (81.66) which was at par with treatments T_6 *i.e.* IBA 1500 ppm (80.01) and treatment T_9 *i.e.* NAA 1500 ppm (78.34) and minimum was observed in control (64.67).

This specific concentration of IBA induced maximum number of roots with considerable length and hence formed well developed root system for better establishment of rooted cuttings (Singh and Singh. 2005) in croton. Due to the better root growth and shoot growth there may be increased survival percentage which was

Table 4.16: Effect of plant growth regulators on survival percentage of croton.

Treatment No.	Name of Treatment	Survival percentage
T_1	IAA 500 ppm	66.31 **(54.51)***
T_2	IAA 1000 ppm	68.67 **(55.96)**
T_3	IAA 1500 ppm	72.34 **(58.26)**
T_4	IBA 500 ppm	76.63 **(61.09)**
T_5	IBA 1000 ppm	81.66 **(64.64)**
T_6	IBA 1500 ppm	80.01 **(63.44)**
T_7	NAA 500 ppm	71.32 **(57.61)**
T_8	NAA 1000 ppm	75.00 **(60)**
T_9	NAA 1500 ppm	78.34 **(62.26)**
T_{10}	Control	64.67 **(53.53)**
S.E(m).±		**1.63**
C.D. @ 5%		**5.01**

* Figures in parentheses are arcsine transformed value

augmented due to absorption and translocation of nutrients by IAA, IBA and NAA (Singh. 2012). IBA is the most effective in promoting root initiation and adventitious root production in stem cuttings (Waisel *et al.* 1991). Auxin as IBA is widely used on stem cuttings for accelerating the formation of adventitious roots (Galavi *et al.* 2013). Earlier rooting and better root characteristics will obviously lead to the formation of healthy plants and higher survival percentage accordingly.

Above results are in conformity with the Hoda (2021) in croton cuttings treated with 2000 ppm IBA recorded the highest survival percentage. Similar results were also reported by Patel (2011) in Bougainvillea, Shadparavar *et al.* (2011) in hibiscus, Parmar *et al.* (2010), Hirapara *et al.* (2007) in jasmine, Torkashvand and Shadparvar (2011) in hibiscus.

The results are also in agreement with the previous research of Kaushik (2017) who reported that the maximum survival percentages (88.33%) of rooted cutting with 300 ppm of IBA.

4.17 Benefit: cost ratio

The benefit: cost ratio differed due to the treatments of rooting hormones (auxins) as indicated in Table 4.17 and depicted in Fig. 4.17

The highest benefit: cost ratio (3.80) was obtained in treatment T_5 *i.e.,* IBA 1000 ppm which was followed by treatment T_6 *i.e.* IBA 1500 ppm and treatment T_9 *i.e.* NAA 1500 ppm.

Highest net realization (Rs.1744.30) was obtain with treatment T_5 (IBA 1000 ppm) followed by treatment T_6 (IBA 1500 ppm) with net realization of (Rs.1662.10). This may be because the plants received the proper concentration of IBA which resulted in better growth, survival and ultimately the highest gains in net realization.

Since the percentage of success was recorded highest (78.86) in IBA 1500 ppm compared to rest of the treatments, the benefit cost ratio was more in IBA.

From the economic analysis, it can be concluded that control treatment recorded lowest B:C ratio (3.07). Hence, IBA and NAA showed synergistic effect in increasing survival percentage and B:C ratio.

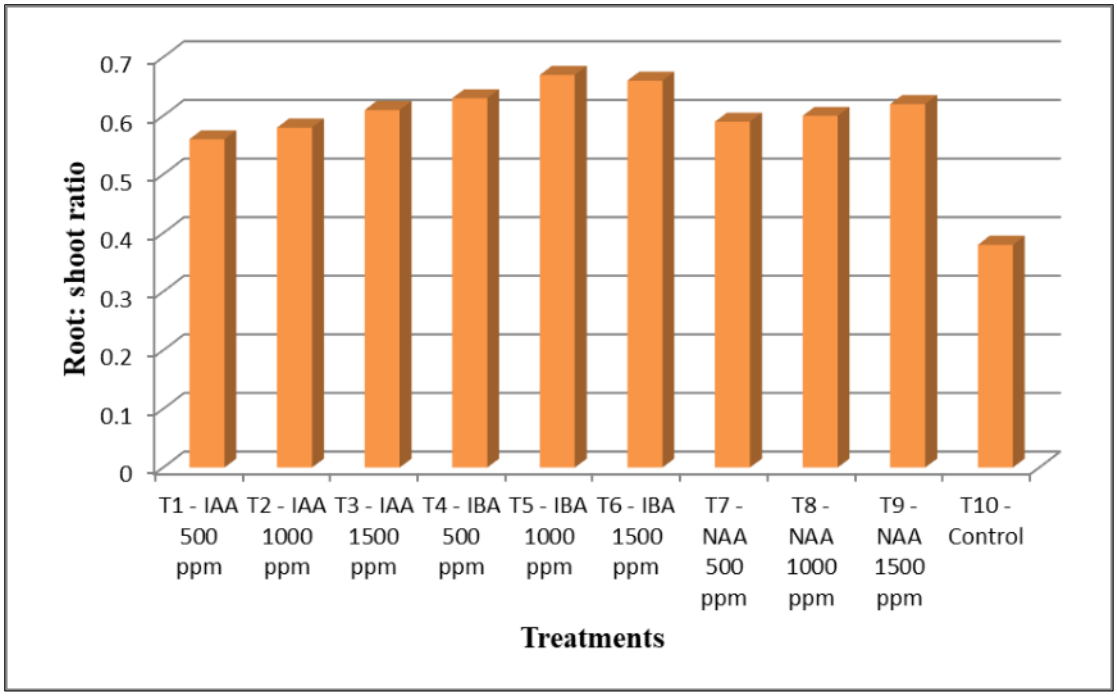

Table 4.15: Effect of plant growth regulators on root : shoot ratio of croton cuttings

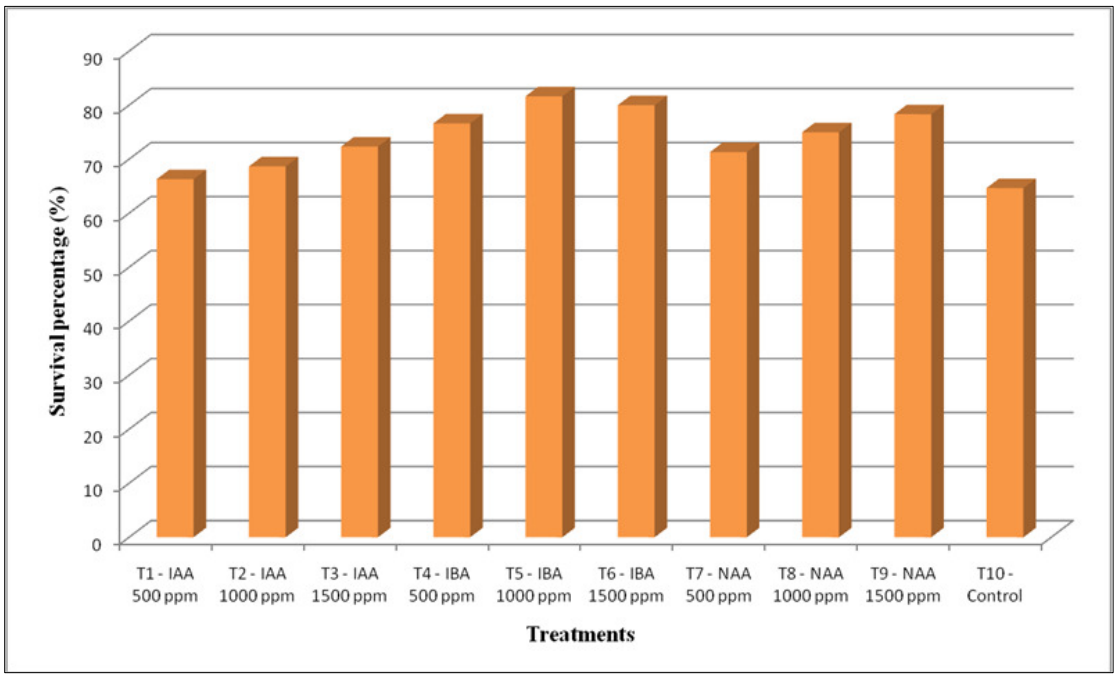

Fig. 4.16: Effect of plant growth regulators on survival percentage of croton

Table 4.17: Effect of plant growth regulators on benefit: cost ratio

Treatment No.	Cost of producing single cutting (Rs)	Price of each rooted cutting (Rs)	Gross Income for 100 cuttings	Expenditure for producing 100 cuttings	Net income for 100 cuttings	B: C ratio
T_1	6.093	30	1904.70	609.30	1295.40	3.12
T_2	6.115	30	1968.30	611.50	1356.80	3.21
T_3	6.165	30	2067.30	616.50	1450.80	3.35
T_4	6.180	30	2204.10	618.00	1586.10	3.56
T_5	6.215	30	2365.80	621.50	1744.30	3.80
T_6	6.230	30	2285.10	623.00	1662.10	3.66
T_7	6.035	30	2077.20	603.50	1473.70	3.44
T_8	6.058	30	2183.40	605.80	1577.60	3.60
T_9	6.063	30	2223.60	606.30	1617.30	3.66
T_{10}	6.015	30	1847.40	601.50	1245.90	3.07

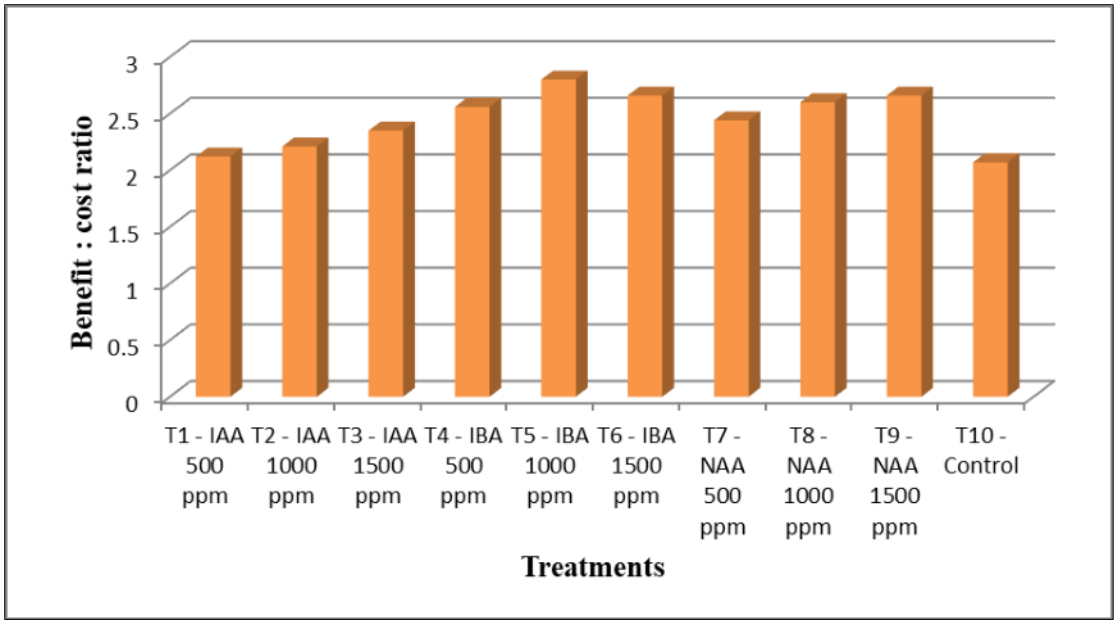

Fig. 4.17: Benefit: cost ratio

Plate 7: Healthy flush obtained in the treatment IBA 1000 ppm

CHAPTER – V

SUMMARY AND CONCLUSION

CHAPTER –V

SUMMARY AND CONCLUSION

The present investigation on **"Studies on effect of different rooting hormones on stem cutting of croton (*Codiaeum variegatum*)''** was carried out at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, during the year 2021-22.

The experiment consisted of three different concentrations of IAA (500ppm, 1000ppm, 1500ppm), IBA (500ppm, 1000ppm, 1500ppm) and NAA (500ppm, 1000ppm, 1500ppm) with control, which were replicated thrice. The experiment was laid out in Completely Randomized Design (CRD), and cuttings were planted on polybags under shade net house.

The observations on vegetative parameters like number of days taken to sprouting, success percentage, mortality percentage, number of shoots per cutting, length of the shoot per cutting (cm), number of leaves per cutting, plant height (cm), fresh weight of shoot per cutting (g), dry weight of the shoot per cutting (g), root: shoot ratio, survival percentage and root parameters like number of days taken to root formation, number of roots per cutting, length of the root per cutting (cm), fresh weight of the root per cutting (g), dry weight of root per cutting (g) were recorded.

The results of the investigation are summarized as follows:

1. Number of days taken to sprouting was found significantly minimum with 1000 ppm IBA and the maximum number of days taken to sprouting was observed in control.

2. Number of days taken to root formation was found significantly maximum with 1000 ppm IBA and the maximum number of days taken to root formation was observed in control.

3. Success percentage of croton cuttings was found maximum with 1000 ppm IBA and the lowest success percentage of cutting was observed in control.

4. Mortality percentage of croton cuttings was found minimum with 1000 ppm IBA and the minimum mortality percentage of cutting was observed in control.
5. Number of shoots per cutting was found maximum with 1000 ppm IBA and the lowest number of shoots per cutting was observed in control.
6. Numbers of roots per cutting were found to be the highest with 1000 ppm IBA and the lowest number of roots per cutting was observed in control.
7. Length of shoot per cutting was found to be the maximum with 1000 ppm IBA and the minimum length of shoot was observed in control.
8. Length of root per cutting was observed maximum with the treatment by 1000 ppm IBA the minimum length of longest roots per cutting was observed in control.
9. Number of leaves per cutting was found maximum with the application of 1000 ppm IBA and the lowest number of leaves per cutting was observed in control.
10. Plant height was observed maximum with the treatment by 1000 ppm IBA the minimum plant height was observed in control.
11. Fresh weight of shoots per cutting was found to be the maximum with 1000 ppm IBA and the lowest fresh weight of shoots per cutting was observed in control.
12. Dry weight of shoots per cutting was found to be the highest with 1000 ppm IBA and the lowest dry weight of shoots per cutting was observed in control.
13. The fresh weight of roots was recorded significantly higher under 1000 ppm of IBA and the lowest fresh weight of roots per cutting was observed in control.
14. The dry weight of roots was recorded significantly higher under 1000 ppm of IBA and the lowest dry weight of roots per cutting was observed in control.
15. The root: shoot ratio was recorded significantly higher under 1000 ppm of IBA and the lowest root: shoot ratio was observed in control.

16. Survival percentage found significantly maximum with 1000 ppm IBA and the minimum survival percentage was observed in control.

17. Benefit: cost ratio found significantly maximum with 1000 ppm IBA and the minimum benefit: cost ratio was observed in control.

CONCLUSION

On the basis of the results obtained by the investigation entitled “Studies on effect of different rooting hormones on stem cutting of Croton (*Codiaeum variegatum*)” it may be concluded that an application of T_5 (1000 ppm IBA) proved better than all other treatment recording the maximum value of various attributes related to the growth of shoot parameters like number of days taken to sprouting, number of shoots per cutting, length of the shoot per cutting, number of leaves per cutting, plant height, fresh weight of shoot per cutting, dry weight of the shoot per cutting as well as root parameters like number of days taken to root formation, number of roots per cutting, length of the root per cutting, fresh weight of the root per cutting, dry weight of root per cutting and survival of croton cuttings.

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APPENDIX

APPENDIX

Weekly weather data during study period (1 August 2021 to 30 October 2021)

Week	RF	Temperature ^{o}C		Humidity (%)		EVP (mm)	BSS (Hrs.)	WS (Kmph)
		Max	Min	RH1	RH2			
30	9.9	30.5	21.4	89	65	3.4	4.5	5.3
31	1.4	30.9	21.6	84	63	3.3	2.7	5.8
32	2.3	33.1	22.5	84	52	4.9	6.2	4.2
33	48.5	29.4	22.2	89	70	3.6	4.7	4.6
34	5.9	30.6	22.4	92	64	3.1	5.2	2.9
35	48.8	30.0	22.7	78	59	3.0	3.4	2.8
36	233.1	28.2	21.8	94	78	1.6	3.9	3.3
37	44.4	30.9	22.0	90	69	3.4	6.6	4.3
38	48.6	30.9	22.3	105	71	4.0	5.1	3.7
39	133.9	5.0	28.9	21.8	94	75	1.6	2.2
40	112.9	3.0	32.7	22.4	94	59	3.5	7.3
41	3.0	0.0	33.0	21.2	92	46	4.4	7.8
42	45.8	1.0	31.1	19.6	89	48	4.2	7.0

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Course/ Degree	Name of the college/ institute	University/ Board	Year of passing	Percentage (%)/ CGPA	Class/ Grade
SSC	English school, Mangalwedha.	Pune	2014	86.80	Distinction
HSC	Shankarrao Mohite Mahavidyalaya, Akluj.	Pune	2016	68.00	First
B. Sc. (Agri.)	Sharad College of Agriculture, Jainapur.	MPKV, Rahuri	2020	77.70	First

Omkarpandit.

Place : Parbhani

Date : 30/11/2022

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